LandCorp

Report for Broome North

District water management strategy

October 2009

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Executive Summary

Broome North lies north of the Broome townsite and bounded by Broome Road to the east and Gubinge Road to the south and Fairway Drive splits the proposed development in half. The proposed development is situated on a flat to gently undulating plain on the Dampier Peninsula with predominantly Pindan soils.. There is little or no organised surface drainage and seasonal runoff forms sheets of water behind coastal dune systems

This *District water management strategy* has been prepared in accordance with *Better urban water management* (Western Australian Planning Commission, 2008).

Principles

The key principles of integrated urban water management are:

- Minimise total water use in the Development Area;
- Protect infrastructure and assets from inundation and flooding;
- Manage groundwater levels to protect infrastructure and assets; and
- Protect environmental values of receiving water bodies.

Potential water sources

Options for various water sources are discussed, including potential for a recycled water scheme, rainwater tanks and the expansion of the Water Corporation groundwater supply scheme.

The preferred water source for Broome North is the existing Water Corporation groundwater supply scheme since there is sufficient sustainable yield to provide for the development with substantially less required infrastructure than other options.

Water conservation and efficiency

The Broome North development will be subject to compulsory water conservation measures described on the Water Corporation's 'Waterwise' website or its subsequent programs.

To maximise the water efficiency of the development the following additional measures are preferred to be implemented within the development:

- New homes in the development have water efficient fittings installed. This would include water efficient taps, showerheads, toilets and appliances such as washing machines, although these will be the responsibility of the individual home owners;
- Plans for irrigation of public open space to occur only at night, to reduce evaporation losses.

Managing surface water quantity

Surface water management is based on the following principles:

- The development is to have a detention system so that the peak runoff outflows for 5, 10, 50 and 100 year average recurrence interval events are no greater than that which would occur under pre-development conditions.
- Finished floor levels for the buildings on all lots are to be at least 0.5 m above the crown of the road to ensure that no flooding of the residences occurs.
- The 50 and 100 year average recurrence interval events are to be contained within the road reserve and the 10 year average recurrence interval event is to be contained within the kerbs.
- A minimum of 0.3 m freeboard is required between the flood level of a 100 year average recurrence interval design event and the finished floor level of all buildings on the site.

Managing groundwater quantity

No subsoil drainage is proposed to be constructed within the development due to the depth to groundwater, the low permeability and the collapse potential of the soil.

The site is underlain by pindan sands which do not allow for infiltration of stormwater runoff to the groundwater. Therefore there will be little impact on the groundwater levels within the study area and no specific management strategy is proposed.

Managing water quality

The water quality of stormwater originating from the catchment will be managed by the following methods:

- Vegetated swales and dry/ephemeral detention basins;
- Use of grassed public open space area and multi-use parks;
- Detention basins with sedimentation traps;
- Where possible, restoration of natural drainage pathways;
- Planting and regeneration of low-lying native vegetation;
- Maintenance and education programs; and
- Potential re-use of existing sand mining area for infiltration.

Managing wastewater

In Broome, wastewater is collected via a traditional gravity sewer and transferred to the wastewater treatment plant owned and operated by the Water Corporation. Expansion of the existing gravity system to include the Broome North development will be required.

1. Introduction

GHD Pty Ltd was commissioned by LandCorp to coordinate the production of a *District water management strategy* in conjunction with Sinclair Knight Merz Pty Ltd (SKM) in support of a proposed amendment of the Shire of Broome *town planning scheme No 4* and master plan for the proposed Broome North development.

LandCorp proposes to develop 700 ha of land located to the north of exiting Broome townsite (Figure A.1). Under the current Shire of Broome: *Town planning scheme No. 4*, the Site is zoned 'development', 'rural living' and 'environmental cultural corridor'. A development plan and supporting *Local water management strategy* is currently being prepared for the section of the land that has been zoned 'development' in a previous scheme amendment. A further amendment to the scheme is required to develop the remainder of the site.

In accordance with state government planning framework as outlined in *Better urban water management* (WAPC, 2008), a *District water management strategy* is required to accompany the *Town planning scheme* amendment. A *Local water management strategy* is required at the subsequent development plan stage.

1.1 Total water cycle management - principles and objectives

Total water cycle management, also referred to as integrated water cycle management, 'recognises that water supply, stormwater and sewage services are interrelated components of catchment systems and therefore must be dealt with using a holistic water management approach that reflects the principles of ecological sustainability' (DoW, 2004-07, *Stormwater management manual for Western Australia*).

The *State planning policy 2.9: Water resources* (WAPC, 2004), outlines the key principles of integrated water cycle management as:

- Consideration of all water resources, including wastewater in water planning;
- Integration of water and land use planning;
- The sustainable and equitable use of all water sources, having consideration of the needs of all water users, including the community, industry and the environment;
- Integration of human water use and natural water processes; and
- A whole of catchment integration of natural resource use and management.

The principles and objectives for managing urban water as stated in *the Stormwater management manual for Western Australia* (DoW, 2004-2007) are as follows:

- 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.

1.2 Planning background

The planning framework for land and water planning is illustrated in Figure 1. The *District water management strategy* demonstrates how water resources can be considered in the land use planning system and to ensure consistency with *State planning policy 2.9: Water resources* (WAPC, 2004).

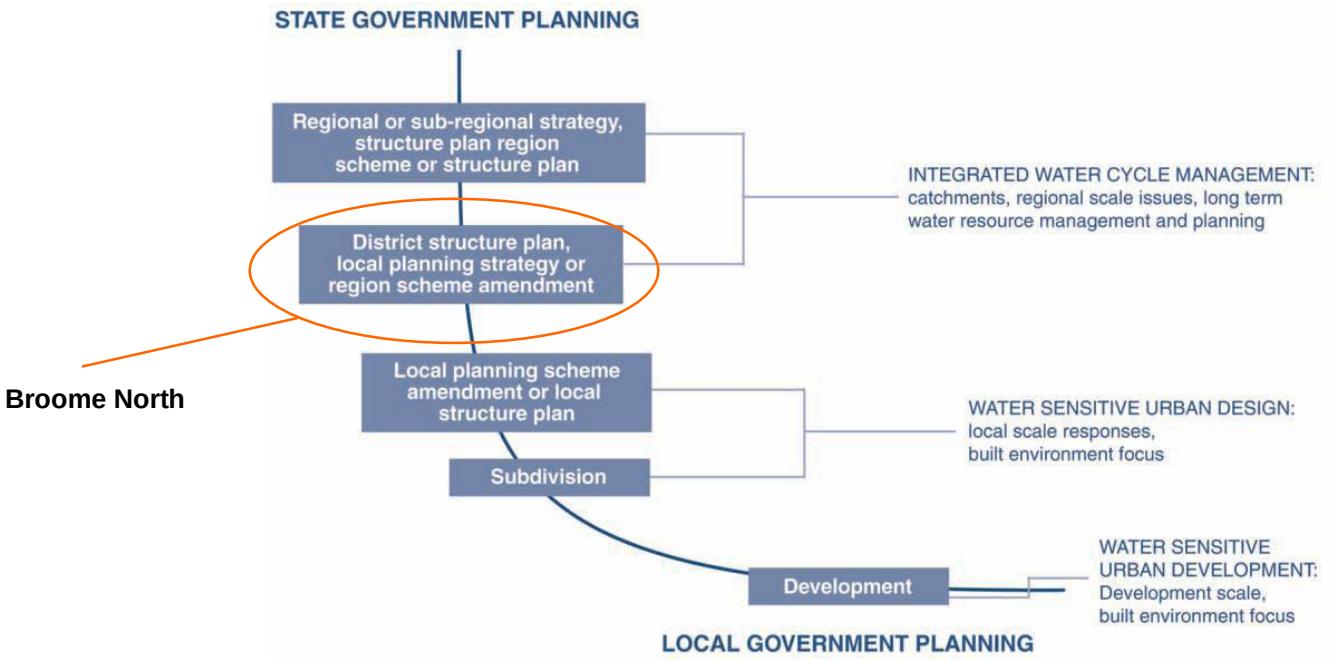


Figure 1 Planning framework for integrating the drainage planning with land planning

SOURCE: *Better Urban Water Management* (WAPC, 2008)

1.3 Previous studies

Information relevant to this report includes:

- *Broome North planning design forum information pack (2009).* This information pack was provided to stakeholders for discussion at the forum held in Broome on 19 - 22 August 2009. Information related to water management is included in the Servicing section of this report.
- *Study for Broome groundwater management plan review (2008).* This report, prepared by Groundwater Consulting Services for the Department of Water, provides an assessment of the groundwater resource in the Broome area.
- *Report on geotechnical investigation for Broome North (2009),* Lots 3150 and 304 - Coffey Geotechnics. This report provides an assessment of the overall geotechnical conditions on the site and also a desktop hydrological investigation. The work also includes chemical testing of the existing soils on the site for Nitrogen and Phosphorus.
- Januburu residential development, Broome: *Drainage and nutrient management plan* for Stage 4, Sinclair Knight Merz Pty Ltd 2009.

2. Design and management objectives

The design criteria adopted for this *District water management strategy* have been based on the design objectives outlined in *Better urban water management* (WAPC, 2008). These criteria are summarised in the sections below.

2.1 Water Conservation

The overall intention of this *District water management strategy* is to achieve the sustainable management of all aspects of the water cycle within the development and that potable water use should be as efficient as possible. Specifically the objectives for integrated urban water management for the development are:

- Minimise total water use in Broome North. The Western Australian *State water pan* (Government of Western Australia, 2007) sets a target of reducing unrestricted annual water consumption to 100 kL/person, including an aspirational target to achieve not more than 40 – 60 kL/person/year scheme water use.
- The developer will investigate with the relevant authorities to substitute drinking quality water with fit-for-purpose water for non-drinking water uses. The *State water strategy* (Government of Western Australia, 2003) sets a target of 20% reuse by 2012. The development could potentially aim to reduce the use of scheme/potable water by providing an alternative fit for purpose water supply for non-drinking use.
- Potable water use outside of buildings should be limited and as efficient as possible.
- Encourage the installation of 5 Star Plus provisions for all new fittings.
- The use of native plants is to be promoted, with native species constituting a minimum of 30-35% of total public areas and gardens.

2.2 Water quantity management

The post development annual discharge volumes and peak flows are to be maintained relative to pre-development conditions, unless otherwise established through determination of ecological water requirements for sensitive environments. To achieve the above principle the following criteria will be applied:

- *Ecological protection* - For the critical one year average recurrence interval event, the post development discharge volume and peak flow rates shall be maintained relative to pre - development conditions in all parts of the catchment. Where there are identified impacts on significant ecosystems, maintain or restore desirable environmental flows and/or hydrological cycles as specified by the Department of Water.

- *Flood management* - Manage the catchment runoff for up to the 1 in 100 year average recurrence interval event in the development area to pre - development peak flows, unless otherwise indicated in an approved strategy or as negotiated with the relevant drainage service provider.
- *Protect infrastructure and assets from inundation and flooding* - Urban development usually results in the removal of significant areas of vegetation and replacement of permeable areas with buildings, roads and paved areas. This results in increased volumes and flows of surface runoff, which has the potential to cause flooding and inundation.

2.3 Water quality management

Maintain surface and groundwater quality at pre-development levels (winter concentrations) and if possible, improve the quality of water leaving the development area to maintain and restore ecological systems in the sub catchment in which the development is located. To achieve the above principle the following criteria will be applied:

- If the pollutant outputs of development (measured or modelled concentrations) exceed catchment ambient conditions, the proponent shall use best endeavours to achieve water quality improvements in the development area or, alternatively, arrange equivalent water quality improvement offsets inside the catchment. If these conditions have not been determined, the development should meet relevant water quality guidelines stipulated in the *National water quality management strategy* (ANZECC and ARMCANZ, 2000).
- Ensure that all runoff contained in the drainage infrastructure network receives treatment prior to discharge to a receiving environment consistent with the *Stormwater management manual* (DoW, 2004-2007).
- Protect groundwater as a resource.

2.4 Water quality modelling criteria

If it is proposed to use a water quality modelling tool to demonstrate compliance with design objectives, the following design modelling parameters are recommended. As compared to a development that does not actively manage stormwater quality, the water quality measures should achieve:

- At least 80 per cent reduction of total suspended solids;
- At least 60 per cent reduction of total phosphorus;
- At least 45 per cent reduction of total nitrogen; and
- At least 70 per cent reduction of gross pollutants.

2.5 Commitment to best management practice

In order to meet the design criteria of reductions in total phosphorus, total nitrogen, total suspended solids and gross pollutants as compared to developments in which water treatment is not undertaken, it is necessary to use a combination of best management practice strategies. In addition, best management practice strategies reduce risks of flooding on housing and infrastructure while maximising the potential for stormwater to be treated as a resource.

The hierarchy of best management practice principles is as follows:

- Implement controls at or near the source to prevent pollutants entering the system and/or treat stormwater.
- Install in-transit measures to treat stormwater and mitigate pollutants that have entered the conveyance system.
- Implement end-of-system controls to treat stormwater, addressing any remaining pollutants prior to discharging to receiving environments.

Structural and non-structural best management practice strategies must be used in combination to achieve the required stormwater treatment outcomes. Recommended best management practices in increasing order of scale include:

- Residential lot scale:
  - On-site detention devices
  - Water-wise and nutrient-wise landscaping
  - Rainwater tanks for harvesting, detention and
  - Wastewater re-use
- Commercial/light industrial lot scale:
  - On-site detention
  - Water-wise and nutrient-wise landscaping
  - Contaminant management and sediment traps
  - Rainwater tanks for harvesting, detention and re-use
- Street scale:
  - Sediment traps
  - Conveyance bioretention systems (swales)
- Estate scale:
  - Detention (including water quality treatment) areas integrated within public open space, in accordance with the objectives and requirements of Elements 4 (Public parkland) and 5 (Urban water management) of *Liveable Neighbourhoods Edition 4* (WAPC, 2007)
  - Non-structural best management practices such as interpretive signage, garden education programs, publishing a water-sensitive urban design web-page for the estate and inviting residents to engage with existing community catchment groups

- Area scale:
  - Non-structural best management practices such as; public education campaigns, support of local community catchment groups, installation of interpretive signage and web pages and the adoption of appropriate planning principles including local laws for on-site detention and retention.

The above practices may be limited by several factors, including: local soil and hydrological conditions, the depth and type of fill imported, public safety and public health standards, design life/reliability requirements, maintenance/management costs, legal authority and streetscape aesthetics. Advice should be sought from the local authority on the practices most appropriate for adoption within the development.

2.6 Disease vector and nuisance insect management

To reduce health risks from mosquitoes, retention and detention treatments should be designed to ensure that between the months of November and May, detained immobile stormwater is fully discharged in a time period not exceeding 96 hours.

The Shire of Broome will not accept permanent water bodies in the drainage system. All detention basins are required to grade out and discharge over a period of up to 3-4 days to prevent inhabitation by mosquito larvae to the satisfaction of the Shire of Broome on advice of the Department of Water and Department of Health.

3. Pre-development environment

3.1 Study area

Broome North lies north of the Broome townsite and bounded by Broome Road to the east and Gubinge Road to the south. Fairway Drive splits the proposed development in half with the north proportion being 350 ha in size, and the southern portion, 365 ha in size (Figure A.1).

3.2 Climate, rainfall and evaporation

The proposed development is located in Broome within the Kimberley region of Western Australia. This region has a tropical climate with hot and humid summers and warm winters. There are two distinct seasons: the 'wet' usually from December to March and the 'dry' for the remainder of the year (Bureau of Meteorology, 2009). Tropical cyclones can be experienced during the months from November to April, but are most common in January and February (Bureau of Meteorology, 2009).

The closest weather recording station to the proposed development is Broome Airport. Recorded historical climate data for the Broome Airport has been summarised below:

- Mean annual maximum temperature range: 34.3º C (April) to 28.8ºC (July)
- Mean annual minimum temperature range: 13.6ºC (July) to 26.4ºC (December)
- Mean annual rainfall: 602.4 mm
- Mean annual rain days per year: 34.8 days
- Evaporation is high with November recording a mean daily rate of 9.5 mm.

(Source: Bureau of Meteorology (2009a, 2009b))

3.3 Topography, geology and soils

The proposed development is situated on a flat to gently undulating plain on the Dampier Peninsula. The Dampier Peninsula is underlain by the ancient (Pre-Cambrian) rocks of the Canning Basin. The Geological Survey of Western Australia (1982) indicates that the geology of the study area comprises "red sand, fine to medium, minor silt: Aeolian".

The principle soil type of the Dampier Peninsula is the Pindan, which developed during the Quaternary period on desert dune sandstone. The soils of the area are red earthy sands, which are of windblown origin (Kenneally *et al.,* 1996).

The Pindan soils form extensive undulating plains with little or no organised surface drainage; seasonal runoff forms sheets of water behind the coastal dune systems (Kenneally *et al.,* 1996). Within the Broome area the Pindan is often overlain by a layer of more recent, coarser and unconsolidated sand, which assists in water penetration, plant establishment and growth (Kenneally *et at.,* 1996).

3.4 Acid sulfate soils

Acid sulfate soils are wetland soils and unconsolidated sediments that contain iron sulfides which, when exposed to atmospheric oxygen in the presence of water, form sulfuric acid. Acid sulfate soil forms in protected low energy environments such as barrier estuaries, coastal lakes and coastal alluvial valleys, and commonly occurs in low lying coastal lands such as Holocene marine muds and sands. When disturbed, these soils are prone to produce sulfuric acid and mobilise arsenic, iron, aluminium, manganese and other heavy metals. The release of these reaction products can be detrimental to biota, human health and built infrastructure.

The presence of acid sulfate soils has been a recognised issue of concern in Western Australia since 2003. The Department of Environment and Conservation and the Western Australian Planning Commission have released guidance notes on acid sulfate soils covering the requirement for assessment and management of sites where acid sulfate soils is identified. Proponents of developments that involve the disturbance of soil or the change of groundwater levels in areas susceptible to acid sulfate soils are required to conduct desktop and field based investigations. Adequate investigations are required prior to soil disturbance to determine the potential risks and to allow for the formulation of appropriate management strategies.

Mapping of acid sulfate soils by the Western Australian Planning Commission in the Shire of Broome is very limited with no data available for the majority of the shire. No acid sulfate soil data is available for the proposed development however it is located within approximately one kilometre of land designated as high to moderate risk of acid sulfate soils occurring within 3 m of natural soil surface, which is potentially related to the influenced by Dampier Creek.

A desktop investigation conducted by GHD considered the site to have a low to moderate risk of acid sulfate soils (GHD, 2009a).

Field investigations have been undertaken and found that a low risk of ASS materials is likely to be prevalent onsite. Additionally, as limited sampling indicated the presence of ASS materials is negligible in the adjacent high risk area, it is considered unlikely that ASS materials are present at the proposed Broome North Redevelopment area (GHD, 2009d).

3.5 Contaminated Sites

The *Broome North Preliminary site investigation* (GHD, 2009c) investigated the historical and current land uses within the study area in order to determine if there is any potential soil or groundwater contamination present.

For the study area, the following overall conclusions from the *Broome North Preliminary site investigation* (GHD, 2009c) are:

» Given the overall land use within the study area and the presence of illegally dumped rubbish, there is the potential for minor impacts to surface soils which will need to be remediate and validated prior to redevelopment.

» No groundwater investigations were conducted within the study area and unless groundwater investigations are undertaken the groundwater quality cannot be confirmed.

3.6 Aboriginal heritage

The Aboriginal site register is held under Section 38 of the State *Aboriginal heritage act 1972.* It protects places and objects customarily used by, or traditional to, the original inhabitants of Australia.

A search of the Department of Indigenous Affairs database identified eight registered Aboriginal sites within the vicinity of the proposed development. The details of these sites are summarised in Table 1.

Table 1 Aboriginal heritage sites within the study area

Site ID	Site Name	Type	Additional Information
12839	Billingurru	Ceremonial, Mythological	Camp
12841	Marnalakun	Skeletal material/Burial	Camp
12886	Illangarami	Mythological	-
12912	Jurlirr	Ceremonial, Mythological, Artefacts/Scatter, Midden/Scatter	Water Source, [Other: Failed PA 142. ACMC Res 11/89]
12917	Cable Beach 6	Midden/Scatter	Meeting Place, Camp, Water Source
13351	Ngilirirrbanjin	Ceremonial	
13463	Wullulong Ground		[Other: Proposed PA 098. ACMC Res 23/77 (b)]
21408	Broome Crocodile Farm	Ceremonial, Mythological	Camp

Figure A.2 identifies the location of registered Aboriginal heritage sites within the vicinity of the study area.

A search of the Department of Indigenous Affairs database does not comprise of a full assessment under the *Aboriginal Heritage Act (1972).* This would require consultation with Aboriginal people with knowledge of the area, and an archaeological survey to ascertain whether any previously unrecorded archaeological sites are within the proposed works area.

Under the *Aboriginal Heritage Act (1972)*, it is an offence to disturb an Aboriginal heritage site whether it is registered or not. Where an activity disturbs an Aboriginal site or object an application for permission to disturb those sites will need to be submitted under Section 18 of the *Aboriginal Heritage Act 1972.* Where an area of previously unknown Aboriginal heritage is to be disturbed, it is advised that a detailed anthropological and archaeological heritage survey is undertaken to find if there any sites or objects of significance in that area.

3.7 Vegetation

3.7.1 Vegetation description

The proposed development falls within the Dampier botanical district, which is broadly characterised by Pindan formation on sand plains (Beard, 1979). Vegetation can be classified as Pindan or Pindan woodland, with both vegetation types dominated by Acacia species. Pindan is a shrubland with areas of Acacia thickets; while Pindan woodland also has an emergent tree layer, specifically of Eucalyptus and Grevillea species, *Gyrocarpus americanus, Erythrophloeum chlorostachys, Bauhinia cunninghamii, Adansonia gregorii, Buchanania obovata* and *Terminalia canescens* (Wheeler *et al*., 1992). The Dampier district also has areas of low tree savannah in which the grass layer is dominated by Chrysopogon species and the tree layer by *Adansonia gregorii, Bauhinia cunninghamii*, and species of Eucalyptus, Grevillea, Hakea and Acacia (Wheeler *et al*., 1992).

The majority of the Dampier Peninsula contains a relatively uniform environment of low relief undulating red sand plains with few creeks or hills. The vegetation is predominantly Pindan, grassland wooded by scattered trees, particularly Eucalypts, with a middle layer of Acacias (Kenneally *et al*., 1996). Fire is the controlling agent of the Pindan with the variety in the vegetation, particularly the Acacias, relating directly to a fire regeneration cycle (Kenneally *et al.*, 1996).

3.7.2 Threatened ecological communities

Ecological communities are defined as ‘naturally occurring biological assemblages that occur in a particular type of habitat’ (English and Blythe, 1997). Threatened ecological communities are ecological communities that have been assessed and assigned to one of four categories related to the status of the threat to the community, i.e. presumed totally destroyed, critically endangered, endangered, and vulnerable.

Some threatened ecological communities are protected under the *Environment protection and biodiversity conservation act*. Although threatened ecological communities are not formally protected under the State *Wildlife conservation act 1950,* the loss of, or disturbance to, some threatened ecological communities triggers the *Environment protection and biodiversity conservation act*. The Environmental Protection Authority’s position on threatened ecological communities states that proposals that result in the direct loss of threatened ecological communities are likely to require formal assessment.

