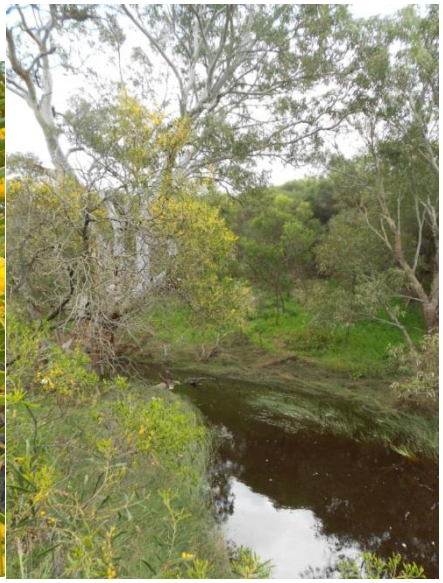
# Indian Ocean Drive Biodiversity Assessment - Flora and Vegetation

Consolidation of existing fine-scale vegetation maps and site based data to assess the biodiversity values in the Dandaragan and Gingin Shires.

**March 2014**



Department of Parks and Wildlife

LOCAL BIODIVERSITY PROGRAM
Councils Caring for their Natural Environment

WALGA

GOVERNMENT OF WESTERN AUSTRALIA
Department of Planning

Cover photo:

Judith Harvey



**Report compiled by:**
Judith Harvey, Ben Bayliss, Van Leeuwen, S., Department of Parks and Wildlife, Perth, AU.

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**ACRONYMS**

| | |
|---|---|
| ANVMP | Avon Native Vegetation Map Project |
| BSA / BVA | Beard systems association / Beard vegetation association |
| DEC | Department of Environment & Conservation |
| DPaW | Department of Parks and Wildlife |
| EIA | Environmental Impact Assessment |
| EPA | Environmental Protection Agency |
| GIS | Geographic Information System |
| IBRA | Interim Biogeographic Regionalisation of Australia |
| IOD | Indian Ocean Drive |
| NP | National Park |
| NR | Nature Reserve |
| NVIS | National Vegetation Information System |
| PER | Public Environmental Review |

**Summary**

The aim of this project is to increase the capacity of priority Local Governments (Shires of Dandaragan and Gingin) to effectively employ land use planning mechanisms to conserve priority natural areas, resulting in increased levels of biodiversity retention and protection.

With the announcement of Jurien Bay as a priority regional centre and the increased demand for development along the Indian Ocean Drive (IOD), the Department of Planning is seeking to better understand the quality of existing vegetation mapping, the relative significance of mapped vegetation types and flora information within areas potentially affected by land use changes and identify any gaps in the current information.

Objectives:

- To collate existing vegetation mapping information, including site based data and assess the comprehensiveness, consistency and adequacy of the various data sources.
- To compile a spatial overview of vegetation mapping sources covering the study area
- To prepare a vegetation and flora information report, providing a preliminary assessment of the relative significance of remnant vegetation outside Department of Parks and Wildlife (DPaW) managed lands and identify data gaps.

Project tasks:

- Collate reports on flora and vegetation mapping, including site based information within the study area, recording the data source, scale of capture and methodology;
- While focusing on lands outside those managed by the DPaW, refer to reports on vegetation and flora significance within the DPaW managed lands for the regional context;
- Reconcile vegetation mapping from various sources with Beard's pre-European extent mapping;
- Compile a spatial layer representing the various vegetation mapping information within the study area, referencing source data and including metadata statement;
- Provide preliminary assessment of the relative significance of vegetation types mapped in the study area, considering other relevant information such as but not limited to mapping of potential Carnaby's Cockatoo habitat, Tuart woodlands, wetland and Threatened and Priority ecological communities.
- Provide guidance on the requirements of further studies to cover current data gaps.

The study area was defined from the coast to 5km east of the IOD in the Shires of Dandaragan and (most of) Gingin with a spur east along Jurien Road. It falls into the most northern part of the Swan Coastal Plain Biogeographic (IBRA) region.