Possible threatened ecological communities that do not meet survey criteria are added to the Department of Environment and Conservation's priority ecological community lists under priorities 1, 2 and 3. These are ecological communities that are adequately known; are rare but not threatened, or meet criteria for near threatened. Priority ecological communities that have been recently removed from the threatened list are placed in priority 4. These ecological communities require regular monitoring. Conservation dependent ecological communities are placed in priority 5.

A search of the Department of Environment and Conservation threatened ecological communities database was undertaken for known occurrences of threatened ecological communities and/or priority ecological communities within the proposed development area. No threatened ecological communities or priority ecological communities were located within the boundaries of the proposed development. However, the site is located within the two buffer zones of one vulnerable community (Figure A.2):

» 'Vulnerable' ecological community – 'vulnerable vine thickets on the coastal sand dunes of Dampier Peninsula'.

The *Environment protection and biodiversity conservation act* protected matters search tool (Department of the Environment, Water, Heritage and the Arts, 2008b) also does not identify any threatened ecological communities within the search area conducted for the proposed development area.

No threatened ecological communities or priority ecological communities were identified as being present on the site during a field survey conducted by GHD in June 2008 (GHD, 2008. and GHD, 2009).

3.7.3 Significant flora

Commonwealth

Species of significant flora are protected under both state and commonwealth acts. Any activities that are deemed to have a significant impact on species that are recognised by the *Environment protection and biodiversity conservation act*, and the *Wildlife conservation act 1950* can trigger referral to the Department of the Environment, Water, Heritage and the Arts and/or the Environmental Protection Authority.

A search of the *Environment protection and biodiversity conservation act* protected matters search tool did not identify any Commonwealth protected flora species within 10 km of the survey area.

State

In addition to the *Environment protection and biodiversity conservation act,* significant flora in Western Australia is protected by the *Wildlife conservation act 1950*. This *Act*, which is administered by the Department of Environment and Conservation, protects declared rare flora species. The Department of Environment and Conservation also maintains a list of priority listed flora species. Conservation codes for flora species are assigned by the Department of Environment and Conservation to define the level of

conservation significance. Priority listed flora are not currently protected under the *Wildlife conservation act 1950*. Priority listed flora may be rare or threatened, but cannot be considered for declaration as rare flora until adequate surveys have been undertaken of known sites and the degree of threat to these populations clarified. Special consideration is often given to sites that contain priority listed flora, despite them not having formal legislatory protection.

A search of the Department of Environment and Conservation rare flora databases and the Western Australian Herbarium records was undertaken. While there records indicate that two declared rare flora and seven priority listed flora species are known to exist in the general Broome area, there are no known records of declared rare flora or priority listed flora species within the study area.

3.8 Fauna

3.8.1 Significant Fauna Species

The conservation of fauna species and their significance status is currently assessed under both State and Commonwealth acts. The acts include the *Western Australian Wildlife conservation act 1950*; *Wildlife conservation (specially protected fauna) notice 2003,* and the *Environment protection and biodiversity conservation act*.

The Department of the Environment, Water, Heritage and the Arts maintains a database of matters of national environmental significance that are protected under the *Environment protection and biodiversity conservation act.* An *Environment protection and biodiversity conservation act* Protected Matters Report was generated (from the website of the Department of the Environment, Water, Heritage and the Arts), for the matters of significance that may occur in, or may relate to, the survey area.

A search of the Department of Environment and Conservation's threatened fauna database for any rare and priority species that may occur in the survey area was undertaken.

From the Department of Environment and Conservation and Department of the Environment, Water, Heritage and the Arts databases and the records of the Western Australian Museum, a number of protected fauna species (33 bird species and 3 mammal species) were identified as potentially occurring within the survey area. It should be noted that some species that appear in the *Environment protection and biodiversity conservation act* protected matters search tool are often not likely to occur within the specified area, as the search provides an approximate guidance to matters of national significance that require further investigation. The records from the Department of Environment and Conservation searches of threatened fauna provide more accurate information for the general area; however some records of sightings or trappings can be dated and often misrepresent the current range of threatened species.

3.9 Reserves, conservation areas and environmentally sensitive areas

No conservation areas or reserves are located within the boundaries of the proposed development.

The Department of Environment and Conservation's online native vegetation viewer was searched to determine the location of any environmentally sensitive areas within the vicinity of the project area, as declared by a notice under Section 51B of the *Environmental protection act 1986*.

The search confirmed that there are no environmentally sensitive areas situated within the Study area. There is one environmentally sensitive area situated east of the study area, east of Broome Road. This environmentally sensitive area is associated with Dampier Creek and will not be impacted as a result of the proposed project due to the distance to it and the drainage management that will be prepared as part of a *Local water management strategy* for the area and further refinements to the drainage design in subsequent urban water management plans. The proposed strategies will provide detailed information on the volumes and qualities of runoff water and the treatment processes which will be designed to retain the majority of water on site and to contain most high rainfall event water in a suitably sized detention and treatment basin adjacent to the site.

3.10 Groundwater

The study area falls within the Cable Beach Groundwater sub area.

The regional groundwater resources of the Broome area (1:250,000 map sheet SE516) comprise both confined and unconfined aquifers of significant extent. The hydrogeology of the Broome area is documented by Laws (1991) and there are three major and two minor aquifers where groundwater occurs (Table 2**)**. The most utilised aquifer is the Broome sandstone that comprises fine to coarse grained sandstone with minor beds of pebble conglomerate, grey siltstone and claystone. The Broome sandstone is unconfined and is separated from the underlying (confined) aquifers, Alexander formation and the Wallal sandstone, by an aquiclude, the Jarlemai siltstone.

Table 2 Summary of the stratigraphy in Broome (based on Laws, 1991)

Age	Formation unit	Estimated thickness	Lithology	Groundwater potential
Quaternary	Superficial deposits	5- 20	Sand, silt, clay; minor gravel, black organic clay	Minor perched Aquifer; fresh
	Bossut formation	20	Sandstone, calcilutite	Minor
Tertiary to Quaternary	Superficial deposits	2	2 Pisolitic and massive laterite	None

Age	Formation unit	Estimated thickness	Lithology	Groundwater potential
	Emeriau sandstone	30	Sandstone; minor conglomerate	None
Early Cretaceous	Melligo sandstone	30	Thin bedded to laminated sandstone	None
	Broome sandstone	283	Fine – to coarse grained sandstone; minor gravel, some mudstone and conglomerate	Major aquifer; Fresh - saline
Late Jurassic	Jarlemai siltstone	259	Siltstone, claystone; minor sandstone	Aquiclude, minor aquifers
	Alexander formation	46	Fine – to coarse grained sandstone; minor mudstone	Aquifer, artesian at Broome; brackish
Early to late Jurassic	Wallal sandstone	>360	Fine – to coarse grained sandstone; minor siltstone, lignite	Major aquifer; fresh to saline artesian at Broome

3.10.1 Groundwater levels

Groundwater in the Broome area moves under the influence of gravity down the hydraulic gradient west toward the ocean and south toward Roebuck Bay (WRC, 2001).

The *Study for Broome Groundwater Management Plan Review* (Groundwater Consulting Services Pty Ltd, November 2008) was prepared for the Department of Water and included presentation of the groundwater levels (Appendix D). From this report, the groundwater levels within the study area are less than 3 m AHD.

The *Report on Geotechnical Information for Broome North Lots 3150 and 304* (Coffey Geotechnical, 2009), did not encounter groundwater levels during the construction of test pits to 2.5 m below ground levels. The *Report on Geotechnical Investigation for Broome North – lots 3150 and* 304 (Coffey Geotechnics, 2009) also estimated the average annual maximum groundwater level and the maximum probable groundwater level based on groundwater bores within a 2 km radius of the site. These estimates are presented below:

» average annual maximum groundwater level: 2.5 mAHD;

» maximum probable groundwater level: 4.5 mAHD.

The topographic information for the site (included as Figure A.3) indicates, the lowest point of the will be approximately 6.6 mAHD. Therefore the depth to groundwater ranges from 2.1 m to 4.1 m at the lowest point on site.

3.10.2 Groundwater quality

Groundwater recharge to the Quaternary aeolian sands is direct from rainfall percolation and is estimated to be 6.5% of rainfall (Hingston and Gailitis, 1976). Recharge to the Broome Sandstone aquifer system is by direct percolation from rainfall and by leakage from the coastal dunes north of Broome. Recharge is estimated to be about 4 to 5 % of the average annual rainfall (Laws, 1987).

Groundwater discharges over a saline interface (WRC, 2001). Groundwater salinity ranges from less than 100 to more than 30,000 mg/L total dissolved solids, the lower levels being in the inland areas increasing towards discharge areas along the coast and Roebuck Plains above the saltwater wedge (Laws, 1991).

The range of observed conductivity levels from 13 Department of Water; water information network sites within the study area and surrounding the study area are presented below. Figure A.2 indicates the locations of the monitoring locations.

Table 3 Groundwater conductivity (µS/cm)

WIN Site ID	Average	Minimum	Maximum
8051	8,045	2,560	15,940
8052	6,358	3,400	10,500
8053	4,446	920	16,680
8054	3,184	1,150	17,490
8055	2,582	1,010	12,740
8056	2,764	930	11,220
8057	19,394	10,700	25,000
8058	4,247	400	7,400
8059	2,041	871	4,990
8060	1,920	1,500	2,550
8082	2,984	2,470	3,530
8083	1,086	563	1,519
8084	3,097	530	4,640

3.11 Surface water

3.11.1 Wetlands and waterways

The proposed development is located in the Cape Leveque Coast drainage basin (Department of the Environment, Water, Heritage and the Arts, 2008a).

The study area is not located in a proclaimed surface water management area (Department of Water, 2008a).

There are no wetlands or watercourses located within the study area.

Department of the Environment, Water, Heritage and the Arts (2008b) identifies Roebuck Bay, an internationally significant wetland (RAMSAR listed site), within 10 km of the study area. It is considered unlikely that this RAMSAR listed site will be impacted as a result of the proposed project due to the distance to it and the drainage management that will be prepared as part of a *Local water management strategy* for the area and further refinements to the drainage design in subsequent urban water management plans. The proposed strategies will provide detailed information on the volumes and qualities of runoff water and the treatment processes which will be designed to retain the majority of water on site and to contain most high rainfall event water in a suitably sized detention and treatment basin adjacent to the site.

3.12 Public drinking water source areas

Public drinking water source areas is a collective term used for the description of water reserves, catchment areas and underground pollution control areas declared (gazetted) under the provisions of the *Metropolitan water supply, sewage and drainage Act* 1909 or the *Country area water supply Act 1947.*

The protection of public drinking water source areas relies on statutory measures available in water resource management and land use planning legislation. The Department of Water policy for the protection of public drinking water source areas includes three risk management based priority classification areas and two types of protection zones.

The Department of Water's *Geographic data atlas* indicates that there are no Public drinking water source areas within the vicinity of the proposed development. The nearest public drinking water source area is approximately 4 km to the northeast of the site.

4. Proposed development

4.1 Key elements of the concept plan

The draft proposed development concept for Broome North is included in Appendix B. The proposed land uses identified in the Detailed Area Plan are:

- town centre;
- town living;
- neighbourhood living;
- bush living;
- environmental cultural corridor;
- public open space;
- light industry; and
- tourism.

4.2 Public open space landscape

The study area proposes to incorporate and retain the existing key landscape features. This will be achieved through creating landscape corridors which connect the urban areas with areas of retained open space.

These corridors will consist of open space uses and landscape dominated land uses. Green links will be incorporated to ensure that the retained vegetation are connected throughout the development and connectivity is maintained. Median strips will also be utilised for landscaping throughout the study area where appropriate.

The draft *Broome North landscape master plan* (UDLA, 2009) (included as Appendix C) outlines a landscaping plan for the development, including street planting examples, public open space section and space plan, the environmental cultural corridor section and typical treatment and suggested planting list.

The dominant species used in the public open space landscaping will be low water use native vegetation.

4.3 Previous land use

The study area is covered predominantly by native vegetation. Historical land use of the study area is grazing and natural vegetation. Recent land uses include a water tank located in the western portion of the study area on a reserve vested to the Water Corporation for water supply purposes. There is also a poultry farm south of Fairway Drive, in the north east of the study area.

Historical land use of the study area includes an abattoir, at the end of Locke Street and grazing of native vegetation. An examination of historical aerial photography was undertaken to identify changes in land use over time. Table 4 provides a description of

the land use changes as can be observed from aerial photography sourced from the Department of Land Administration.

Table 4 Historical land use changes as observed from Department of Land Administration

Year	
1967	There a small clearing directly off Broome Road, it is likely to be man made but photography is not clear enough to identify the land use. There is also an area of localised disturbance in the north east corner of the study area. The remainder of the study area is remnant native vegetation with several roads dissecting the area.
1982	Directly off Broome Road there is a small area of cleared paddocks to the north of the clearing. The clearing contains sheds or market garden facilities. The abattoir, at the end of Locke Street, can be identified on the aerial photo.
1989	The small clearing directly off Broome Road has been expanded and shows the initial construction of the Light Industrial Area (east of the study area boundary). There is a reserve vested to the Water Corporation for water supply purposes containing a clearly marked track showing the location of the yet to be constructed water tank in the western portion of the study area. Directly south of the reserve is the small square clearing present in 1982, and this area has increased to a larger cleared rectangle area. There has been some clearing of native vegetation to the east of the abattoir and two groups of buildings are present in the adjacent cleared area which is likely to be used for farming or a small business. The Broome Waste Management Facility (rubbish tip) has been constructed to the north of the study area boundary. Tracks through the area are more defined.
2000	The Light Industrial Area has been completed and the paddocks above the area are no longer obvious appearing as naturally regenerated vegetation. The Water Corporation tank is now constructed and the poultry farm is now present south of Fairway Drive. The cleared rectangle below the Water Corporation reserve appears largely revegetated but still contains a cleared section with some structures in it at the eastern end.
2007	The rectangular cleared section that was largely revegetated in 1989 still contains a cleared area at its eastern end and is now bordered by tracks and has a structure at its western end at the edge of the site. There have been no changes to land use from 2000 to 2007 however there has been regeneration of native vegetation within the abattoir and property to the east of the abattoir.

Adapted from: *Broome North: Southern Portion, Preliminary Environmental Impact Assessment and Biological Survey (GHD, September 2009).*

5. Fit-for-purpose water source planning

5.1 Existing water balance

An existing water balance for the Broome North site is summarised Figure 1.

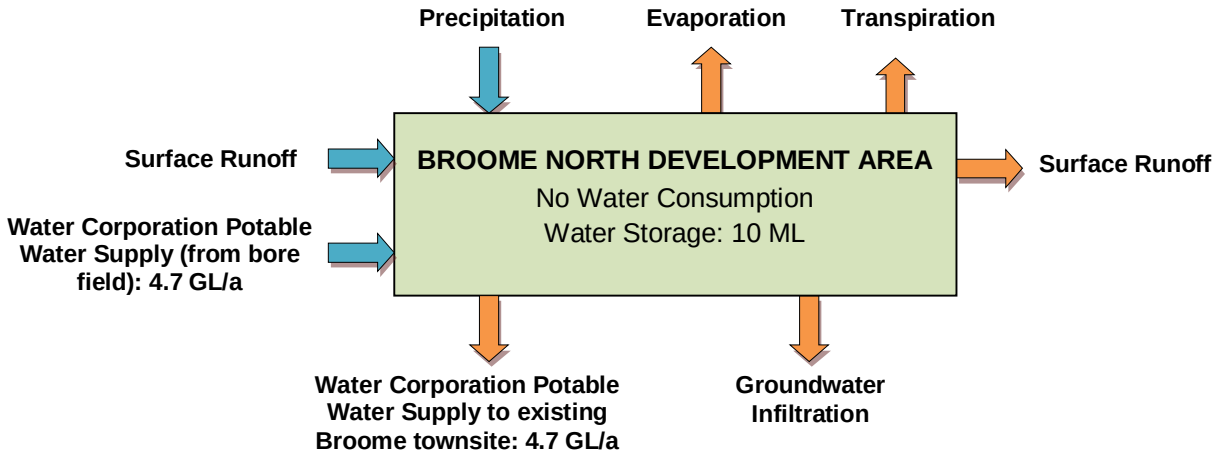


Figure 2 Existing water balance for the Broom North site

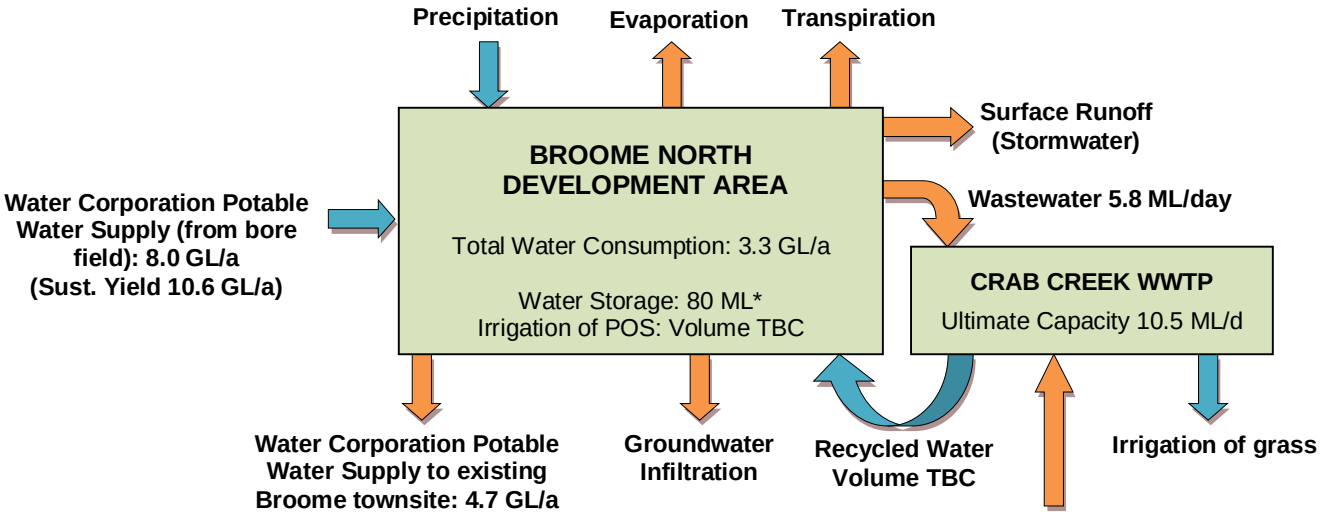
Water falls on the catchment as precipitation, and can either evaporate to the atmosphere, infiltrate into the groundwater or runoff as surface runoff to adjacent areas during large storm events. Groundwater infiltration is expected to be minimal due to the presence of Pindan Soils. Precipitation and evaporation rates are described in Section 3.2. In general, and depending on the variability of the rainfall, the daily evaporation rate exceeds the rainfall in all but the wettest months.

At this stage, no information is available in regard to flood levels for the site however there is evidence (Shire photo) of areas to the north-west of the site in the Waterfall and Lulfitz Drive special rural area, being flood prone. The balance of the area is expected to be above any flood levels.

Under the existing pre-development arrangement, no water is used for human consumption within the Broome North boundary. Water Corporation stores water at a tank site within the geographical boundary of the site, but this water is currently used only in the existing, older part of Broome, and hence the volumes of water entering and leaving the site are equal.

5.2 Proposed water balance

The water balance for the Broome North site under the proposed development is summarised in Figure 3.



*Final storage volume to be determined by Water Corporation as part of its Planning Process

Figure 3 Proposed water balance for the Broom North site

Within the Broome North boundary, the main water uses are household consumption and irrigation of public open space. The breakdown of internal (in house, including for drinking), external (outside of the house, including garden watering) and public open space irrigation water use has not been determined at this stage, and will be examined further during development of the *Local water management strategy* for the site. The use of bores for garden irrigation is unlikely to be feasible in this area due to the presence of Pindan Soils.

The water balance as presented assumes that use of recycled water for certain proposed uses will become the preferred option. It is likely that irrigation of grass at the wastewater treatment plant site will be used by Water Corporation as a re-use option for the treated effluent. Further use of recycled water for irrigation of public open space or other uses within the Broome North development area need to be reviewed at later stages of the planning process.

5.3 Potential water sources

There are a number of points in the water cycle where communities can obtain water for drinking and other needs. Potential water sources may include groundwater, surface water, desalination, recycled water and rainwater collection. For the Broome North development, the most viable water sources have been identified as groundwater from the existing Broome bore field, and recycled water. These are discussed in Section 5.5. Rainwater is also discussed, but use of rainwater will be at the discretion of the individual user.

5.4 Water resources and allocations

5.4.1 Groundwater management

The existing parts of Broome are currently supplied by groundwater from a local Water Corporation production bore field in Reserve 25716 located to the North East of the Broome Township. Water Corporation has identified that the sustainable yield of the Broome bore field is 10.6 GL/annum (pers comm. 2009).

The Water Corporation has also advised that the quality of the groundwater aquifer used for potable water supply is good. The required treatment processes are chlorination and fluoridation only, although pH correction has been identified as a possible treatment process for any future bores if warranted to meet water quality standards.

5.5 Fit-for-purpose water use options

5.5.1 Groundwater

Expansion of the current groundwater supply system is a convenient option for supply to the Broome North development as it would minimise the amount of infrastructure required. The identified sustainable yield of the bore field is more than sufficient to supply the projected town water demands on its own.

5.5.2 Recycled water

Recycled water has many applications that can be considered, including:

- Industrial reuse;
- Public open space irrigation;
- Groundwater replenishment / aquifer storage and recovery; and
- Dual reticulation.

This *District water management strategy* assumes that both dual reticulation and public open space irrigation have potential to be applicable in the Broome North development area. These options will be further examined in later stages of the project. A preliminary list of the advantages and disadvantages of a recycled water scheme is summarised in Table 5.

Table 5 Advantages and disadvantages of recycled water at Broome North

Advantages	Disadvantages
Reduced consumption of drinking water by up to 40% (from Rouse Hill, NSW)	Storage during low demand periods (wet season)
Substitution of potable water use, delayed implementation of bore field expansion	Over treatment – providing higher quality water than is required for the use

Advantages	Disadvantages
Reduced discharges to the environment (e.g. Roebuck Bay)	Technically more complex treatment. Do operator and maintenance skills match?
First major domestic reuse scheme in WA. Opportunity for a pilot scheme.	Cost and operational responsibilities not known

5.5.3 Rainwater

Individual lot users may choose to install rainwater tanks for private use. This is considered to be a decision made at the discretion of the individual homeowner, and is therefore not discussed further in this document.

5.5.4 Preferred water source

The preferred water source for drinking water and other inside use is the Water Corporation's production bore field in Reserve 25716 located to the north east of the Broome Township. There is potential for source substitution for water for toilet flushing, with rainwater, recycled water or local bore water, for example. Inside use may also be supplemented with rainwater capture and storage in tanks at the discretion of the individual user.

Investigation of the extent to which recycled water is acceptable to the community and stakeholders is needed before the preferred water source for toilet flushing, garden watering and irrigation of public open space can be selected. It is recommended that options for a potential recycled water scheme be assessed as part of a later stage.

5.6 Infrastructure – existing and required

5.6.1 Existing infrastructure

Source

Water Corporation's existing town water supply bore field located approximately 10 km north east of the Broome Township, contains 15 operational bores including a peaking bore, with three further bores ready to be connected. This will take the total bore field production to 5.4 GL/a.

Storage

A tank site is located at Cable Beach (off Fairway Drive), as shown in SKM Sketch 2736-3150 SK008 (Rev 8) (included in Appendix A). A 10 ML tank currently exists on the site.

Distribution

As this is a new proposed development there is currently no distribution pipe work in place throughout the site.

5.6.2 Proposed infrastructure

Source

The water source strategy for the Broome North development is summarised as:

- Water for drinking and other indoor uses excluding toilet flushing to be supplied from the Water Corporation bore field. The Water Corporation currently has planning for three additional bores for the existing Broome bore field, with the potential for a further three to be constructed if required.
- Recycled water for irrigation of public open space could be supplied from the future Crab Creek wastewater treatment plant. The viability of such a scheme should be reviewed as part of future planning and option analysis.
- Water for irrigation of gardens and toilet flushing to potentially be supplied from a third pipe recycled water system, pending future discussions with stakeholders. If this option is not feasible, water for these uses will be supplied from the Water Corporation bore field.

Any of the above may be supplemented by stored rainwater at the discretion of individual users.

Storage

Water Corporation is currently undertaking definition design for a second 10 ML tank on the current Cable Beach site, with room allowed for an additional tank or tanks to be constructed in future to bring the total storage volume to 80 ML. A booster pumping station and elevated tank will also be required at this site.

An additional tank site is recommended for the Broome North development area north of Fairway Drive, incorporating the B27 parcel. It is proposed that this area be serviced by a tank located to the west of Buckley's Road. This site may also be used for a future recycled water tank.

It is noted that a proposed 30 ML tank on Blackman Road is currently pending funding approval. This tank does not service the Broome North area.

Distribution (potable water)

Water reticulation mains will be required for the development area.

If recycled water is accepted as a water source for the area, dual reticulation (sometimes referred to as a third pipe system) will need to be installed. A decision on whether recycled water is acceptable as a water source will be made early in the planning process, as retrofitting of recycled water reticulation is expensive and will impact the economic viability of this option.

Treatment (recycled water)

If use of recycled water becomes a preferred option, additional treatment may be required to produce water that is fit for purpose, depending on the use. It is assumed that an advanced treatment process would be supplied at the end of the existing wastewater treatment plant to produce a treated recycled water stream.

Transfer and supply system (recycled water)

A transfer pump station would be located at the recycled water plant delivering recycled water through a pressure main to a storage reservoir.

The recycled water storage reservoir would be located adjacent to the potable water reservoir or at the additional Public Purpose site. It is assumed that a booster pump station to raise the system pressures would be required, similar to the existing Cable Beach water reservoir. The booster pump station would then supply distribution mains. Pipe sizes will depend on lot layout and system design.

Each lot would then have a connection and reticulation that supplied toilets in the dwelling and outside taps for garden watering.

All distribution and pressure mains, reticulation, plumbing, fittings and fixtures would be purple (lilac) to differentiate them from the potable supply.

6. Water management strategy

6.1 Drinking water conservation and efficiency of use

The Broome North development will be subject to compulsory water conservation measures as described on the Water Corporation's 'waterwise' website. These include the permanent water efficiency measures for Western Australia that were introduced on 1 October 2007. For towns north of Kalbarri and Kalgoorlie, which includes Broome, these measures restrict garden watering either before 9 am or after 6 pm on an alternate day roster. The measures also ban the cleaning of driveways, walls or windows of buildings with a hose, except under extraordinary circumstances.

Other measures for water conservation and efficiency of use within the development will be developed as part of later stages of the planning process, and may include:

- Recommendations that new homes in the development have water efficient fittings installed. This would include water efficient taps, showerheads, toilets and appliances such as washing machines, although these will be the responsibility of the individual home owners;
- Plans for irrigation of public open space to occur only at night, to reduce evaporation losses.

6.2 Surface water management

6.2.1 Stormwater management

The stormwater management system in Broome uses the roads as drains to carry the majority of the flows for all events. Gullies and pipes are only used to manage flows where they cannot be carried in the road between the kerbs and for low flow drains from detention basins.

Drainage design uses the following coefficients in accordance with the Shire of Broome's drainage guidelines:

- Road reserve 0.9
- Residential sites 0.7
- Vegetation and bush 0.4 (pre development)

Stormwater carried in the roads is discharged into an open unlined swale/detention drainage system as high as possible in the catchment. This is to ensure that the road system is not overtopped and the water quality treatment train is activated as soon as possible.

Surface water management is based on the following principles:

- The development is to have a detention system so that the peak runoff outflows for Q5, Q10, Q50 and Q100 year average recurrence interval events are no greater than that which would occur under pre-development conditions.

- Finished floor levels for the buildings on all lots are to be at least 0.5 m above the crown of the road to ensure that no flooding of the residences occurs.
- The Q50 and Q100 year average recurrence interval events are to be contained within the road reserve and the Q10 year average recurrence interval event is to be contained within the kerbs.
- A minimum of 0.3 m freeboard is required between the flood level of a Q100 year average recurrence interval design event and the finished floor level of all buildings on the site.

It is recommended that the total stormwater drainage system be modelled using an industry standard surface water modelling software package. Previous developments at Januburu Six Seasons and the Shire of Broome's: *Cable Beach drainage strategy* have been modelled using the XP-SWMM drainage modelling package.

6.2.2 Conceptual stormwater management system

A preliminary drainage catchment plan has been prepared for the overall site, which is shown in SKM Figure C011 Rev C (included in Appendix A).

The site is divided by a ridge line which is a south-west to north-east line along the western third of the site. In general, the western side of the ridge line grades out at a slope from 1% to 2% and the eastern side of the ridge line has similar grades to Gubinge Road and Broome Highway.

For the purpose of a preliminary assessment, the site has been divided into five catchment areas, as shown on the catchment plan. The catchment areas are:

- Area 1 (pink) – 51 ha. This area grades directly to the west, and the Shire of Broome have advised that any discharge from this area cannot be accommodated in the existing Cable Beach drainage system, apart from a DN 300 pipe, which can be used as a low flow drain. This area will require a detention basin with a low flow pipe into the Cable Beach drainage system as well as a low flow pipe to discharge into the open unlined drain along Sanctuary Road.
- Area 2 (light blue) – 69 ha. This catchment has the steepest slopes, with some areas in the 2% to 3% range. This area grades to the west and north, and at present, effectively discharges into the low area to the north of the Lullfitz Drive special rural area. The discharge location for this catchment is to a low point of around RL 5.0 in the north-west corner of the development area. This location is currently encumbered by a sand mining lease (refer to Appendix B) M04/ 209. The soil has been tested for infiltration rates which give good results down to around 2.0 m, however below that level the infiltration rate reduces markedly. The area has been mined for clean white sand for construction purposes, and appears to be suitable as an infiltration basin with a level of RL 3.1, however use as an infiltration basin is subject to a detailed geotechnical investigation. The sand pits do not appear to be in current use, apart from the area to the east.

- Area 3 (green) – 214 ha. This area grades to the east and south towards Magabala and Gubinge Roads. The outlet for the southern section of this catchment is along the northern side of Gubinge Road and then east to the existing detention basin on the corner of Gubinge and Broome Roads. This is currently under investigation to look at ways to improve the water quality effectiveness of the detention basin. The "Lake Broome" basin discharges into the upper reaches of Dampier Creek. The northern section of the catchment will discharge into a swale/detention system on the southern edge of the environmental cultural corridor which outlets into the upper reaches of Dampier Creek via a culvert crossing under Broome Highway.
- Area 4 (dark blue) – 112 ha. This area is to the north of the existing "Blue Haze" industrial area and grades directly east towards Broome Highway. The southern section of this area will discharge to the upper reaches of Dampier Creek though the existing outlet under Broome Highway. This system will have to be upgraded to provide detention in accordance with Section 6.2.1 and will require an upgrade of the culvert outlet under Broome Highway. The northern section of this catchment will discharge into a swale/detention system in the new environmental cultural corridor. The outlet for this system will be a new culvert crossing under Broome Highway south of the Rodeo and then to the upper reaches of Dampier Creek.
- Area 5 (yellow) – 278 ha. This is the largest catchment and generally grades directly east towards Broome Highway, although the northern area grades towards the north-east. This catchment will require a number of linear green spaces extending in an east-west direction to the upper parts of the catchment to allow for the construction of swale/detention systems. The swales will outlet into a north-south detention basin system along Broome Highway which will outlet to the upper reaches of Dampier Creek via two new culvert crossings under Broome Highway on the northern and southern boundaries of the speedway.

To implement the proposed swale/detention drainage system, approximately 3% of the gross land area will be required for detention basins. The swales and detention basins will be designed to integrate into the existing landscape and form natural creeks and streams.

6.2.3 Stormwater quality and best management practises

The development of a catchment affects stormwater quality by increasing the nutrient generation above existing levels. The primary aim of the proposed arrangement of swales and detention basins is to reduce the nutrient input into the receiving environment. The proposed swales and dry/ephemeral basins form the basis of the structural best management practices for the area. Other non-structural measures will take the form of on-going implementation and maintenance of structural best management practices, public education about the system and water quality monitoring.

The water quality of stormwater originating from the catchment is proposed to be managed by the following methods:

- Reduce and minimize stormwater flow velocities to aid sedimentation, reduce erosion and reduce the carriage of seeds into the natural landscape;
- Construction of vegetated swales drains and dry/ephemeral detention basins using weirs and low flow drain system to reduce the water velocity to allow settling out of the silt load and the removal of gross pollutants.
- Design the swales to provide a more natural waterway and creek system rather than a more linear conveyance drainage system with no detention of flows;
- Link grassed public open space area and multi-use parks into the swale/detention systems to improve the water quality through the take up of nutrients. The public open space areas will be constructed as detention systems with low flow drains.
- Detention basins with sedimentation traps to maximize the deposition of silt within the basin;
- Provide for natural vegetation re-growth by using topsoil generated from the site on the sides of the swales and the bases of the detention basins. Additional planting of native plants along the sides of the swales and basins;
- Where possible, restoration of natural drainage pathways to utilize natural nutrient stripping properties of existing vegetation;
- Planting and regeneration of low-lying native vegetation in swale drains for filtering of particulates and removal of dissolved nutrients.
- Implementation of recommended maintenance and education program for optimal performance of stormwater system; and
- Potential infiltration at the outlet for catchment area 2 by the re-use of the existing sand mining area at the north-western corner of the catchment.

6.2.4 Water quality modelling

An industry standard water quality stormwater modelling software tool such as “MUSIC" will be used to assess the efficiency of the water quality treatment system. MUSIC” estimates the quantities of flow, Total Suspended Solids, Total Phosphorus, Total Nitrogen and Gross Pollutants from catchments. When the mean annual loads produced from mitigated and unmitigated developed catchments are compared the effect of the water quality treatment system can be assessed.

The water quality target for the system as compared to a development that does not actively manage stormwater quality are consistent with the criteria listed in Section 2.4, namely:

- At least 80 per cent reduction of total suspended solids;
- At least 60 per cent reduction of total phosphorus;
- At least 45 per cent reduction of total nitrogen; and
- At least 70 per cent reduction of gross pollutants.

6.2.5 Landscaping concepts

The draft *Broome North landscape master plan* (UDLA, 2009) outlines a landscaping plan for the development, including street planting examples, public open space section and space plan, the environmental cultural corridor section and typical treatment and suggested planting list. Some concepts are presented as Figure 4.

Figure 4 Proposed landscaping concepts and examples for Broome North

INITIAL DRAINAGE CONCEPTS
Drawing by UDLA

FREE FORM DRAINAGE SWALES – JANUBURU SIX SEASONS,BROOME
Swales direct water around significant vegetation and landform
Photo by UDLA

CONCRETE WEIRS– JANUBURU SIX SEASONS,BROOME
For water retention and slow release
Photo by UDLA

6.3 Groundwater management

6.3.1 Groundwater levels

Data from the Department of Water's water information network database within the development area and from the surrounding regions (Figure A.2) was used in conjunction with previous studies to present the information in the following groundwater level and quality sections.

The *Report on Geotechnical Investigation for Broome North – lots 3150 and* 304 (Coffey Geotechnics, 2009) estimated the average annual maximum groundwater level and the maximum probable groundwater level to be:

- average annual maximum groundwater level: 2.5 mAHD
- maximum probable groundwater level: 4.5 mAHD

The groundwater levels from Coffey's investigation correlate well with the levels presented in the *Study for Broome Groundwater Management Plan Review* (Groundwater Consulting Services Pty, Ltd, November 2008), therefore it is proposed to adopt these levels in the district water management strategy.

The topographic information for the site (included as Figure A.3) indicates, the lowest point of the will be approximately 6.6 mAHD. Therefore the depth to groundwater ranges from 2.1 m to 4.1 m at the lowest point on site.

No subsoil drainage is proposed to be constructed within the development due to the depth to groundwater.

The site is underlain by pindan sands which do not allow for infiltration of stormwater runoff to the groundwater. Therefore there will be little impact on the groundwater levels within the study area and no specific management strategy is proposed.

6.3.2 Groundwater quality management

The proposed stormwater management for runoff generated from the development will be detained on site and very small volumes of stormwater runoff will be infiltrated to the groundwater due to the Pindan sands, therefore potential for groundwater quality to be impacted is low. As such, no specific groundwater quality management strategy is proposed.

6.4 Wastewater management

In Broome, wastewater is collected via a traditional gravity sewer and transferred to the wastewater treatment plant owned and operated by the Water Corporation. Expansion of the existing gravity system to include the Broome North development will be required.

Collected wastewater will be transferred to a new wastewater treatment plant being constructed on Crab Creek Road. The wastewater will be treated at this wastewater treatment plant and treated wastewater will be managed by the Water Corporation by

irrigating Rhodes Grass adjacent to the wastewater treatment plant. The Water Corporation may review the treated wastewater management options in the future.

Reusing treated wastewater can provide offsets by reducing the demand on potable water supply. This can delay upgrades or expansion of the water supply system, such as construction of new water production bores. Opportunities for treated wastewater reuse, such as irrigation of public open space or toilet flushing, in the Broome North development will be reviewed at later stages of the planning process.

7. Implementation framework

7.1 Local planning

A Development Area Plan effectively guides subdivision and development of an area. It provides the rationale for development and is a good indication of the developer's intentions for the area. A Development Area Plan is required to provide detailed information regarding site characteristics and the context of the area. It also outlines constraints and opportunities associated with the site, along with solutions to deliver the identified outcomes.

Detailed information relating to water use (potable and non potable), surface water and groundwater management is to be included in the Development Area Plan in the form of a local water management strategy. This *District water management strategy* provides information that would be used in the preparation of local water management strategies for Broome North. The environmental information and monitoring data will be used to select the most appropriate water sensitive urban design best management practices for local conditions. The local water management strategies will need to be prepared by the developer.

The local water management strategies will need to be prepared in accordance with *Better urban water management* (WAPC, 2008) and include, but not be limited to, the following:

- Geotechnical investigations;
- Stormwater concept design including flow paths, flow depths, sizing of detention basins and their indicative locations;
- Site Water Balance based on a land use plan; and
- A post development water monitoring plan.

In addition to the local water management strategies, it is recommended that construction environmental management plans are prepared. Each specific development site will require the preparation of an urban water management plan.

The construction environmental management plans should address any potential impacts associated with development or construction activities, including acid sulfate soils, soil erosion, surface water management, waste management, materials storage, vegetation and other natural asset protection, and heritage issues.

The urban water management plan will need to be prepared in accordance with *Better urban water management* (WAPC, 2008) and include industry specific:

- Water requirements/source options;
- Disposal options;
- Efficiency plan;
- Contingency plan.

7.2 Monitoring program

7.2.1 Pre-development monitoring program

As there will be minimal impact on groundwater from the proposed development and substantial data already exists in the vicinity, no additional pre-development monitoring is proposed.

The baseline groundwater levels and the baseline groundwater quality have been determined from existing monitoring data presented in Section 3.10.

7.2.2 Recommended post-development monitoring program

As infiltration to the groundwater is highly limited by the Pindan soils deterioration of groundwater quality as a result of development is not likely. Therefore no groundwater monitoring (level or quality) is proposed.

It is recommended that opportunistic surface water sampling is undertaken when the drainage infrastructure is wet. The recommended monitoring parameters are outlined in Table 6.

Post-development monitoring will be the responsibility of the developer except where site specific monitoring of light industrial premises is required where it will be the responsibility of the proponent.

Table 6 Recommended post-development monitoring program

	Site	Frequency	Parameter
Surface water	Discharges from drainage infrastructure	Opportunistic when the infrastructure is wet	◗ **In-situ** pH, EC and temperature. ◗ **Unfiltered sample**: pH, EC, TN, FRP, TKN, ammonia, TP, heavy metals (As, Cd, Cr, Cu, Pb, Ni, Zn, Hg). ◗ **Filtered sample**: nitrate/nitrite and PO_4

7.2.3 Reporting

The Developer will prepare an annual water quality report for each year of post-development monitoring, which will be presented to the Shire of Broome and the Department of Water. This report will summarise the sampling results from the previous year.

Reporting and Monitoring shall be in accordance with ANZECC & ARMCANZ (2000) and the Department of Water quality assurance/quality control systems to allow inclusion into Department of Water's WIN database.

7.2.4 Contingency action plan

As the recommended monitoring program is only based on opportunistic sampling events, no specific contingency action plan is proposed.

However, when samples are collected, the results should be compared with the relevant ANZECC guideline values for the region. Where there is a significant variation between the observed water quality and the ANZECC guideline value a discussion is to be held between the developer, Department of Water, Department of Environment and Conservation and other relevant parties to discuss appropriate ways forward.

7.3 Funding and ongoing maintenance responsibilities

7.3.1 Funding

Funding for the design and construction of both flood management measures and water quality measures can be sourced from a variety of stakeholders depending on the type of work being undertaken, and the point in time in which the funding is required. For example, swales and bioretention swales form part of the road reserve and are a substitute for hard engineering pit and pipe networks. Such capital works may therefore be funded by the developer of the road infrastructure as they are simply an alternative drainage solution and not an additional structure to what would normally be required. Maintenance and renewal of the bioretention swales and biofiltration pockets will be required after the developer's involvement in the area has concluded, so funding and responsibility for this work will need to be decided in advance.

7.3.2 Responsibilities

Table 7 outlines the roles and responsibilities for the actions recommended in this *District water management strategy*.

Table 7 Roles and responsibilities

Role	Responsibility	Requirement and Period
Local Water Management Strategies	Developer	During structure planning.
Design and construction of drainage system	Developer	Hand over to Shire of Broome at practical completion.
Non-structural controls: *Land use and Management*	Developer	Sediment and erosion control during construction.

Role	Responsibility	Requirement and Period
Non-structural controls: *Public awareness campaigns*	Developer	Sustainability information packs, including educational information regarding non-structural control measures, such as fertiliser application, native gardens, herbicide use, weed control and waste management, to be provided at settlement.
Non-structural controls: *Street sweeping and waste management*	Shire of Broome	Street sweeping to be undertaken biannually for a period of three years from practical completion.
Structural control compliance	Shire of Broome after practical completion	Drainage structures to be cleared biannually for a period of three years from practical completion and monitored to ensure functionality.
Water quality monitoring and reporting	Developer (and proponents in light industrial areas)	Monitoring program (Section 7.2.2). Annual reports should prepared by the landowner to be submitted to the Shire of Broome and DoW for review for a period up to 3 years from practical completion.
Provision for 1 year 1 hour average recurrence interval event retention/ detention and bioretention areas	Developer	Location and design of 1 year 1 hour average recurrence interval event retention/detention and bioretention areas to be determined in the urban water management plan.

7.4 District water management strategy technical review

It is intended that this district water management strategy be reviewed within ten years or earlier if deemed necessary until development has occurred.

The review should be undertaken by the developer, with agreement from the Department of Water, Environmental Protection Agency, Western Australian Planning Commission, and the Shire of Broome. The review should cover, but not be limited to the following:

- Assessment of impacts of development;
- Design objectives; and
- Requirements for water management strategies.

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Appendix A

Figures

410,000 420,000 430,000

8,030,000 8,020,000 8,010,000

WATERBANK

CAPE LATREILLE

TWELVE MILE

CABLE BEACH

BROOME ROAD

MILLIYA RUMURRA

District Water Management Strategy (DWMS) Study Area

YAWURU

GANTHEAUME BAY

BROOME

SADDLE HILL

GANTHEAUME POINT

BROOME BIRD OBSERVATORY

FALL POINT

INNER ANCHORAGE

RIDDELL BEACH

ROEBUCK BAY

ENTRANCE POINT

ROEBUCK DEEP

INDIAN OCEAN

LEGEND

DWMS Study Area

1:100,000 (at A3)

0 500 1,000 2,000 3,000 4,000

Metres

Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia (GDA)
Grid: Map Grid of Australia 1994, Zone 51

N

CLIENTS | PEOPLE | PERFORMANCE

Landcorp
Broome District Water Management Strategy

Job Number 61-24599
Revision 0
Date 13 OCT 2009

Locality Map

Figure A.1

G:\61\24599\GIS\Maps\Mxds\61_24599_003_Rev0.mxd

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

Data Source: GHD: DWMS Study Area - 20091001; GA: 250k Topo Data - Series 3 - 2004. Created by: wdavis, kdiralu

418,000 420,000

8,022,000 8,020,000 8,018,000 8,016,000

JILBANUNG. WANGKUNAN. JURLIRR. YARRARRA. CABLE BEACH 6. BILLINGURRU. MARNALAKUN. ILLANGARAMI NGILIRIRRBANJIN BULGURGUN. WUNDORDA UNDANDA. FISHERMENS BEND 1.

8059 8060 8058 8051 8052 8053 8054 8055 8083 8056 8084 8082 8057

WULLULONG GROUND Broome Crocodile Farm

LULLFITZ DR BUCKLEYS RD LOCKE ST BROOME RD WATTLE DR FAIRWAY DR MILLINGTON RD SANCTUARY RD GUBINGE RD MURRAY RD MAGABALA RD CRAB CREEK RD TANAMI DR LORIKEET DR JIGAL DR OLD BROOME RD DJAIGWEN RD SANDPIPER AV

LEGEND

- DWMS Study Area
- DEC Estate
- Environmentally Sensitive Areas
- TEC Buffers
- Aboriginal Heritage Sites
- Win Sites

Declared Rare & Priority Species

- (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

1:20,000 (at A3)

0 100 200 400 600 800

Metres

Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia (GDA)
Grid: Map Grid of Australia 1994, Zone 51

N

CLIENTS | PEOPLE | PERFORMANCE

Landcorp
Broome District Water Management Strategy

Environmental Constraints and WIN Sites

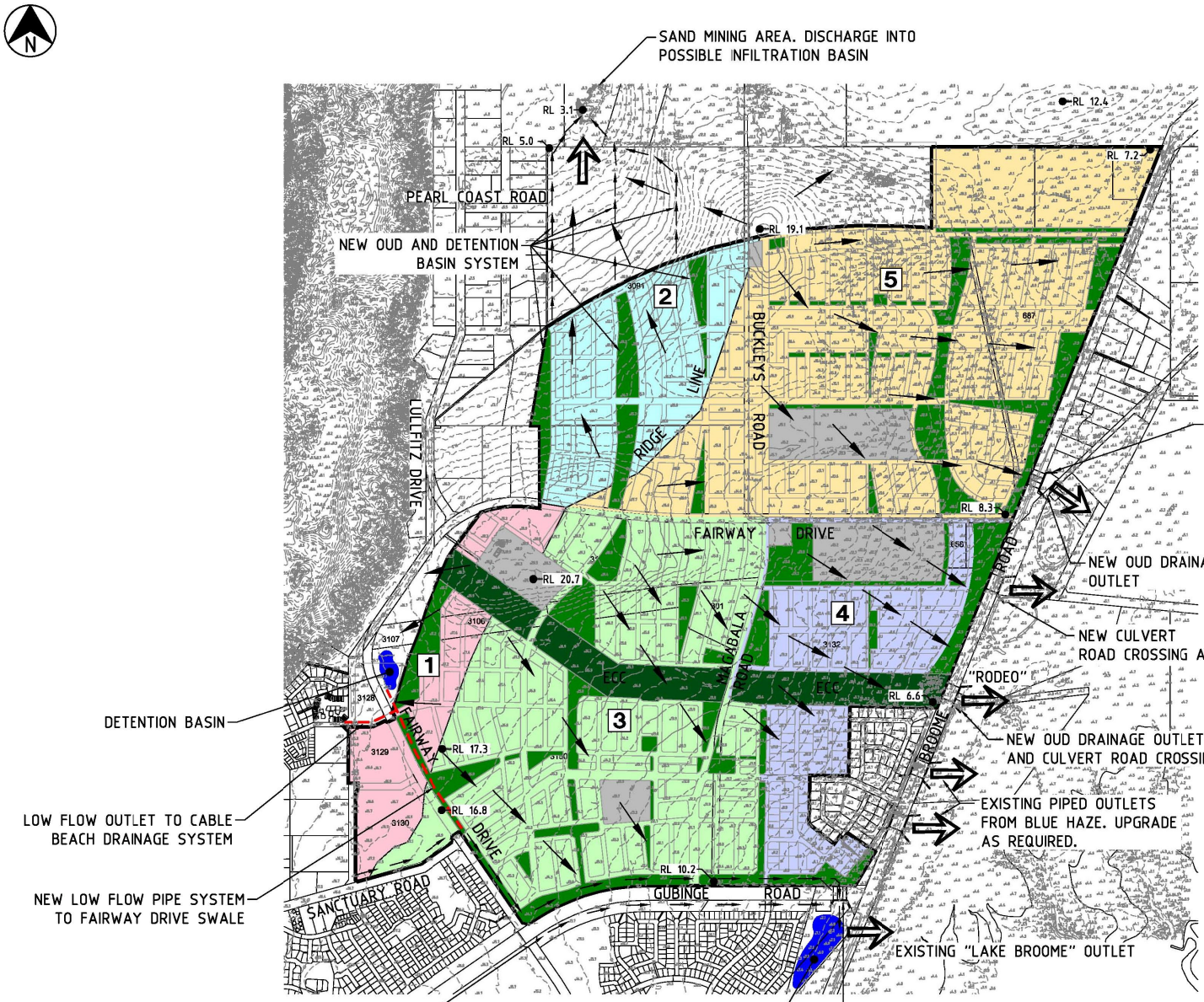
Job Number	61-24599
Revision	0
Date	13 OCT 2009

Figure A.2

G:\61\24599\GIS\Maps\Mxds\61_24599_004_Rev0.mxd

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

Data Source: GHD: DWMS - 20091013; DoW: WIN SItes - 200909; DEC: Declared Rare & Priority Flora - 20080605, DEC Estate - 20080605, TEC Buffers - 20080606, Environmentally Sensitive Areas - 200804; Landgate: Broome Townsite Mosaic 2007 - 2007. Created by: wdavis, kdiralu



NOTES

1.0 ALL BASE PLANS PROVIDED BY WHELANS SURVEYS.
2.0 OUD - OPEN UNLINED DRAIN.

LEGEND

- EXISTING SURFACE CONTOUR
- SITE BOUNDARY
- AREA 1 - 51Ha
- AREA 2 - 69Ha
- AREA 3 - 214Ha
- AREA 4 - 112Ha
- AREA 5 - 248Ha
- POS AND DRAINAGE
- FLOW ARROWS
- CULVERT OR PIPE ROAD CROSSING
- OUD — OPEN UNLINED DRAIN (SWALE)

1:10000

No	DATE	DRAFTING CHECK	DESIGN REVIEW	REV'D P.MGR	APP'D P.DIR	AMENDMENT
C	05.10.09					ISSUED FOR ENGINEERING REPORT
B	17.08.09					ISSUED FOR INFORMATION
A	29.07.09					INITIAL ISSUE FOR REVIEW

No	DRAWING NUMBER	REFERENCE DRAWING TITLE
	.	

SKM
Sinclair Knight Merz Pty Ltd
A.C.N. 001 024 095
Durack Centre 263 Adelaide Tce
Perth Western Australia 6000
Ph (08) 9469 4400 Fax (08) 9469 4488

LANDCORP

CLIENT	LANDCORP		
PROJECT	BROOME NORTH		
DRAFTER C.RAYNER	DRAFTING CHECK	REVIEWED PROJECT MANAGER	APPROVED PROJECT DIRECTOR
DESIGNED P.OLIVER	DESIGN REVIEW		

TITLE: DEVELOPMENT PLAN - DRAINAGE CATCHMENT PLAN

SCALE	SKM PROJECT No	DRAWING No	AMDT
1:10000	PB50119	C011	C

NOTES

1. THIS DRAWING SHALL BE READ IN CONJUNCTION WITH THE CONTRACT DRAWINGS AND SPECIFICATION.

LEGEND

- W — EXISTING WATER
- SITE AREA BOUNDARY
- INDICATIVE PROPOSED DEVELOPMENT

PROPOSED PUBLIC PURPOSE (RECYCLED WATER TANK SITE)

EXISTING WATER CORPORATION TANK SITE

EXPANDED WATER CORPORATION TANK SITE

PROPOSED DN500 WATER MAIN

PEARL COAST ROAD

LULLFITZ DRIVE

BUCKLEYS ROAD

FAIRWAY DRIVE

MAGABALA ROAD

BROOME ROAD

DISTRIBUTION MAIN

CABLE BEACH ROAD

GUBINGE ROAD

SANDPIPER AVENUE

0 100m 200 300 400 500 600 700 800 900 1000 1100 1200 1300 1400 1500

1:10000

No	DATE	DRAFTING CHECK	DESIGN REVIEW	REV'D P.MGR	APP'D P.DIR	AMENDMENT
B	05.10.09	*TJ	*TJ	*VMW	*PJ	ISSUED FOR ENGINEERING REPORT
A	17.08.09					ISSUED FOR INFORMATION

Sinclair Knight Merz Pty Ltd
A.C.N. 001 024 095
Durack Centre 263 Adelaide Tce
Perth Western Australia 6000
Ph (08) 9268 4400 Fax (08) 9268 4488

'*' INDICATES A COPY OF AN ORIGINAL SIGNED DRAWING

CLIENT: LANDCORP

PROJECT: BROOME NORTH

DRAFTER	DRAFTING CHECK	REVIEWED PROJECT MANAGER	APPROVED PROJECT DIRECTOR
C. LEGERSTEE	T. JOHNSTON	05.10.09	05.10.09
DESIGNED	DESIGN REVIEW		
A. MICENKO	T. JOHNSTON	*V. WARDLEY	*P. JORDAN

TITLE: EXISTING AND PROPOSED WATER INFRASTRUCTURE PLAN

SCALE	SKM PROJECT No	DRAWING No	AMDT
1:10000	PB50119	SK002	B

A1

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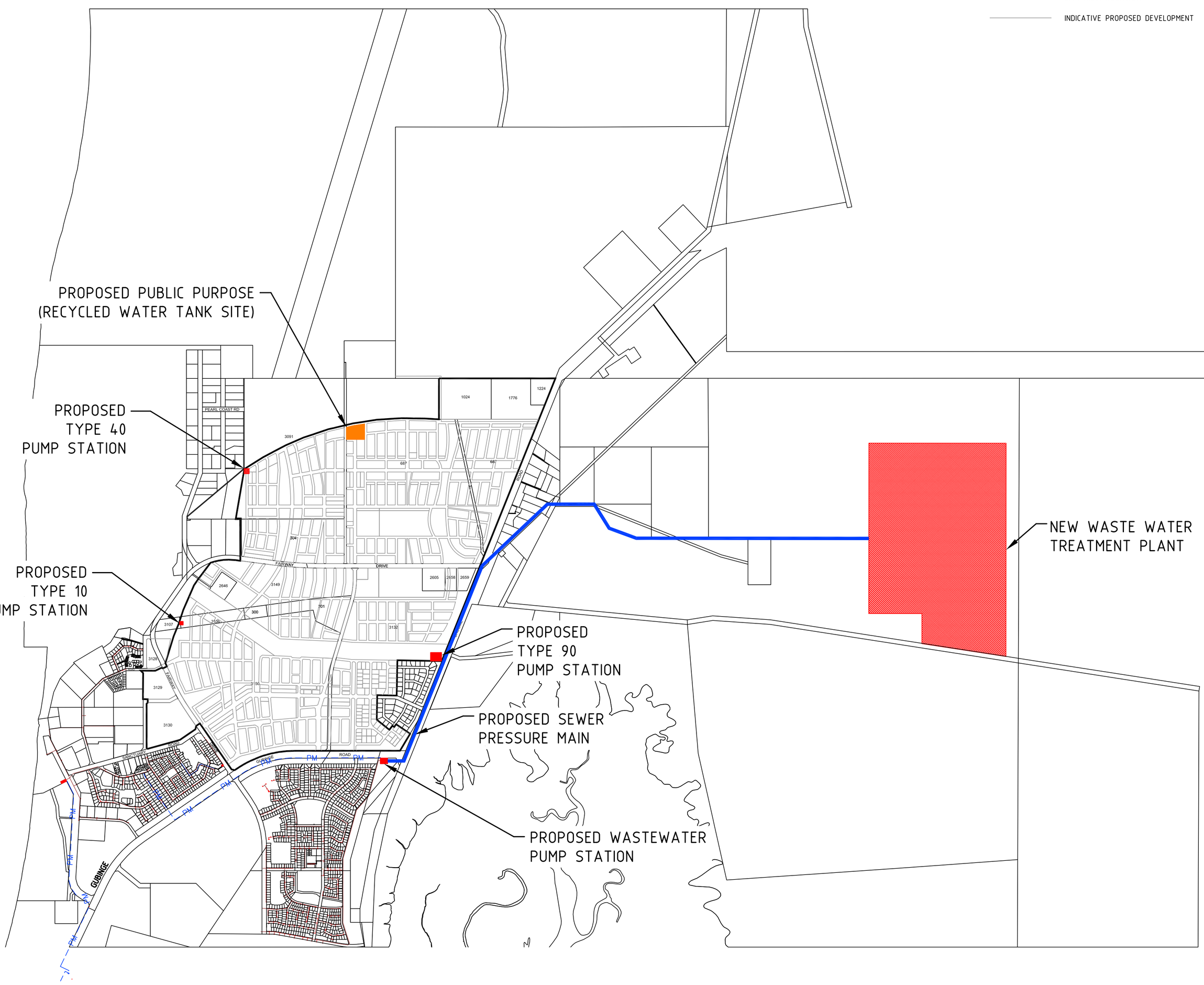
NOTES

1. THIS DRAWING SHALL BE READ IN CONJUNCTION WITH THE CONTRACT DRAWINGS AND SPECIFICATION.

LEGEND

- S — EXISTING GRAVITY SEWER
- PM — EXISTING PRESSURE MAIN
- PROPOSED PRESSURE MAIN
- SITE AREA BOUNDARY
- INDICATIVE PROPOSED DEVELOPMENT



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B	05.10.09	*TJ	*TJ	*VMW	*PJ	ISSUED FOR ENGINEERING REPORT
A	17.08.09					ISSUED FOR INFORMATION

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'*' INDICATES A COPY OF AN ORIGINAL SIGNED DRAWING

CLIENT: LANDCORP			
PROJECT: BROOME NORTH			
DRAFTER: C. LEGERSTEE	DRAFTING CHECK: T. JOHNSTON	REVIEWED PROJECT MANAGER: 05.10.09 *V. WARDLEY	APPROVED PROJECT DIRECTOR: 05.10.09 *P. JORDAN
DESIGNED: A. MICENKO	DESIGN REVIEW: T. JOHNSTON		

TITLE: EXISTING AND PROPOSED WASTEWATER INFRASTRUCTURE PLAN

SCALE	SKM PROJECT No	DRAWING No	AMDT
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A1

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Appendix B

Concept Layout

- Town Centre
- Town Living
- Neighbourhood Living
- Bush Living
- E.C.C.
- Public Open Space
- Light Industry
- Tourism
- Yawuru

Total Area	**699.5902ha**
Deductions:	
PS (x2)	8ha
HS	10ha
AS	15ha
HP	1ha
WC	7.6890ha
PP	1ha
ECC	34.8ha
Commercial (incl retail)	15,000sqm
Industrial	22.3691ha
Total Deductions	101.3581ha
Gross subdividable area	**598.2321ha**
Required 10% POS	59.8232ha
Actual POS provided (incl approx 21ha (3%) drainage)	**97.3163ha (16%)**

500m Buffer to Transfer Station

Transfer Station

Road Reserve to be closed

Public Purpose

PEARL COAST RD

ROAD

PS

HS

FAIRWAY

DRIVE

HP

AS

Water Corporation

Road Reserve to be closed

BROOME

ROAD

FAIRWAY

Tennis Club

PS

SANCTUARY

ROAD

DRIVE

GUBINGE

ROAD

NOTE: CONCEPT FOR PRELIMINARY DRAINAGE CALCULATIONS ONLY

LANDCORP

DEVELOPMENT CONCEPT
BROOME NORTH
SHIRE OF BROOME

ISSUE	DESCRIPTION	YYMMDD	DRAWN	APPV'D
E	Modifications to design	090930		
D	Open Day Concept			
C	Roads and Yawuru boundary			
B	Yawuru boundary			
A	PDF Design Concept	090908	SJ	SG

PROJECT: BROOME NORTH

CLIENT: LANDCORP

SCALE 1:7500 (0, 150, 300m) SHEET A1

DRAWING NUMBER: UD1 102 REV: E

REFERENCE NUMBER: LAN BRO

Issued for design intent only. All areas and dimensions are subject to detail design + survey.

robertsday
perth | sydney | melbourne | dubai
Level 1 | 130 Royal Street East Perth
Western Australia 6004 AUSTRALIA
T: 61 8 9218 8700 | F: 61 8 9218 8701
www.robertsday.com.au

Appendix C

Draft Broome North landscape masterplan report

DRAFT

LAY OF THE LAND
knowing country

BROOME NORTH LANDSCAPE MASTERPLAN REPORT

Opportunities, directions and strategies for the open space associated with Broome North

Prepared by UDLA

Prepared

September 2009

UDLA (urban design and landscape architecture)

Suite 1 / 64 High Street
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(08) 9336 7577
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On behalf of LandCorp

1 LANDFORM & BIODIVERSITY

Unnecessary clearing and levelling of land has been common practice for development within Western Australia in the past, especially within the Swan Coastal Plain. If these unsustainable practices are replicated in the Northwest, rehabilitation is difficult and costly in the highly sensitive landscapes of the region.

In addition, existing landscape features such as rock outcrops, drainage lines and local vegetation in the Northwest, all play an important role in heightening experience of the 'place', its amenity and the ongoing protection of a 'natural' site.

The significant cost of construction in areas such as Broome combined with the issues listed above strongly suggest that implementing built forms and landscape solutions that respond to existing conditions is the most appropriate response to the design of new development and follows best practise methodologies.

It is important to maintain existing ecosystems in order to 'maintain lifestyle'. This again involves vegetation retention (flora /fauna corridors), slope retention (maintain landform integrity) and in regard to drainage, maintaining existing drainage paths and systems.

As Broome is subject to extreme weather events (including cyclones), drainage is of primary concern within any development, and the provision of sufficient systems to deal with the large weather events can often be the cause of loss of landform and subsequently vegetation. Furthermore, development and unnecessary clearing can lead to a series of events that degrade not only the immediate site but the land surrounding it and even ecosystems well beyond the site. Previously, Broome has installed large engineered systems to deal with major stormwater events and Broome's pindan soils which have low infiltration properties. Standing water in Broome is also not an ideal situation and can lead to health problems if mosquito breeding is allowed to occur.



EXISTING DRAINAGE WITHIN BROOME
Photo by UDLA

1.1 PRECENDENT PROJECT: JANUBURU SIX SEASONS (BROOME)

Site Drainage

The latest subdivision in Broome, Januburu Six Seasons, attempted to change the way development has dealt with drainage. Januburu drew heavily on the concept of using the existing site and local knowledge to inform and guide the design, ensuring minimal site disturbance and allowing the development to relate to its context. The drainage system at Januburu exemplifies this concept by re-establishing and connecting existing drainage networks,

Januburu incorporates the following interventions to deal with site drainage:

- Maintaining overland flow rate volumes as recorded prior to development
- Redirect and evenly distribute clean water flows from the development area across Gubinge Road (historically this area acted as a superficial dam) into the highly valued Minyirr Park area.
- Evenly distribute overland flows to the back of dunes along Cable Beach where large areas of vegetation occur within the Broome Peninsula.
- Drainage run-off is directed from housing lots onto roads, then into free form swale retention basins
- Basins designed to slow overland water flows and deliver the volumes at a lesser pace to large compensating basins. These basins allow settlement of free pindan soil particles and more importantly exotic weed seed before distribution to Minyirr Park.
- Low infiltration properties of the deep red Broome pindan soils requires drainage management to includes low flow devices, such as V-weirs and dam structures with small outlet pipes (low flow pipes) whose purpose is not to hold the water, but to impede or slow the run-off rate back to a natural flow rate, i.e. a rate that existed before development occurred.

The benefits of the Januburu drainage management system include:

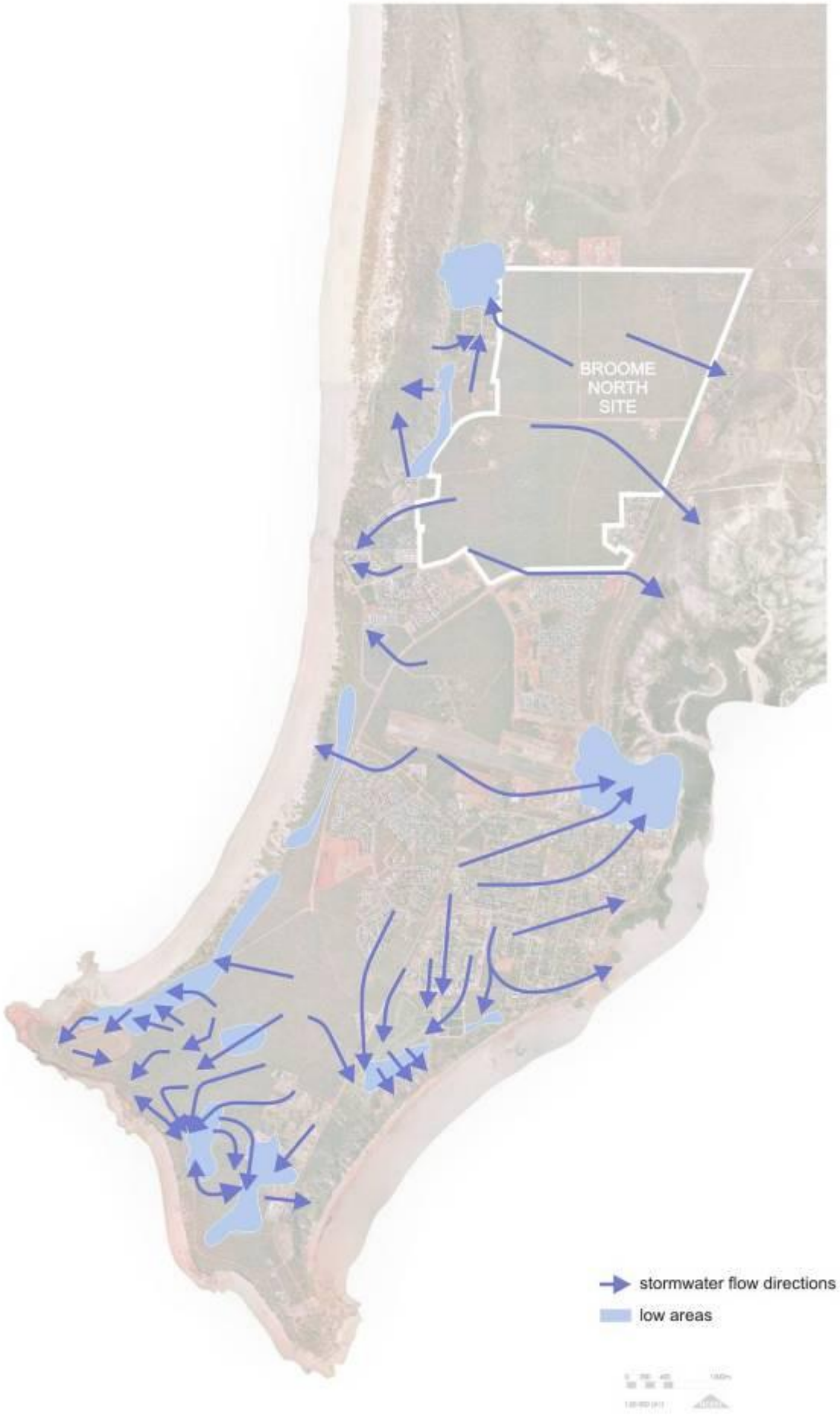
- Low silt/pindan soil distribution
- Less scouring or flood damage to drainage or development infrastructure
- Less spread of exotic seed to natural areas such as Minyirr Park
- Direction of water from development to back of Cable Beach dunes for natural health of local vegetation
- Drainage water is not directed as one large volume to historical flood prone or weed infested areas
- Drainage swales are free form with a natural aesthetic
- Drainage swales negotiate existing significant vegetation

INITIAL DRAINAGE CONCEPTS
Drawing by UDLA

DISCUSSING NEW DRAINAGE SOLUTIONS
Photo by UDLA

FREE FORM DRAINAGE SWALES – JANUBURU SIX SEASONS,BROOME
Swales direct water around significant vegetation and landform
Photo by UDLA

CONCRETE WEIRS– JANUBURU SIX SEASONS,BROOME
For water retention and slow release
Photo by UDLA



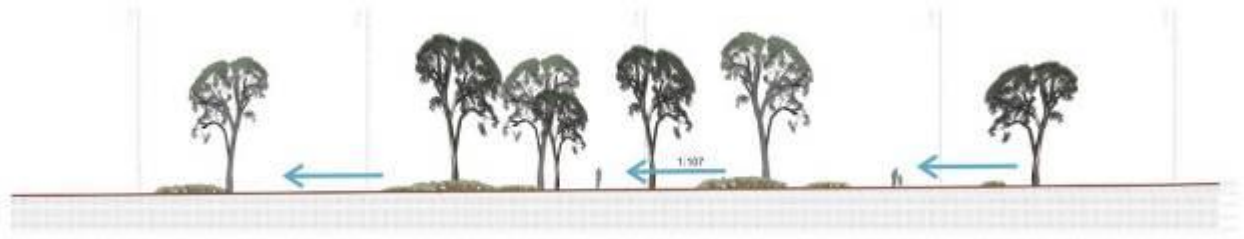
EXISTING DRAINAGE - BROOME
Base drawing courtesy of Margetts, 2008
Modified drawing by UDLA, 2009

EXISTING DRAINAGE – BROOME NORTH SITE
Drawn by UDLA, 2009 (using information from Broome Shire, Roberts Day and SKM)

1.2 PREVIOUS LOT DESIGN WITHIN THE BROOME LANDSCAPE

Grading of individual lots requiring drainage to runoff towards lot frontage has a major impact on the overall drainage system in regard to pindan runoff, water flow rates and dealing with weed control and infiltration etc.

Januburu Six Seasons (Broome), explored new options in regard to dealing with lot drainage, and has a similar site gradient and flow to the Broome North site. On both sites, the majority of the land highlighted for development has a relatively gentle gradient.



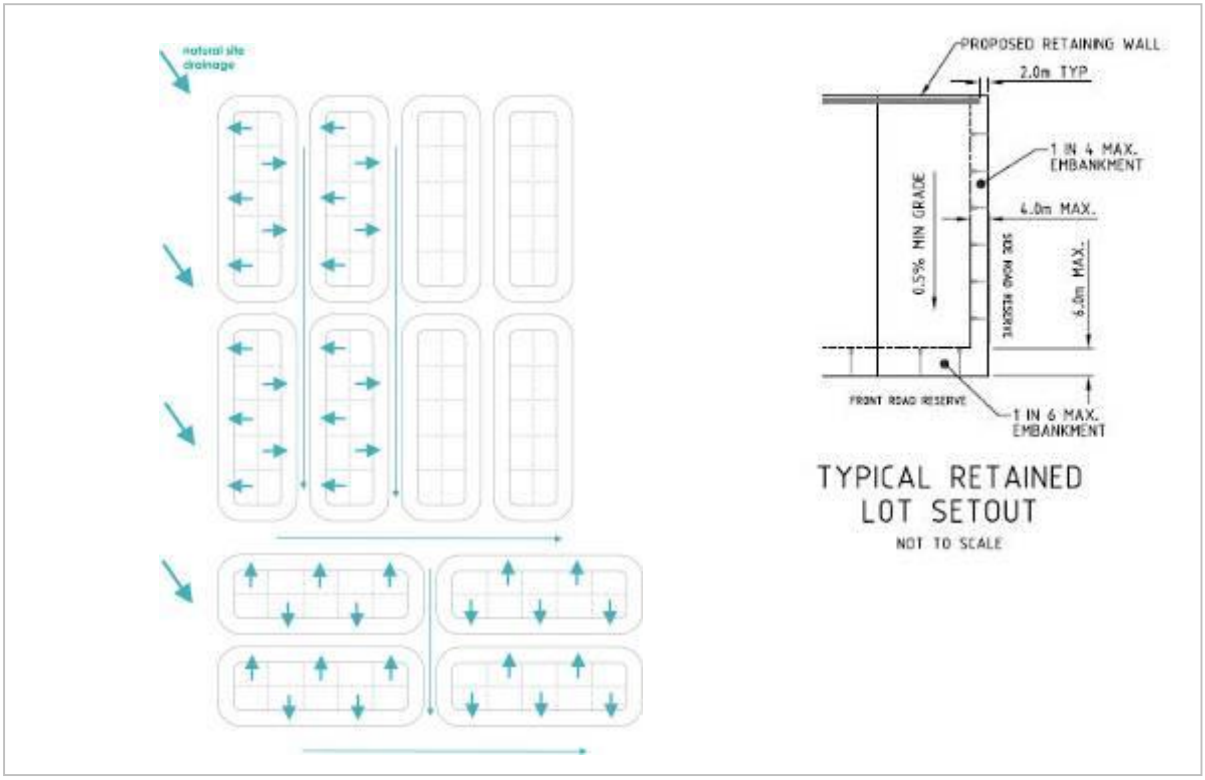
STANDARD SITE DRAINAGE
Drawing by UDLA

The existing site for Januburu saw each block graded to a gentle 1 in 107 slope with several significant trees and soil binding vegetation on site. Despite this, and attempts to retain natural slope and vegetation, extensive clearing was undertaken in earlier stages. In an attempt to improve this situation different techniques were applied to achieve more successful outcomes in subsequent stages of development. Slope retention primarily helps aide vegetation retention (refer to section 3.3 for benefits of this outcome) but also allows the site to maintain existing flow rates, drainage networks and through minimal soil disturbance, weed invasion is less prevalent, as is erosion and pindan runoff, and an finally, a local 'sense of place' is retained. This may encourage new homeowners to interact with their new surroundings with an understanding of the landscape of 'the place' and be more sympathetic in the responses to the design of their own gardens.

1.2.1 STANDARD LOT DESIGN (DRAINAGE)

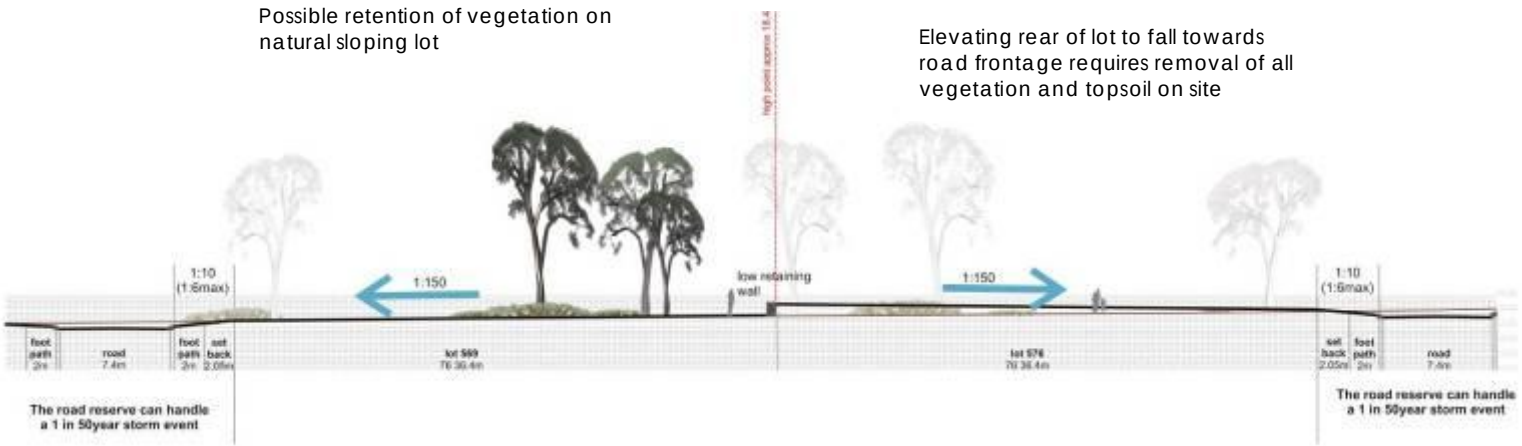
Unlike Perth drainage solutions (that requires water from lots to be dealt with onsite only) it is a requirement within the Broome region for residential development to drain water off the front of

the lot, and essentially the roads becomes large drainage networks directing water to retention or infiltration basins and swales. (This is due to the large storm events experienced in Broome)



CONVENTIONAL LOT DRAINAGE BROOME – CARDINAL LOT LAYOUT
Drawn by UDLA, 2009

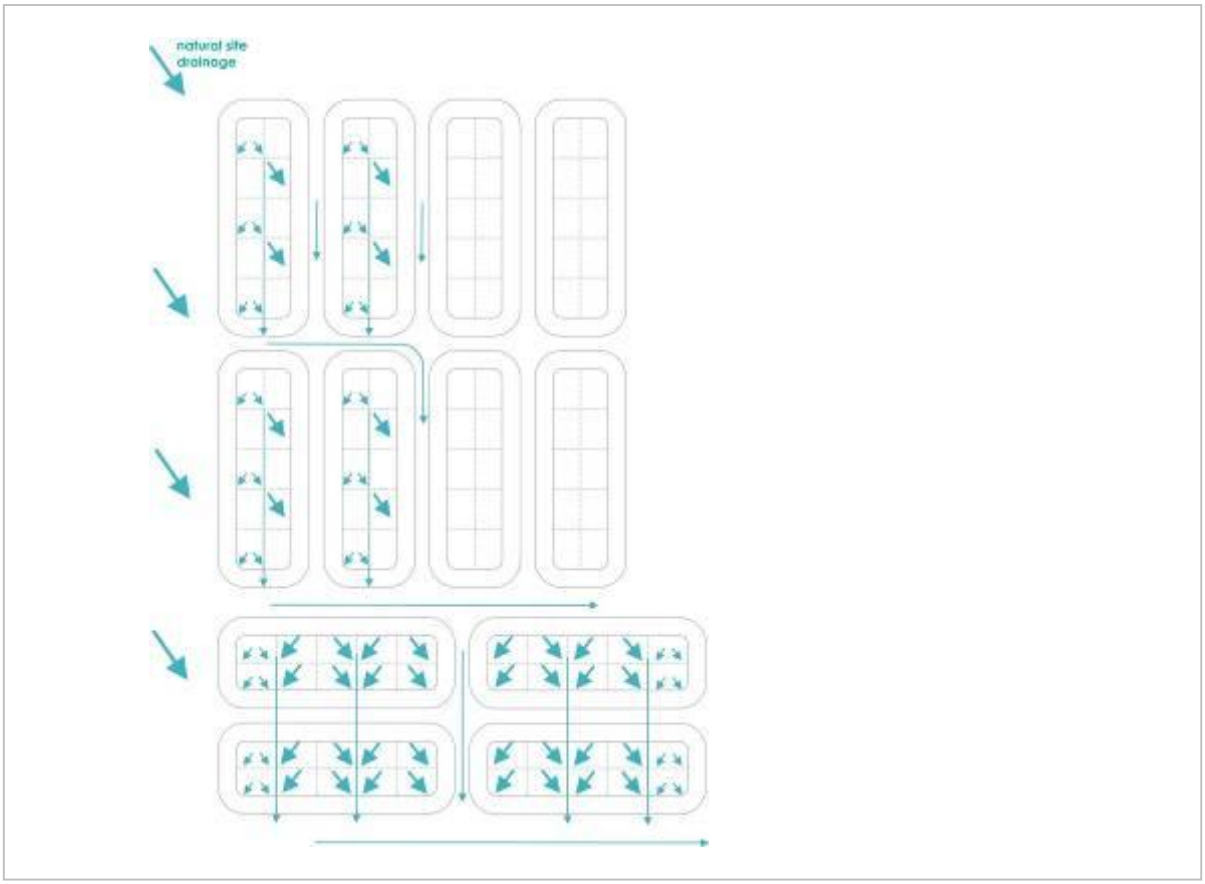
This outcome appeared unavoidable and has resulted in the loss of vegetation and the conventional benching of the site in Januburu Stage One by the inclusion of retaining walls. Despite efforts to retain as many significant trees as possible, due to the drainage outcome most of the site was cleared.



CONVENTIONAL DRAINAGE RESPONSE
Drawing by UDLA

1.2.2 ALTERNATIVE LOT DESIGN

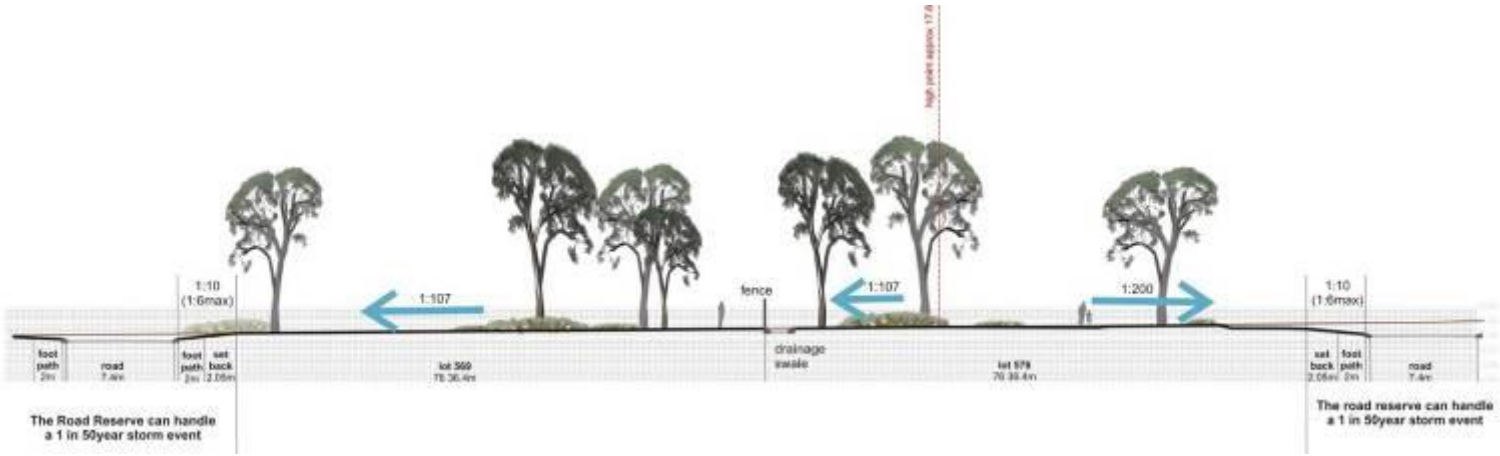
Working with the local Broome Authority and project engineers, Stage Four, Januburu recognises benefits that are gained by retaining the natural slope and vegetation of lots wherever possible. A new response was also tested on the lots that required regrading.



DRAINAGE TO CENTRE OF LOTS
Cardinal lot layout
Drawing by UDLA, 2009

The lots that required regrading tested a new method of drainage in order to retain slope and biodiversity. These lots were graded in two directions allowing approximately half the lots to drain to the road and half to drain towards the rear boundary. The introduction of a lined drain allowed this water to flow towards the flanking roads.

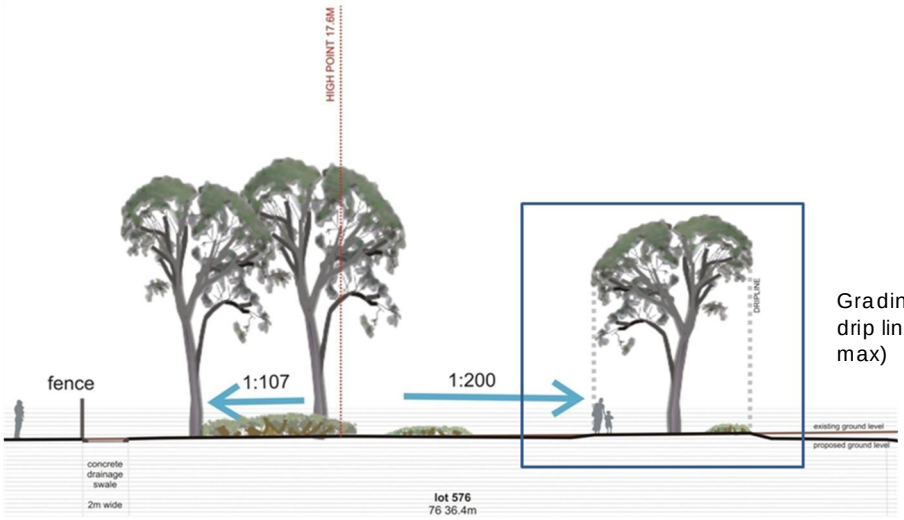
By maintaining the slopes close to natural gradients (1:107) and shaping the land to allow water to flow positively in two directions across the lots, many benefits were seen in regard to retention of top soil, vegetation and landform.



ALTERNATIVE DRAINAGE RESPONSE
Drawing by UDLA

Occasionally significant trees were situated were minor grading was required. If maximum soil removal was not plus or minus 300mm and no soil was disturbed within the trees drip line this vegetation could be retained through localised grading.

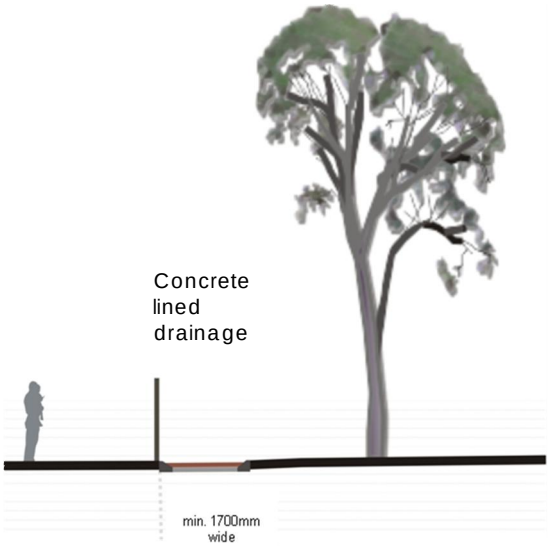
Care taken to retain the existing ground level within the tree's drip line meant many more significant trees were retained on site.



Grading to elevated drip line (+ / - 300mm max)

DETAIL – RETENTION OF GROUNDLEVEL AROUND SIGNIFICANT TREES
Drawing by UDLA

Due to maintenance concerns by the Local Authority, it was required that the rear of lot drainage easements be concrete lined and a minimum of 1700mm wide. Any curves in drains were required to be designed in relatively wide arc so a small excavator could turn in the drains when maintenance and cleaning is required. .



CONCRETE LINED DRAINAGE EASEMENT
Drawing by UDLA

CONCRETE BASED DRAINAGE EASEMENT – JANUBURU STAGE FOUR
Photo courtesy of SKM, 2009

1.3 VEGETATED REAR LOT DRAINS

Aligning with LandCorp's Retention of Landform and Ecology Policy, Januburu Six Seasons saw the progress of drainage solutions within development in Broome. Although the progression enjoyed a level of success, Broome North proposes to create a new benchmark for drainage outcomes in Broome.

The most significant advance in this area is the proposal to removal concrete lined drains to be replaced by a vegetated or gravel mulched swale to prevent erosion, however allow natural infiltration.

Although this method has been utilised worldwide and received predominantly positive feedback from community members during the recently held Planning and Design Forum, there are still various concerns associated with this method from both community and Shire Perspective. Some of these issues are explored below:

1.3.1 ONGOING MAINTENANCE

This is in regard to level of maintenance required and who will be the responsible for its ongoing care. Currently, the concrete lined basins serving rear lot drains are the responsibility of the Local Authority. UDLA believe that once significant vegetation has established within the swale, maintenance will be low and propose responsibility for this area should fall onto individual lot owners. This may be formally incorporated as a caveat forming part of the sale agreement and/or more informally as a Shire guideline.

1.3.2 LANDSCAPING OPTIONS

Owners have different ideas for their garden designs and may not aspire to the 'bush aesthetic' and perceive this proposed drainage solution requires them to apportion part of their rear lot to native bushland which may be viewed as an unreasonable expectation.

Fortunately, the proposed drainage swales will be shallow and lot owners will have many options in regard to its treatment. The swale can be planted with exotic plant species or similarly the swale could have lawn (would act as a very effective treatment to prevent scouring, filter runoff and in slowing water velocity).

1.3.3 SCOURING

Swales cannot be left untreated as this would cause scouring, increased water velocity and pindan runoff. Binding the pindan with vegetation and grasses is the most effective way to prevent scouring. A bio degradable geo-fabric may be beneficial to stabilise the soil before plants have established prior to the wet season.

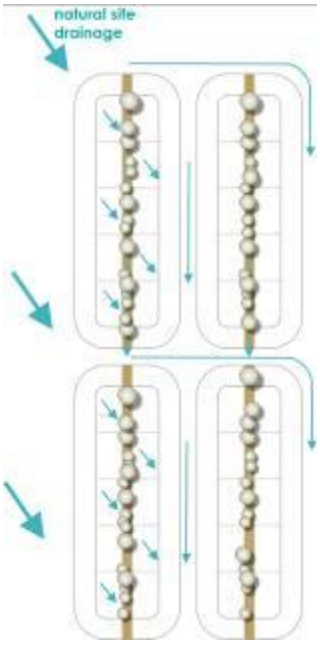
1.3.4 SWALE BLOCKAGES

There are always risks associated with drainage easements that require residents to maintain them such as the potential for one of the lots downstream to block his/her swale thus causing flooding further up the swale. The best way to minimise this risk is to provide suitable education to the lot owners and potential fines for people not adhering to the swale standards put into place.

Another effective way to minimise the risk is to limit the number of lots that water must pass through before linking into the road drainage system. The drawings on the following page demonstrate two block layouts: in the first example the swales effectiveness relies on many lot owners undertaking correct design and maintenance, whereas the second example layout relies on only two lots within

each swale system. This would make it easier to pinpoint problems if they arise due to less residents being involved in the chain. In other locations where these systems have been prototyped any issues which arise can usually be sorted at a neighbour discussion level. If the issue needs to be raised with the local authority then they would need the authority to request this to be rectified.

1.



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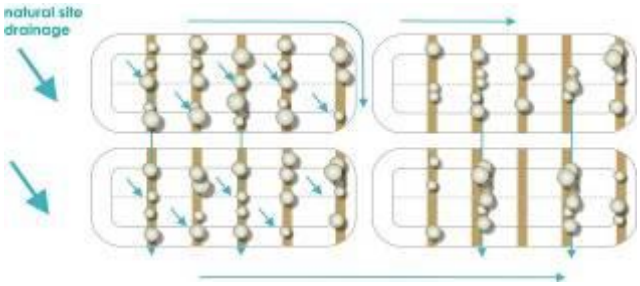


REAR LOT DRAINS – JANUBURU STAGE FOUR
1. A longer swale means more people must maintain the swale correctly to ensure there is no flooding upstream.
2. The second block orientation means only two blocks are caring for one swale system and as result the swale is more manageable and does not need to handle as much volume of water
Drawing by UDLA, 2009

There is potential for these drainage easements in Broome to become a natural feature with planting, local gravels and boulders. Keeping the area unsealed will aide infiltration and as vegetation establishes itself the roots will bind the pindan soil which discourages erosion, pindan runoff and slows flow rates and trapping invasive weed seeds before they reach significant dune systems or cultural places. The vegetation lines will also help to conceal fence lines between lots and provide shade amenity to the subdivision.

DETAIL – NATURAL SWALE
Drawing by UDLA

However these vegetated drainage lines do not have to be tree planted and individual homeowners may opt to have lawn to the back fence. Their only requirement is to retain the swale and keep the area vegetated in some way to bind the pindan and filter the water runoff.

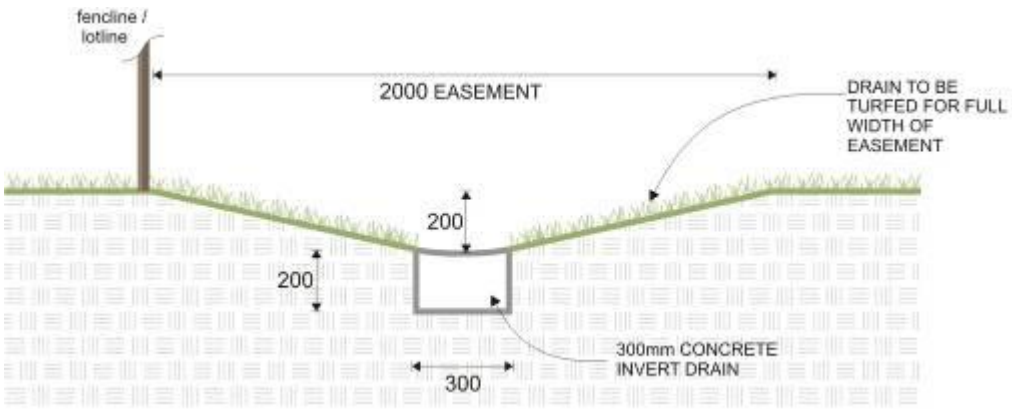



VEGETATED DRAINAGE FEATURES
Images courtesy of UDLA, 2009 and landcare research.com

1.3.5 IMPLEMENTATION IN STAGE ONE

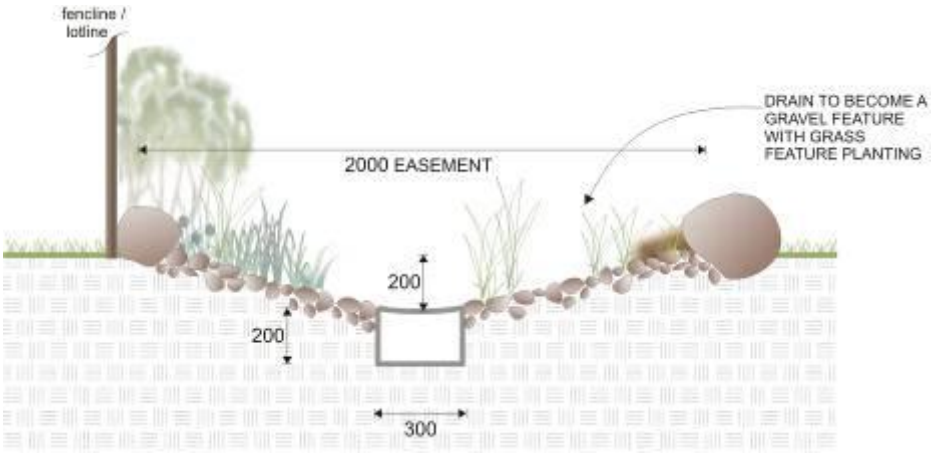
The Vegetated drainage lines implemented as part of Stage One works will incorporate a drainage swale model used by the Mackay City Council. From information gathered by the engineer consultants for Broome North (SKM) it appears that allotment drainage swales are used regularly inthe City of Mackay with the following general principles:

- Side and Back drains are used
- Turf drains with a 300mm wide concrete base are part of their standard allotment drawings (The concrete base defines the invert level and helps to ensure it is well maintained at that level overtime.



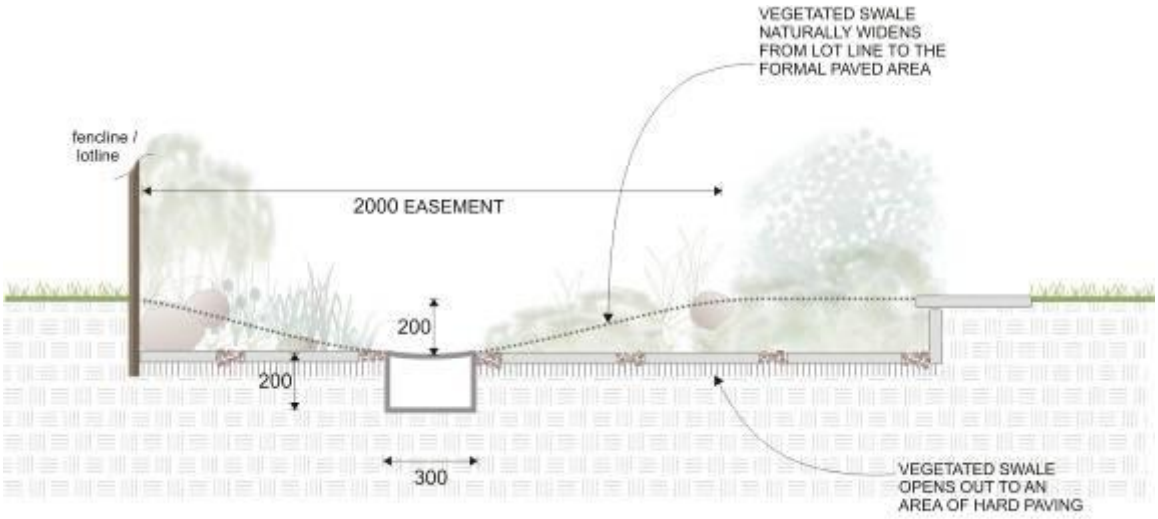
MACKAY CITY COUNCIL
Allotment drain detail – standard treatment

It is proposed that within Stage One of Broome North, the Mackay model of drainage easements will be applied, however there is opportunity for alternative landscaping options to be explored within individual lots.



ALTERNATIVE LANDSCAPING

A gravel and/or planted out swale offers an ephemeral feature in peoples yards.



ALTERNATIVE LANDSCAPING

A more considered design could see tapering of the swale to a hard paved step down area within the backyard.

1.4 RESIDENTIAL

Drainage solutions can be dealt with at the smaller 'micro' scale. Within each lot, land owners can make a difference with water run-off applying solutions which incorporate less areas of hardstand, larger areas of garden beds/groundcovers and mulches that allow infiltration. Residents are often inspired and informed by the landscapes around them, so by developing prototype examples of working 'dry creek beds' and vegetated drainage lines this may influence residents in their residential garden designs. This helps create an integrated 'micro' managed system to deal with overland flows, from 1:1 storm events to 1:100 year events.

Another popular and successful initiative in Januburu Six Seasons was to offer a landscape 'package' to new residents that allows them to have their front gardens designed and planted, up to a specified value, if they are willing to use a majority of native plant species, local materials and water wise objectives.

This has proven popular at Janubaru Six Seasons and similar packages could be used within Broome North.

EXAMPLE OF A RESIDENTIAL REBATE PACKAGE AT JANABURU – FRONT LANDSCAPING
This type of initiative not only helps aide a local sense of place and local industry, it also helps deal with water at its source by encouraging infiltration.
Photo courtesy of UDLA, 2009

1.5 GARDEN BEDS

1.5.1 LOCAL GRAVEL FEATURE MULCH

Januburu explored widespread use of local aggregates featured in contrasting bands with backdrops of endemic plants, adding to site specific design. They require little ongoing maintenance, withstand the unforgiving conditions and are useful tools in enlivening a dry landscape and displaying local stories. Furthermore, the Broome Township is often viewed from the sky[1] these aggregate features read as large local patterns on the landscape.

1.5.2 SITE MULCH

Vegetation that must be removed from the site can be mulched down and used as mulch for future garden beds (provided it does not contain weed seed). The existing native seed bank within the mulch has proven to provide a good source for propagating and establishing local plants within swales and garden beds.

1.6 PLANTING PALETTE

Historically, landscaping in the Northwest has relied heavily on exotic nursery planting stocks that often give the impression of a tropical or sub-tropical paradise. This treatment offers no clues to the greater surrounding unique and natural landscape and practically speaking, requires high maintenance, high water requirements that are costly, supporting a largely unsustainable practice.

The case for supporting local plant palettes within the Broome North development is as follows:

Environmental

When 'native' plant stocks are sourced for the Northwest they are often secured from other parts of the continent (Eastern Australia or the Perth Region of Western Australia) and are not endemic to the region. These stocks are mostly unsuited to Northwest environmental conditions; i.e. have mismatched water, soil and nutrient requirements, become invasive and promote a foreign landscape.

Introduced exotic nursery stocks that may thrive in the Northwest conditions may have the potential to become invasive and cause future problems with weed management and their removal. (E.g. Neem and Fig Trees).

In general, many exotic plants are not be suited to local conditions of the Northwest and would continue to require high levels of maintenance and care whereas endemic species compliment their unique conditions, provide habitat and food for the survival of local fauna and continue to support local ecosystems.

Visual and Social

[1] Due to the central location of the airport in Broome, aeroplanes fly in low over the township, offering a unique aerial views of the Broome

From a visual aesthetic, endemic plants showcase the unique landscape of the Northwest Region and act as a unique attraction. Use of local vegetation within a streetscape setting provides an opportunity to display unique flora and fauna, aiding in creating a 'sense of place' and fostering community pride. Tourists and visitors, especially remember these types of visual queues when visiting foreign places.

Nursery stocks suitable for landscape purposes should be cultivated from 'solid' performing local plants that provide the required landscape outcomes i.e. low compact shrub forms, broad spreading groundcovers, respond well to trimming, strong performers with respect to fruits, flowers or scent, and most importantly of all, shade trees that are suitable in terms of their form and structure for street or residential garden use

Cultural

By including local species within landscapes, an important layer of culture is nurtured offering an opportunity for indigenous communities to continue using the plants for traditional uses; a resource for themselves and an educational tool for interested parties. It also offers the trees, animals and humans a continuing 'lifestyle'. This ongoing lifestyle for all life is a very important concept to the local Yawuru people.

Maintenance

Many organisations and community groups e.g. local authority – 'SKIPS', Nurseries etc. are now recognising that endemic plant stocks suited to the area offer a sustainable option that requires minimal maintenance requirements due to their suitability to the local condition.

LOCAL PLANTING PALETTE BROOME
Photo courtesy of UDLA

1.7 STREET TREE PLANTING

One of the most important streetscape features will be bringing shade into the area to improve pedestrian amenity. The following are different methods of supplementing vegetation within the streetscape. Street trees are important for a variety of reasons, in particular;

- Shade amenity
- Visual amenity
- Informs place, provides street hierarchy / character
- Variety of street tree opportunities
- Recognised a number of local species are appropriate to provide streetscape form

STREET TREE PLANTING EXAMPLES
Street trees can create a pleasant environment for pedestrians and encourage traffic to slow down. It is important for Broome North to make use of local species to create their own unique aesthetic.
Photo courtesy of UDLA and sourced from flickr.com

During the planning and design forum, community members provided the project team with some local trees that they believe should be featured within the streetscape. These include;

- *Eucalyptus miniata* – Woolly butt (should be planted in groups with a low understorey of plants mimicking there natural condition) The *E. miniata* grows to 6-20m, with a rough, fibrous-flaky bark. It may be self pruning, so planted in groups within garden beds would be the best outcome.

- *Ficus opposita var. indecora* (fast growing and suitable as a singular specimen street tree for avenue planting)

- *Melaleuca sp*. (street tree or drainage lines)

- *Terminalia petiolaris x Terminalia ferdinandiana* - Red Gubinge - Suitable as a street tree and potential within drainage lines as they like to kee there feet wet)

- *Adansonia gregorii*- Boab (although not known to originate from the area, some local trees are estimated to be approx. 300 years old and therefore the seeds was believed to have been traded by local indigenous people... meaning the tree has a long cultural connection with the place. The Boab grows 5-15m with a distinctive bottle shaped trunk.

- Eucalyptus camaldulensis (Northwest var.) (stately tree, not to be pruned so may be useful in larger open space areas where major top pruning will not be carried out. These are a large tree for the area)






E. miniata *Ficus opposita* *Melaleuca* sp. Red Gubinge *E. camaldulensis* *Adansonia gregorii*

Photo courtesy of UDLA (trees located within Broome town site)

Further trees that could be investigated as part of the streetscape are outlined on the following pages.

1.7.1 SUITABLE STREET TREES – LOCAL TO THE BROOME REGION

Corymbia flavescens

Wrinkle-leaf Ghost Gum

Form	tree
Height	3-15m
Bark	Smooth, white, shedding in thin scales
Flowers	white, cream. Apr-Jun/Nov
Soil	Red earth soil
Located	Often along drainage lines
Notes	May be self pruning


Melaleuca dealbata

Freshwater Paperbark

Form	tree
Height	6-15m
Bark	Papery and layered
Flowers	Cream. Aug - Nov
Foliage	Blue grey
Soil	Sand or sandy soils
Located	coastal dunes, seasonally wet depressions, and small watercourses.
Notes	Relatively slow growing



Corymbia ptychocarpa

Swamp Bloodwood

Form	tree
Height	4.5 - 18(-20) m
Bark	rough, tessellated
Flowers	Pink. Feb-May
Soil	Sand, alluvium
Located	Along watercourses, near springs


Corymbia bella C. papuana

Ghost Gum

Form	tree
Height	6-20m
Bark	smooth, white, shedding in thin scales
Flowers	cream, white. Jul-Dec
Soil	Usually on alluvial soils
Located	Along watercourses, floodplains
Notes	May tend to be self pruning. Shapely crown with a weeping habit


Eucalyptus alba

White gum

Form	tree
Height	5-15m
Bark	smooth
Flowers	cream, white. Jul-Sept.
Soil	Sand, clay, alluvium
Located	Along watercourses, seasonally wet depressions
Notes	May tend to be self pruning

Corymbia polycarpa

Long-fruited Bloodwood

Form	tree
Height	(3-)5-15(-25)m
Bark	rough, tessellated
Flowers	white, cream. Apr-Aug
Foliage	shiny and green
Soil	Sand over sandstone, laterite or quartzite, alluvium
Located	Usually low lying areas

Eucalyptus bigalerita

Northern Salmon Gum

Form	tree, generally single trunked
Height	6-18m
Bark	smooth, pale grey to copper
Flowers	white, yellow. Aug-Sep
Foliage	light green leaves, broad and large
Soil	Alluvium, sandy
Located	Along watercourses, low lying flats
Notes	Culturally not appropriate as a street tree for Broome

Eucalyptus jensenii

Ironbark

Form	tree
Height	3-10(-15m)
Bark	rough, deeply furrowed
Flowers	white, cream. Jan-May
Soil	Red sand, sandy loam, sometimes with gravel
Located	Sandstone plateaus, lateritic rises and plains

Eucalyptus microtheca

Coolibah

Form	tree
Height	5-10m
Bark	rough, box type
Flowers	white. Dec-Feb
Soil	Clay
Located	Seasonally waterlogged flats, along watercourses, swamps

Planchonia careya

Cocky apple

Form	tree or shrub
Height	1-15m
Flowers	showy white, cream, pink. Jan-Dec
Soil	Sand to clay, sandstone
Located	Edges of creeks and swamps, screes

Terminalia petiolaris

Marool, Blackberry tree

Form	semi- deciduous tree
Height	4-14m
Bark	fissured, dark brown to black
Flowers	cream, white. Feb-May/Dec
Foliage	Green, often red to purplish before falling.
Soil	Sandy soils, sandstone
Located	Coastal areas, often vine thickets

Mimusops elengi

Mamajen

Form	tree or shrub
Height	2-16m
Flowers	white. Jan- Sep
Soil	Sandy soils, sandstone, basalt
Located	coastal or near coastal areas

Melaleuca argentea

Silver cadjeput

Form	tree or shrub (rarely)
Height	3-18(-25) m
Flowers	Cream, white. Jul-Nov
Soil	Alluvium, sand or clay, sometimes saline
Located	Along watercourses, swamps

Lophostemon grandiflorus

Freshwater mangrove

Form	tree
Height	4-8m
Flowers	Cream, white. Jan- Dec . highly scented
Foliage	small glossy leaves
Located	Damp habitats (swamps, seepages)

Nauclea orientalis

Leichardt pine

Form	tree with horizontal branching
Flowers	attractive yellow golf ball flowers during summer
Notes	A distinctive tree, can be used a pioneer establish an area. Hardy and fast growing

Lysiphyllum cunninghamii

Kimberley bauhinia, Jigal

Form	tree. usually stout trunk with weeping branch habit.
Height	up to 6m
Bark	dark coarsely flaking bark
Flowers	bright red. Apr- Aug
Foilage	two lobes joined like butterfly wings. New flushes of growth are a colourful display of red and pink.
Notes	Ideal shade tree, attraction for local fauna. Allow other shrubs to grow beneath canopy. Connection to local indigenous stories and use.

Canarium australianum

Styptic tree

Form	tree, with open spreading crown
Height	3-20m
Bark	smooth creamy grey bark
Flowers	yellow, green, white. Nov-Apr
Foliage	pinnate leaves
Soil	Sand, clay shallow skeletal soils, basalt.
Located	Lateritic scree, Sandstone ridges and cliff faces

* The initial list of trees mostly originates from the top end and northwest Australia and is proving to provide reasonable growth rate and shade amenity

Wherever possible, site specific spaces and places should be created whereby local planting can be used appropriately. The Planning and Design Forum reinforced a strong community desire to use local street trees.

However, in some cases it may be necessary to incorporate some tree species that are not endemic to the Kimberley region for provision of amenity. If this situation arises, the following planting list may be referred to with regard to similar water and soil requirements.

1.7.2 INTRODUCED SPECIES TREE LIST

Leptospemum longifolium

White wood, Weeping tea tree

Form	weeping graceful tree
Height	3-5m
Bark	smooth cream to white deciduous bark
Flowers	small cream flowers Jul-Nov
Located	Permanent freshwater streams

Eucalyptus herbertiana

Kalumburu Gum

Form	mallee or tree
Height	4-8 (-10) m
Bark	smooth powdery white
Flowers	white cream, Jan
Soils	skeletal
Located	Sandstone outcrops and rocks, base of ridges, hillsides
Notes	from north of Broome to Darwin

Delonix regia

Royal Poinciana

Peltophorum pterocarpum

Yellow flame tree

Tipunana tipu

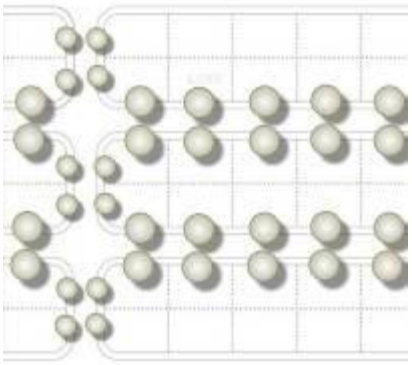
Rosewood

1.7.3 AVENUE PLANTING

Avenue planting is one of the most popular methods of introducing trees into the urban environment. It is achieved by selecting a specimen tree in linear alignments along a road or footpath. This will often result in adding a formal effect to the streetscape character of the street or open space.

One species is typically designated to one avenue. By varying species and/or densities of tree plantings (including creating double or triple avenues) this can provide hierarchy to streets within a subdivision.



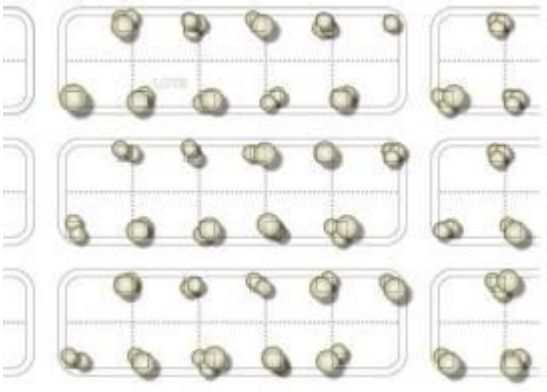



AVENUE STREET TREE PLANTING
Sketch plan by UDLA, photos courtesy of UDLA and sourced from flickr.com

1.7.4 RETENTION OF NATIVE VEGETATION AREAS WITHIN EACH LOT

Retention of native vegetation is possible in areas within limited road reserves. A portion of each lot may retain groupings of local trees and companion planting.



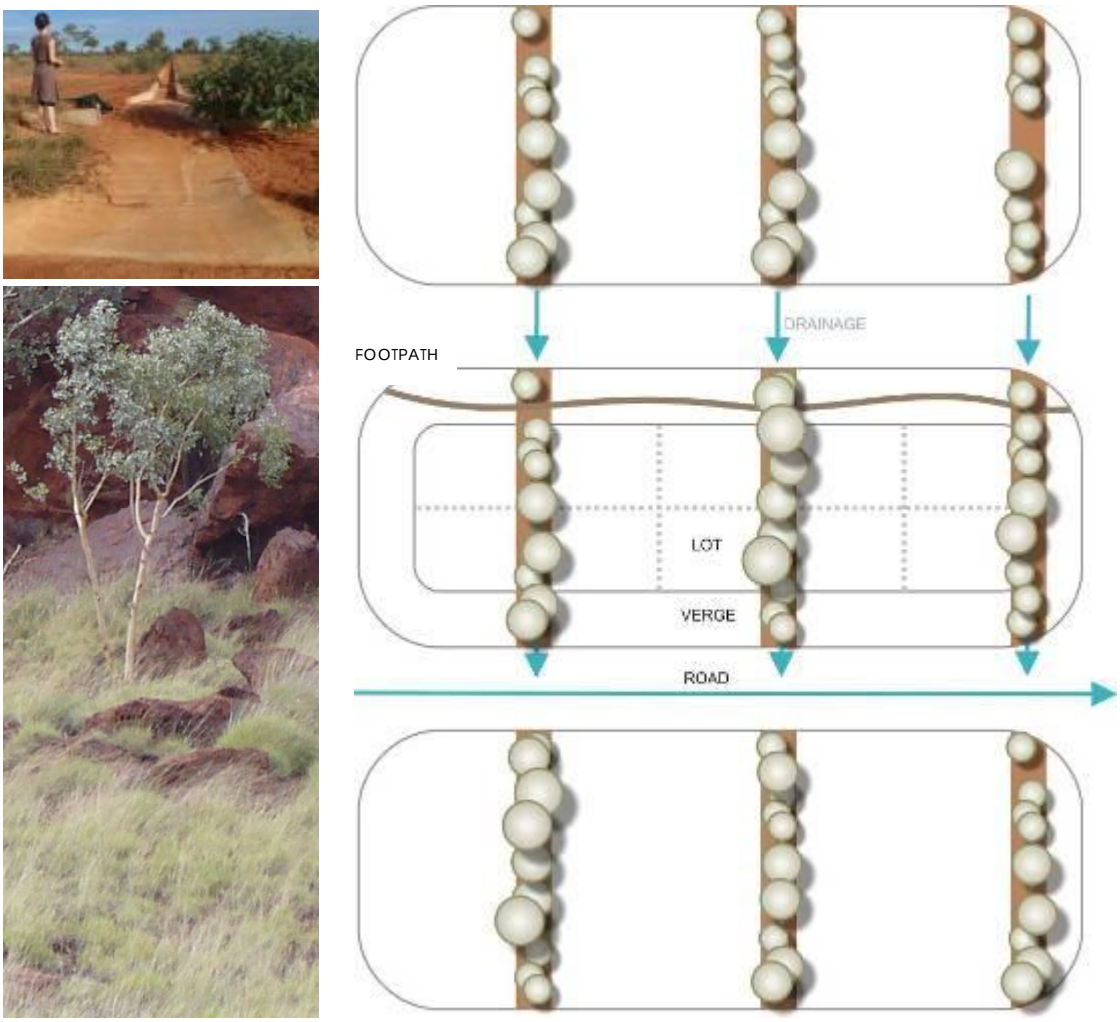


GROUPED PLANTING
Drawing by UDLA, 2009, photos courtesy of UDLA and sourced from realadventures.com

Following discussions at the Planning and Design Forum, these types of vegetation treatments could be used within 'tighter' streetscapes where areas are set aside for local planting. There is an idea that these set 'preserved' areas could become optional planting areas. For example, a homeowner may wish to utilise this area for verge parking but at any time could apply to council to plant it out and there is a possibility for the council providing suitable local plant lists and perhaps a reduced rate of plant purchase from a local contractor, to support the local landscape industry and monitor the types of plants within the streetscape.

1.7.5 PLANTING WITHIN DRAINAGE LINES

Vegetated drainage lines will help to filter water runoff from the lots, stabilise the pindan and act as attractive features and ecological corridors for the site. Where the vegetated drainage line connects back to the street, the trees will provide shade amenity for the pedestrian.



VEGETATED DRAINAGE FEATURES
Drawing by UDLA, 2009 and images courtesy of UDLA, 2009

1.7.6 COMPLICATIONS

Although street tree planting has many advantages, it is rare to find a street within Broome with a solid example of street trees. If trees are planted in copses or linear systems it is likely they will have a greater chance of surviving, however singular tree planting is often very difficult to establish in this kind of location. The harsh climatic condition of Broome means that selecting appropriate species is imperative.

However, in recent times the main issue facing street tree establishment is a culture of little value being placed on these trees by contractors and individuals, leading to vandalism predominantly by large vehicles. Januburu *Six Seasons* attempted to establish local trees within the streetscape, the developer had the majority of street trees planted early in the civil stages of works, to ensure some maturity of plant stock at the time residents moved to their new homes. This included a 2 year low cost sacrificial irrigation system for establishment. Unfortunately, many of the trees were destroyed by contractors during the construction of homes. People could not see the worth of these street trees during construction and many trees were run over by large vehicles.

Attempts to use more mature stock is very difficult to source in the current Northwest landscape industry, however early ordering of stock; at least 18 months in advance (advice given by a local supplier) will ensure suitable mature stock is available. Unfortunately, there are disadvantages using mature tree stock. Mature plant stock is considerably more expensive for a developer and regardless of their size, street trees warrant little respect and are subject to vandalism from large vehicles, particularly construction vehicles. Furthermore, larger, mature trees are more difficult it is to establish as healthy, stable trees. The majority of trees local to Broome do not establish if retained in pots as the root system will wrap itself around the pot, forming a deformed growth habit. Some tree varieties are more suited to being grown in a pot and the project team were advised at the Planning and Design Forum that the Gubinge tree is one local tree that can successfully be raised in a pot to a mature size (approx 2m within 18 months).

Other solutions to overcome issues related to establishing street trees could include:

- Similar to Januburu Six Seasons Stage Four, a front garden landscape rebate that includes streetscape planting to lesson damage by contractors (being installed when major building works are completed) This also encourages homeowners to develop a level of ownership for the street tree as part of their overall front garden and therefore care for it; and/or;

- Implement the use of robust stakes/bollards that place importance on each street tree. These stakes/bollards have the potential to be viewed as part of a larger art strategy that could reflect local themes or introduce contemporary themes.





1.7.7 SUPPLEMENTED VEGETATION

The rate of plant growth within the Broome area is fast, due to the ideal growing conditions, provided planting is carried out within the correct times of the year and with the appropriate care. In one season tube stock plants can establish themselves if planted prior to, or at the beginning of the wet season.

The availability of appropriate local plants is one of the greatest factors affecting the successful outcome of establishing native gardens and landscapes in Broome North. Plants need to be sourced months in advance to ensure quantities of appropriate stock are available.

Old Broome has a mature plant palette which provides excellent shade amenity and aids cooling and shading of the streets. However, Old Broome relies heavily on tropical exotic planting such as;

TREES

African Mahogany, Mangoes, Poincianas (*Delonix regia),* Figs, Palms (e.g. Carpentaria, Foxtail, Coconuts)

SHRUBS

Ixora, Ginger, Alamanda, Mock Orange, Hibiscus, Bougainvillea, Golden Cane, Exotic Gum trees (e.g. *E. maculata*), Duranta, Tamarind

As part of a 'new Broome' style the project team proposes to use local species where possible. A local plant palette will support the local landscape industry, reflecting a local sense of place and enable water wise outcomes that are adapted to local conditions and as a consequence requires little ongoing maintenance.

Maintenance is an important issue. Native species are highly suited to the area with regard to climate, soil and water requirements; however all planting requires a certain level of maintenance and the premise that native plants do not require maintenance is unrealistic.




PLANT GROWTH OF LOCAL SPECIES
One year's growth at Januburu Six Seasons (from tube stock and seed stocks within site mulch)
Photos courtesy of UDLA

1.7.8 SUGGESTED PLANTING LIST (OF WEST KIMBERLEY)

TALL SHRUBS / SMALL TREES

Caesalpina major
Goolyi

Height 4m
Spread 2m

Dolichandrone heterophylla
Jumburru
Lemonwood

Height 6m
Spread 2 - 3m

Ehretia saligna
Miganiny
Native Willow

Height 5m
Spread 3 - 5m

Exocarpos latifolius
Jarnba
Mistletoe tree

Height 5m
Spread 5m

Grewia breviflora
Goolmi
Currant or Coffee tree

Height 8m
Spread 3 - 5m

Hakea arborescens
Irrgil
Yellow Hakea

Height 4m
Spread 2 - 3m

Hakea macrocarpa
Jarridiny

Height 5m
Spread 2 - 3m

Mallotus nesophilus
Badarrbadarr
Yellow ball flower tree

Height 5m
Spread 2 - 3m

Santalum lanceolatum
Gumamu
Tropical Sandalwood

Height 8m
Spread 8m

Sesbania formosa
Irirrwal
White Dragon tree

Height 13m
Spread 8m

LOW SHRUBS / GROUNDCOVERS

Acacia adoxa
Prostrate Acacia

Height 0.3m
Spread 0.8m

Acacia bivenosa
Nirliyangarr
Dune wattle

Height 2m
Spread 2m

Acacia colei
Lirrirngin
Soapy wattle

Height 3m
Spread 3m

Acacia eripoda
Yirragulu
Broome Pindan wattle

Height 3m
Spread 3m

Acacia translucens
Balalagoord
Poverty Bush

Height 2m
Spread 2m

Caesalpina major
Goolyi

Height 2m
Spread 2m

Canavalia rosea
Windi
Beach bean

Height 0.5m
Spread 0.5m

Carissa lanceolata
Gungkarra
Conkerberry

Height 2m
Spread 2m

Crotalaria cunninghamii
Minmin
Green birdflower tree

Height 2m
Spread 0.5 - 1.5m

Crotalaria sp.
Rattle pod

Height 0.5m
Spread 0.5m

Crotalaria medicaginea Lam

--

Height 0.5m
Spread 1m

Flueggea virosa
Goowal
Snowball bush

Height 2.5m
Spread 2.5m

Grevillea dryandri
Prostrate Grevillea

Height 0.5m
Spread spreading

Grevillea refracta
Willing jamoordoo
Silverleaf grevillea

Height 4m
Spread 1- 3m

Ipomoea pes-caprae
Goordayoon
Beach morning glory

Height 0.5m
Spread 1m

Scaevola parvifolia
--

Height 0.3m
Spread 0.4m

SWALE REHABILITATION (TREE PLANTING)

Acacia platycarpa
Ghost wattle

Height 8m
Spread 4m

Corymbia dampieri
Biilal
Dampier's Bloodwood

Height 11m
Spread 8m

Corymbia flavescens
Gunurru
White Gum

Height 8m
Spread 8m

Eucalyptus tectifica
Ngarrban
Grey box

Height 8m
Spread 8m

Ficus opposita
Wgamarnajina
Sandpaper fig

Height 8m
Spread 8m

Gyrocarpus americanus
Mirda Stinkwood

Height 8m
Spread 8m

Hakea macrocarpa
Jarridiny

Height 8m
Spread 8m

Lysiphyllum cunninghami
Jigal
Kimberley bauhinia

Height 8m
Spread 8m

Melaleuca dealbata
Garnboorr
Freshwater paperbark

Height 8m
Spread 8m

Santalum lanceolatum
Gumamu
Tropical Sandalwood

Height 8m
Spread 8m

Terminalia ferdinandiana
Gabiny
Gubinge tree

Height 8m
Spread 8m

Terminalia petiolaris
Marool
Blackberry tree

Height 8m
Spread 8m

SWALE REHABILITATION (SHRUB AND GROUNDCOVER PLANTING)

Acacia adoxa
Prostrate Acacia

Height 0.3m
Spread 0.8m

Acacia colei
Lirrirngin
Soapy wattle

Height 3m
Spread 3m

Acacia eripoda
Yirragulu
Broome Pindan wattle

Height 3m
Spread 3m

Acacia monticola
Warraka
Scratchy wattle

Height 4m
Spread 3m

Acacia translucens
Balalagoord
Poverty Bush

Height 2m
Spread 2m

Caesalpina major
Goolyi

Height 2m
Spread 2m

Canavalia rosea
Windi
Beach bean

Height 0.5m
Spread 0.5m

Carissa lanceolata
Gungkarra
Conkerberry

Height 2m
Spread 2m

Crotalaria cunninghamii
Minmin
Green birdflower tree

Height 1.5m
Spread 0.5 - 1.5m

Fluegga virosa
Goowal
Snowball bush

Height 2.5m
Spread 2.5m

Ptilotus exaltatus
Bardirl Bardirl
Pink Mulla Mulla

Height 1m
Spread 0.5m

Trioda sp.
Spinefex

Height 0.3m
Spread 0.8m

2 LANDSCAPE SPACES

Portions of this section are extracted from the Shire of Broome 'Open Space Review' 2009

Further investigations have been made before and during the Planning and Design Forum (PDF) to research the elements should define the spaces within these transects.

An outcome of the Planning and Design Forum for UDLA was the investigation of a variety of spaces within the Broome North development. These include;

1. An Environmental Cultural Corridor(ECC)
2. Multi Use Corridors
3. Neighbourhood Centres (including meeting spaces)
4. Neighbourhood Connector streets (30m road reserve)
5. Access streets (20m road reserve)

The Shire of Broome Open Space Review 2009 notes that ...Open Space within the Town site of Broome has not been provided in accordance with a predetermined plan or philosophy...and with open space planning there is an opportunity to maintain or heighten the existing Broome 'lifestyle'.

New open spaces need to provide the connection back to country and serve many uses as drainage, open space amenity and connections for animals, people and plants. All of these spaces are required to;

- Allude to the Broome 'lifestyle' , heritage and culture theming
- Pedestrian amenity and scale
- Be sensitive to local conditions
- Create meaningful and practical connections, informal and formal recreation

The following spaces explore how these qualities can be reflected in the development of Broome North.

2.1 ENVIRONMENTAL CULTURAL CORRIDORS

Environmental Cultural Corridors (ECC's) are an initiative used previously within developments in Broome and serve a variety of purposes. The concept was born out of previous meetings with the Yawuru and is essentially a tract of land set aside to be retained without development. This land must provide important connections between significant sites for the indigenous people and may follow important drainage networks or significant tracks or trails (maintaining fauna, flora and peoples lifestyle).

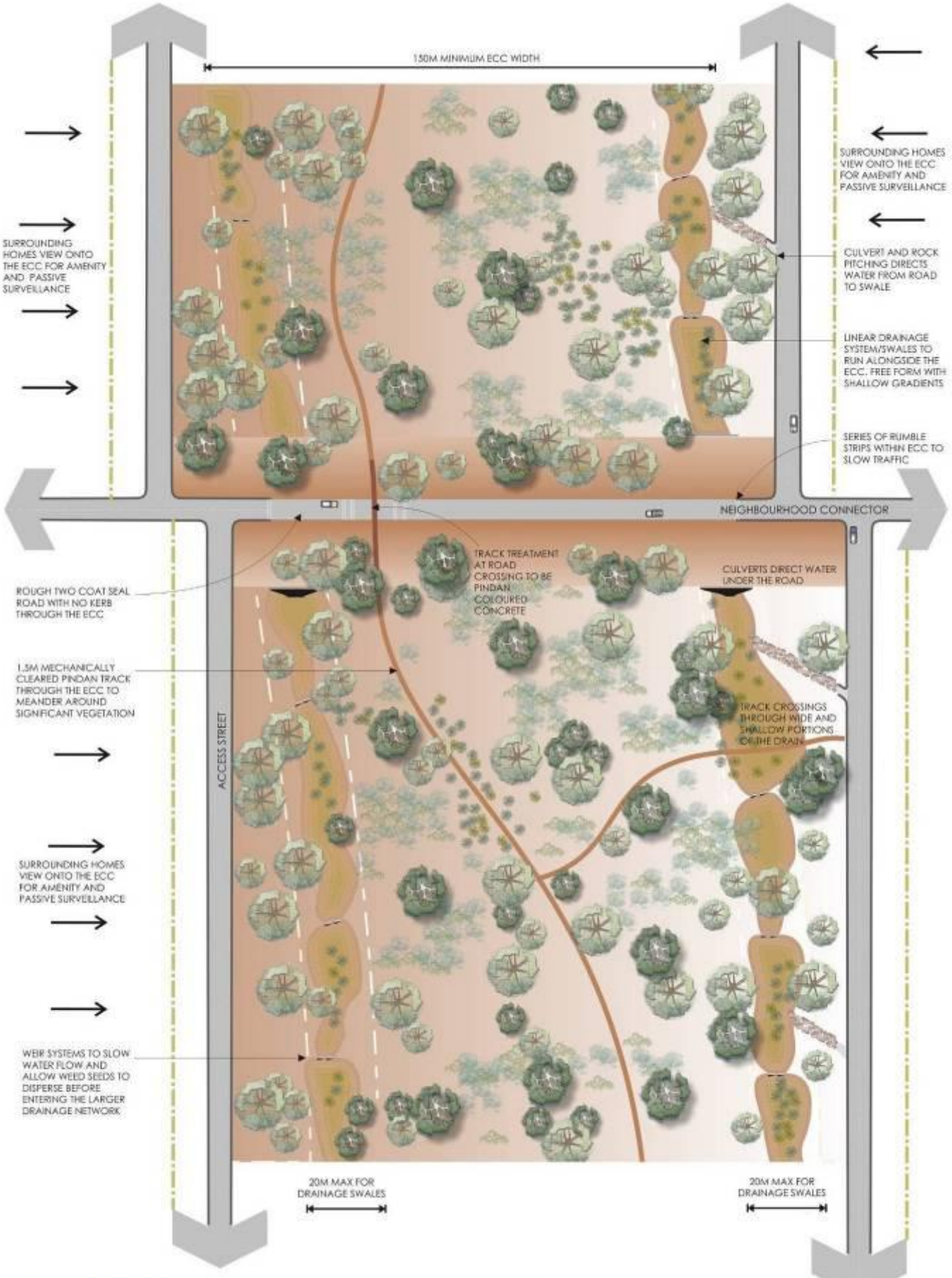
TYPICAL VIEWS WITHIN AN ECC
Photos courtesy of UDLA

- a buffer between the development and existing infrastructure, or significant areas;
- a buffer and linkage for indigenous people and for animals to move through the landscape between important places;
- retains a significant portion of local bushland to establish the sense of place and provide a constant connection to country for the development;
- allows education and traditional practices to continue on the land, and;
- supports biodiversity and local ecology through a natural tract of landscape.

The area is proposed not to be formally designed and low maintenance cleared pindan tracks are preferred to other more solid path materials. A rural style perimeter fence to discourage trails bikes and vehicles from entering the site will bound the corridor .

TYPICAL FENCING INTO THE JANUBURU ECC
Photo courtesy of UDLA

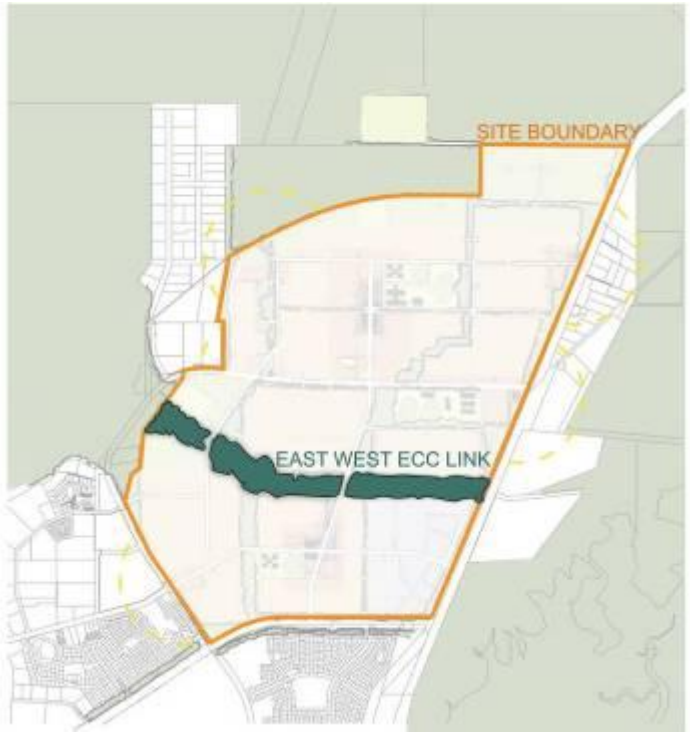
ECC SECTION
Drawing by UDLA



ENVIRONMENTAL CULTURAL CORRIDOR

TYPICAL TREATMENT INCLUDING DRAINAGE TO EDGES - Drawing by UDLA

The exact location of the ECC's was a time consuming mapping exercise which could only be established through ongoing discussions with the Yawuru. The result is a strong connection through 'country'. The outcome of the ECC (following ongoing discussions and the Planning and Design Forum) was to maintain a strong east west connection, a minimum width of 150 metres.



ECC LOCATION (indicative)
Base drawing courtesy of Roberts Day, 2009
Modified image by UDLA, 2009

The Yawuru have provided permission for drainage to be contained within the ECC but bound only to the edges of the ECC and to be carried out in a similar way to the drainage swale basins in Januburu Six Seasons. Refer to section 5.1 *Precedent Projects: Januburu Six Seasons*.The drainage is to take up a maximum of 20metres within either side of the ECC boundaries.



DRAINAGE SWALES WITHIN THE ECC
Photos courtesy of UDLA, 2006-2009

There is a strong desire by the Yawuru people to have the ECC meander through the Town Centre nodes. There were genuine attempts to make this happen within the structure plan, however other security concerns raised by other members of the community and the logistics of having a 150 metre 'natural' bushland tract through a Town Centre resulted in the ECC being offset to the north of the neighbourhood centre location.

A hierarchy strategy of green linear spaces has also been implemented within the overall plan to allow animal, plant, water and human movement through the landscape in almost every direction. This open space will dissect and softens the edges of future built form. These linear parks have provided an opportunity to allow 'green spaces' to interlink to the major urban centre and provide a connection to country, a 'Broome style' meeting space and an interpretative local link back into the ECC. An investigation of the design possibilities of this space was sketched at the Planning and Design Forum and is included within Section 8.5.

2.2 MULTI-USE CORRIDORS

(This transect would be categorized as a 'Nature Transect' as part of the Roberts Day transect approach.)

As Broome continues to grow, components of the community have expressed the strong desire for areas of native vegetation and open space to be retained to support ongoing cultural connections across the peninsula and continuing connectivity from the' Beach to Bay'.(*Shire of Broome 'Open Space Review' 2009*)

Aside from the ECC, the overall structure plan produced during the Planning and Design Forum, reflects these kinds of connections throughout the development.

MULTI USE CORRIDORS (indicative)
Base drawing courtesy of Roberts Day, 2009
Modified image by UDLA, 2009

'Bush' or 'nature' areas within the subdivision have the opportunity to provide informal connection to 'country' through local planting, materials and informal open spaces.

It is proposed that the 'nature' transect can be located adjacent to any of the other transects, and there is potential for it to be incorporated adjacent ECC corridors.

Ideally linear in shape, this area would become a multi use corridor, providing the community with a myriad of opportunities including the following.

- Provide informal connection to 'country' through local planting, materials and informal open spaces
- Can be located adjacent to any of the other transects
- Potential for it to be connected to adjacent ECC corridors (Refer to section 6.5)
- Ideally linear in shape
- Natural and urban drainage including flood management
- Flora and fauna linkages and habitat
- Cultural linkages
- Community opportunities
- Kick about areas
- Formal play
- Dual use paths/ tracks
- Exercise equipment
- Cultural, Heritage and environmental interpretation/ education
- Public and community art opportunities
- Drainage opportunities
- Buffer Planting
- Irrigated open lawn areas provide opportunity for grey water usage



MULTI USE CORRIDORS
Open lawn areas can act as kickabouts, amphitheatres, and drainage areas etc
Images from UDLA (2009), Flickr.com

2.2.1 PROPOSED DRAINAGE

The multi use corridors are proposed to include urban and natural drainage programs. In general these areas would include low flows and large storm event capacity. Specific area planning that copes with the above drainage requirements, including gentle grading will ensure the space is still functional for other uses (e.g. recreation).

For example, during a large storm event the lower portion of the corridor would act as infiltration swales and basins. Therefore, formal and dry areas would be located on higher ground to protect equipment and facilities.

This transect maximises urban drainage retention and infiltration by including full cover vegetation, thus minimising the amount of hard runoff area. Solutions such as mulch, lawn or vegetated surfaces allow water to be retained and potentially reinfiltrate.

An important point highlighted during the PDF was the opportunity for hydro-zoning the landscape. For example, different factors such as contours and vegetation types will impact water availability. Through considered deign and the use of varied reticulation lines, the appropriate amount of water will be delivered to the various areas, minimising wastage.

2.2.2 ACTIVE AND PASSIVE RECREATION

A gentle grade within the multi use corridor can be utilised as kick about areas and coupled with retained and supplemented vegetation, rolling lawns can provide incidental moments for visitors to relax under the shade of a tree with slight elevation for passive surveillance of the surrounding parkland. Grading of these lawn areas could also provide opportunities for cultural and festival events within an informal lawn amphitheatre.

It is proposed that lawn areas are well considered so that there is no excessive maintenance or nutrient runoff issues

From experience within present day Broome, these areas often experience high levels of vandalism. For this reason, furniture and facilities are to be extremely robust and situated in highly visible locations for passive surveillance purposes. (E.g. robust seating consists of local sandstone boulders etc.)

2.2.3 LANDSCAPE BEAUTIFICATION

Within the multi use corridors it is proposed that landscaping is to maintain a local sense of place by retaining and utilising local materials where possible. With this mind, it is important that edge treatments are well considered. For example: the juxtaposition of well maintained lawn against the natural bushland; the use of mulches as a contrast to lawn and natural bushland; and using paths to segregate lawn and bushland.

The multi use corridors will retain vegetation where possible. Where areas are graded for drainage and development construction purposes, it is proposed that local vegetation suitable to provide pedestrian amenity is to be supplemented where possible.

The use of local mulch or slashing during development construction will provide an immediate seed bank for revegetation. Other areas will require additional tube stock planting.

2.2.4 MAINTAINING ENVIRONMENTAL SYSTEMS AND LINKAGES

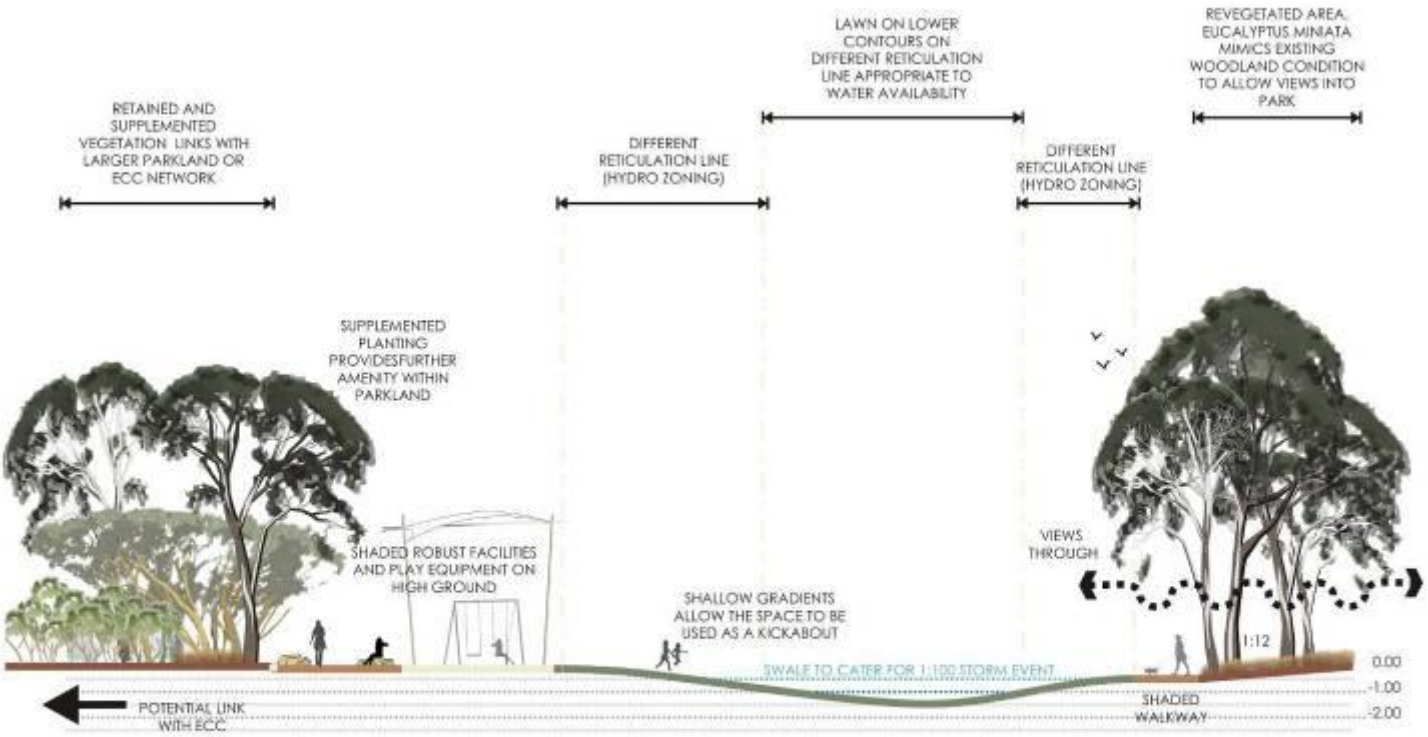
It is proposed that multi use corridors fulfil an environmental role such as maintaining habitat including fauna and flora linkages. For example the retention of trees within this corridor, provides habitat and linkages for the existing possum colony identified within the development area.



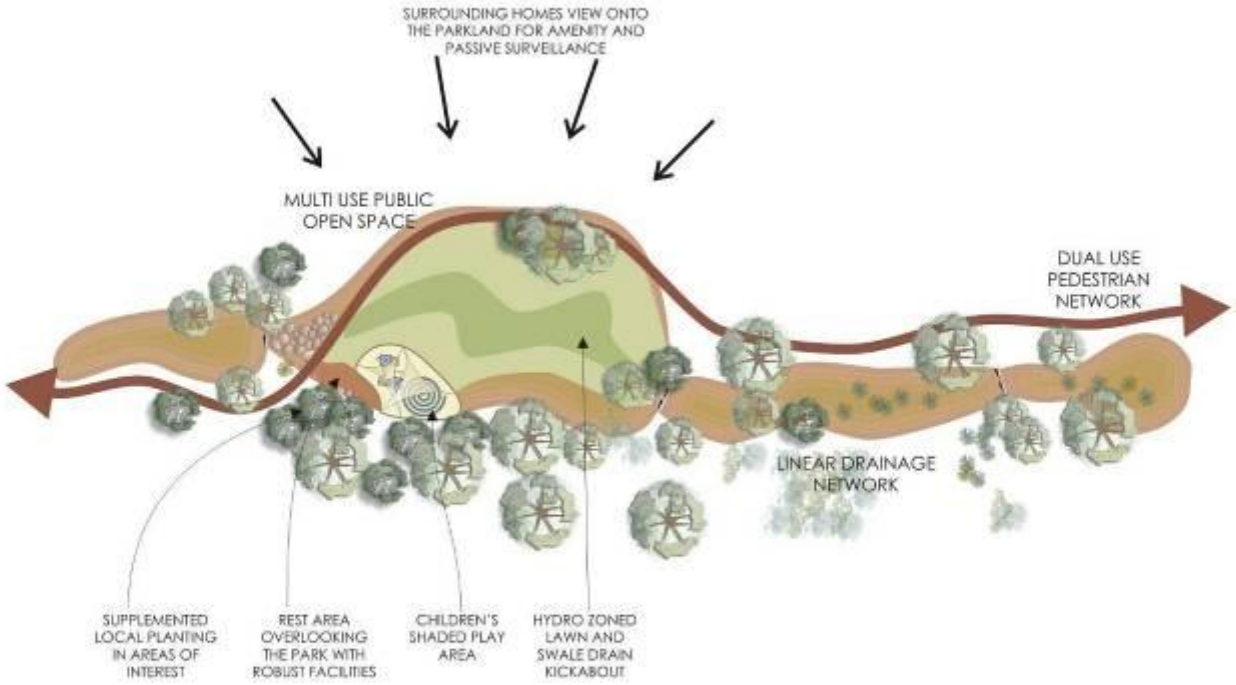

The multi use corridors propose to retain the existing natural drainage flow paths and maintain natural flow rates at discharge points pre-development. For this reason and due to development area constraints there will be increased volumes of water restricted within these corridors. Therefore, it is important that innovations such as weirs and natural holding areas (including full vegetation cover to act as a natural slow flow device) are incorporated and used to their full capacity.

2.2.5 ROADS

Proposed roads that dissect these multi use corridors need to be kept pedestrian friendly with dual use path crossings, the ability to allow stormwater to 'run across' areas (ie limited kerbing) and easy access for fauna.



MULTI USE PUBLIC OPEN SPACE SECTION
RESEARCH SKETCH (BROOME NORTH)
1:200 (A3)



MULTI USE PUBLIC OPEN SPACE PLAN
RESEARCH SKETCH (BROOME NORTH)
1:1000 (A3)

2.2.6 PRECENDENT PARK

Within Broome, this style of park has been executed successfully at Sunset Park (Old Broome) It is a multipurpose park where the open lawn area;

- Acts as a drain directing water to a larger drainage swale network;
- Allows infiltration;
- Filters runoff; and has,
- A useable kick about area.

Large trees also stabilise areas of the swale slope where scouring may occur.



SUNSET PARK
Images courtesy of UDLA (2009)

The drawbacks of this park is its high level of maintenance. Large areas of lawn with single trees standing within the lawn area has contributed to this problem.

Another issue within this park was highlighted previously; the lack of planning according to water availability has led to overwatered lawn areas. For example, the lawn area covers varying contour levels, this has resulted in the low lying lawn areas becoming 'boggy' due to the high watering required for the higher levels. A way to avoid this is to ensure the park design is hydro zoned. This means that different contours are planted according to water availability. If lawn is required over several contours then each level should be reticulated by irrigation lines providing individual and specific water volumes.

3 CONCLUSION

The development of Broome, and more specifically the Broome North site, is challenging as it "*...must navigate the boundary of cross cultural processes*".[2] These boundaries are often flexible, intangible and often prove to be emotionally driven, which can both enhance and hinder the design processes. Broome's growth will place inevitable pressure on the local culture and ultimately impact physical and spiritual connections existing throughout Broome.

The project team proposes to acknowledge this cultural connection by continuing the existing Broome lifestyle with special consideration for the existing indigenous culture, landform and ecosystems. Recognising these factors will aid to intrinsically connecting the project to 'country'.

Broome North has the potential to;

- Provide cultural and community connections to 'country';
- Continuation of the Broome 'lifestyle';
- Maintain connections and linkages through the landscape (flora, fauna and people);
- Protect and repair natural systems so traditional practices can take place alongside development;
- Create spaces that promote growth and learning, and;
- Combine recreation, preservation, education/ interpretation and urban/ natural drainage systems.

Through consideration of the existing landscape, the local spatial order and cultural understanding, Broome North will aim to set a new benchmark for development in the North West Region.

[2] V. Margetts, 2008

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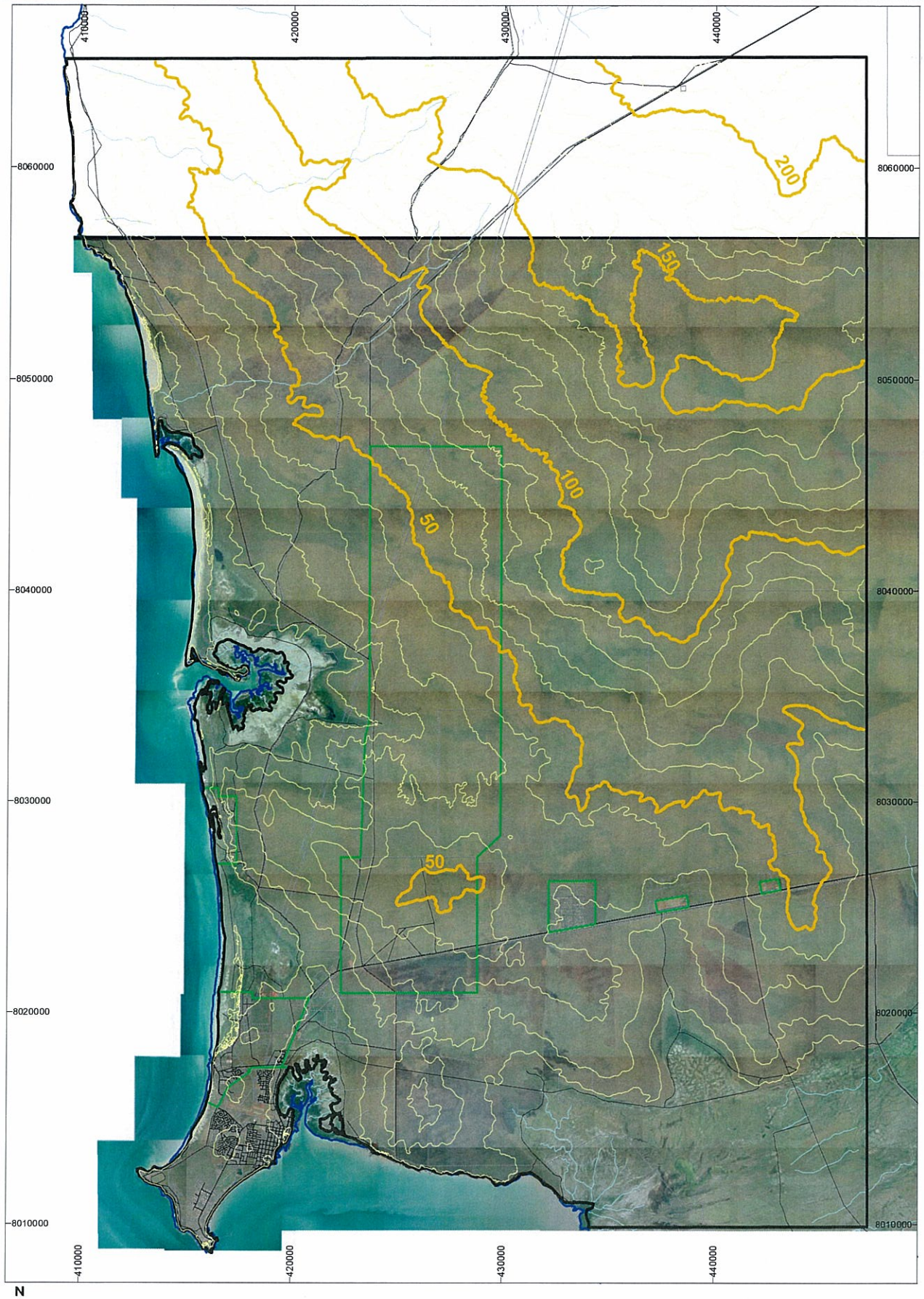
Appendix D

Groundwater levels



10m interval topographic contour (mAHD)

50m interval topographic contour (mAHD)

Legend for additional figure items provided at start of this section.

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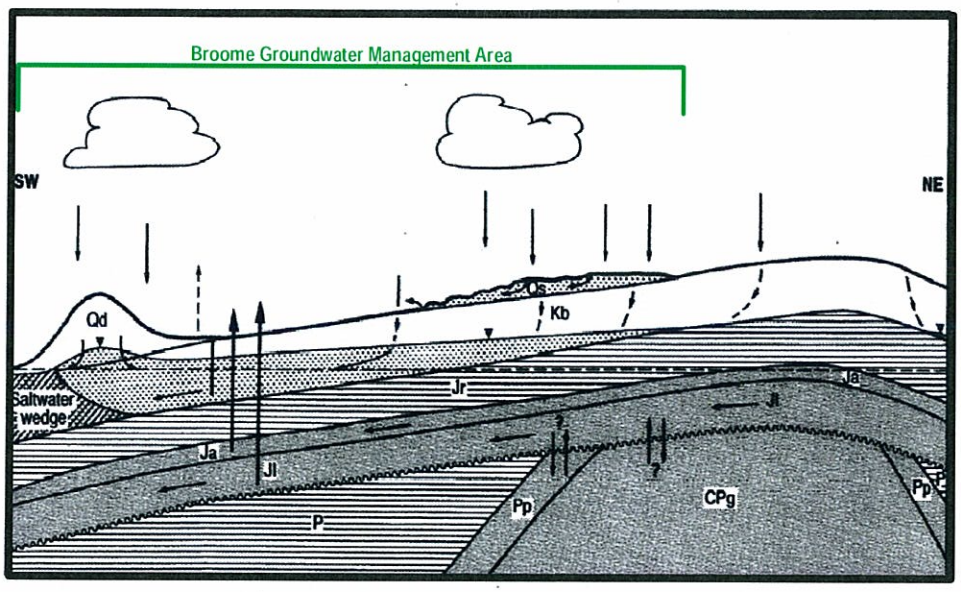
Study for Broome Groundwater Management Review

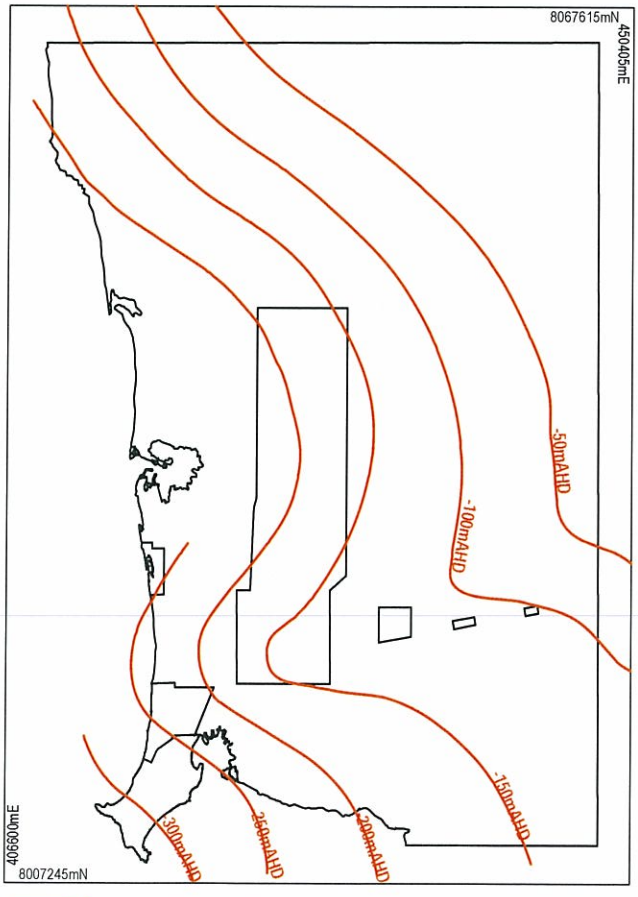
Figure 2

TOPOGRAPHY

Date: April 2008

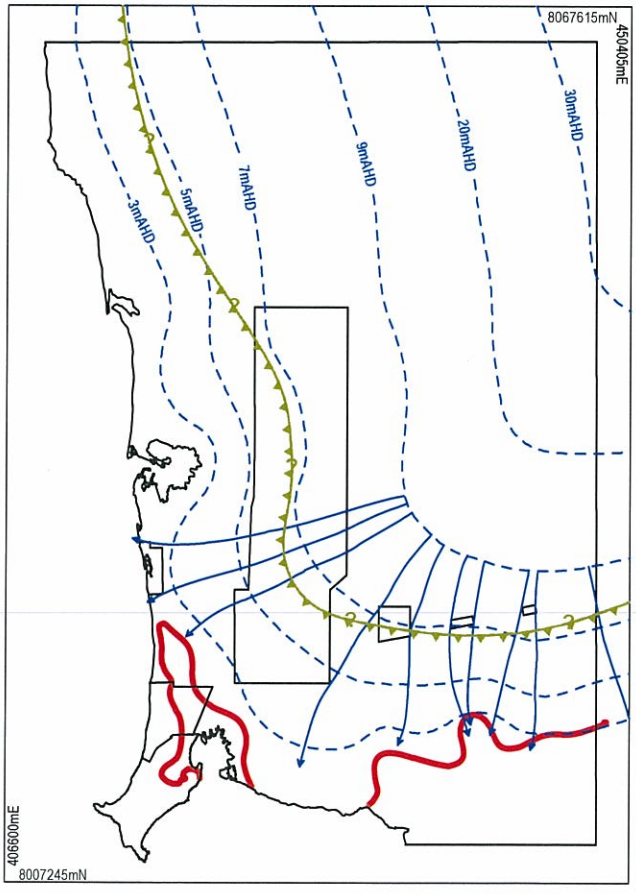


Broome Sandstone
Base Elevation



Base of Broome Sandstone (mAHD)

Broome Sandstone Aquifer
Groundwater Flow



5,000mg/L Salinity contour truncating groundwater flow.

20mAHD "Pre-pumping" groundwater level contour (mAHD) based on 1993 groundwater levels.

Groundwater flow direction.

"Toe" of saline wedge, based on 1985 geophysical log interpretations.

0 5 10km

Reference: Laws (1991) and WAWA (1994).

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Department of Water
Study for Broome Groundwater Management Review

HYDROGEOLOGICAL SETTING

Figure 4

Date: April 2008

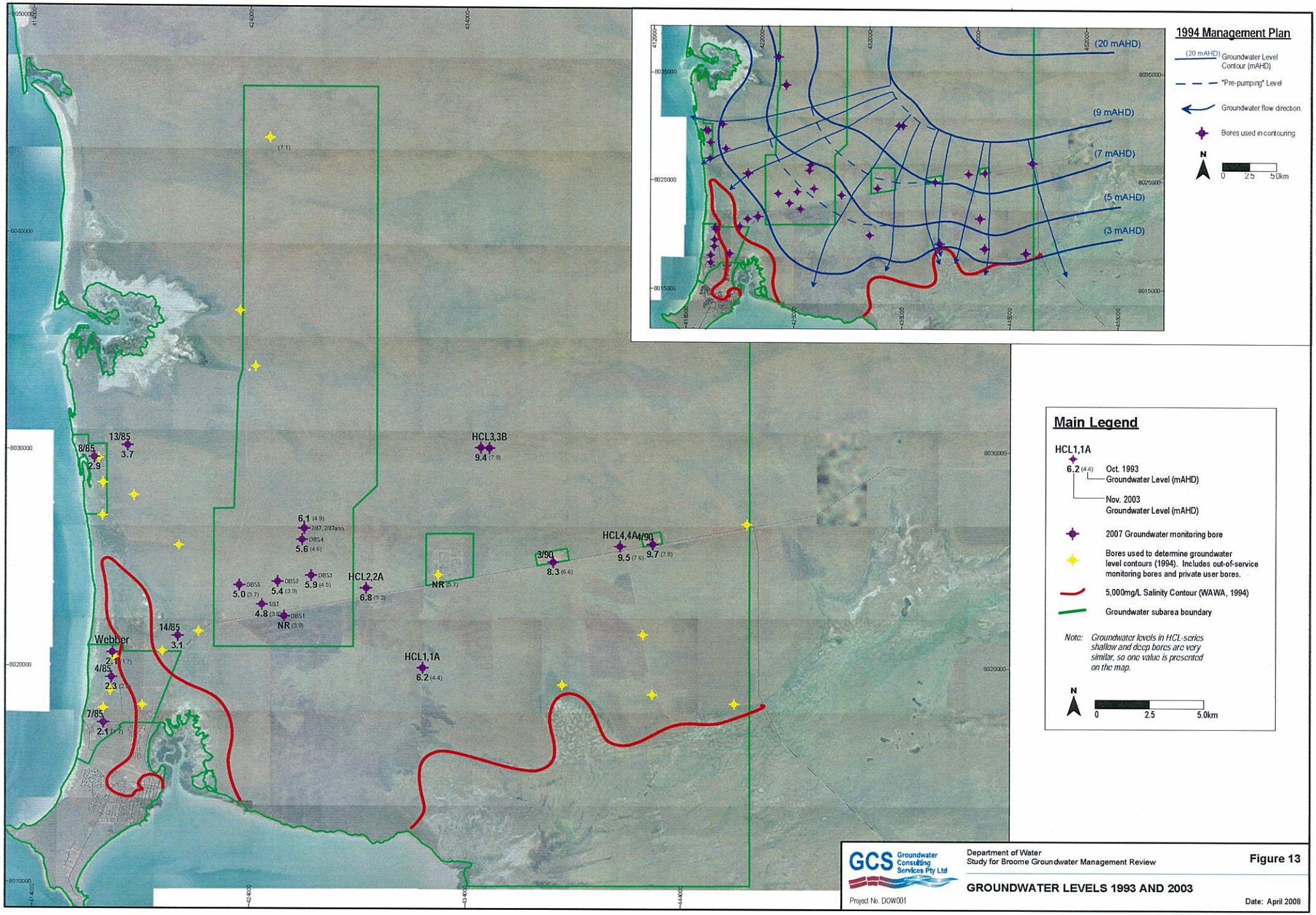

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Figure 13

GROUNDWATER LEVELS 1993 AND 2003

Date: April 2008

SKM Document History and Status

Revision	Date issued	Reviewed by	Approved by	Date approved	Revision type
A	25/9/09		H Forster	25/9/09	Draft for Internal Review (nominated sections only)
B	25/9/09	N Lavery	H Forster	25/9/09	Draft for GHD input and collation (nominated sections only)
C	9/10/09	H Forster / P Oliver	P Jordan	09/10/09	Final draft issued to GHD for final collation

Printed:	9 October 2009
Last saved:	9 October 2009 03:52 PM
File name:	I:\PBIF\Projects\PB50119\Technical\Water Management Strategy\DWMS\Final Draft\DWMS Rev C FINAL 091009.doc
Author:	Alice Micenko, Helen Forster, Peter Oliver
Project manager:	Vikki Wardley
Name of organisation:	LandCorp
Name of project:	Broome North Development
Name of document:	DWMS Rev C FINAL 091009.doc
Document version:	C
Project number:	PB50119

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Document Status

Rev No.	Author	Reviewer		Approved for Issue		
		Name	Signature	Name	Signature	Date
Draft for circulation	C. Skalski /A Fell	H Brookes		H Brookes		
0	A Fell	H Brookes M Van Tuyll		H Brookes		
1	A Fell	H Brookes		H Brookes		21/01/10