Over 75 reports, including Public Environmental Reviews (PER), planning strategies, regional contextual descriptions and biological surveys were sourced and summarised.

As existing digital datasets were generally unavailable, source maps were incorporated into a GIS environment by georeferencing and rectifying hardcopy source map images and digitising their extent boundaries. These boundary features or 'map footprints' comprise a spatial catalogue ('map of maps summarising the extent, location, configuration and source of mapped data. Where possible, vegetation units and selected data site locations were also digitised as vector features, GIS spatial layers for these digitised maps have been attributed where possible with the source vegetation map unit codes as annotated in the source map image, legend or related text document.

Nine information sources interpreting vegetation data as mapped units and six representing site data were identified as being most useable under the current projects terms of reference. Information from these sources was, summarised and compared with existing regional vegetation, soil and geomorphology map units.

The spatial summary indicated that the footprint of mapped vegetation represented about 30% of the core study area. Maps were often linearly configured and for this reason did not adequately capture or interpret the true extent of the vegetation units represented. There are considerable gaps in vegetation data interpreted as mapped units along the coast between Guilderton and Cervantes. These gaps would be partly filled if Nilgen and Nambung Nature Reserves (NR) and the Jurien Defence Training Area were mapped. Only two Nature Reserves within the study area (Southern Beekeepers and Wanagarren) have been mapped.

Habitat connectivity provided by the continuous corridor of remnant vegetation along the coast is not reflected in the reserve system. This is an issue which is pertinent in the context of climate change and possible movement of seed and animals. The preservation of the Defence Training Area and the remnants between Southern and Northern Beekeepers NRs and south of Lancelin would significantly bridge these gaps.

Sources of map information were variable in their scale of resolution, classification and coding of vegetation, level of floristic and structural detail, as well as botanical expertise supporting vegetation interpretation and identification. Attempts made to standardise and integrate such vegetation attributes using the National Vegetation Information System highlighted vegetation data variability issues, such as descriptions of vegetation strata in relation to the dominant species or structural parameters such as height, cover or growth form.

The degree of correlation between source map information and other data themes such as soil/landforms with Beard's regional vegetation mapping was variable. Those data sources representing major units associated with boundaries between the main soils systems (Quindalup and Spearwood dunes) were generally consistent apart from an anomalous polygon of (Spearwood) scrub-heath associated with Beard's mapping within the Quindalup system. Beard's map was of too broad a scale to pick up the finer patterns of vegetation apparent from digital aerial orthophoto images. Mapped units from sources representing regional coastal geomorphology and soil landscapes correlated well with these orthophoto images, However, apart from areas of bare

dunes and some wetlands, this correlation was not well reflected in those sources interpreting vegetation units at a more local scale.

Lists and locations of threatened and priority species of flora and fauna were obtained, and plant species with range limits were identified.

For a number of species, their occurrence within the study area represents an isolated occurrence or range limit. Such occurrences include:

- Pockets of Tuart, (*Eucalyptus gomphocephala*), woodlands and open woodland which are at its northern limit of distribution
- *E. decipiens and E. petrensis*, where collection records indicate that these species represent the northern limit of their distribution.
- Illyarrie, (*E. erythrocorys*), at its southern natural limit.
- *E. rudis* dominating fringing vegetation along the Hill River
- Western occurrences of tea tree and paperbark (*Melaleuca* spp.) thickets limited in extent and poorly reserved
- Northern occurrences of marri (also with tuart and flooded gum (*E. rudis)* associated with the Moore river are partly cleared and not reserved.

Shallow limestone patches in the Quindalup dune system appeared to support a diverse range of native species with few weeds. The Banksia low woodlands (*B. prionotes* and *B. sessilis*) on the Spearwood dune system are prime feeding habitat for Carnaby's cockatoo as is the *B. attenuata* and *B. menziesii* woodland on the Bassendean sands in the north eastern and southern portions of the study area.

Wetlands included the Hill River system, the mouth of which is arguably one of the last remaining intact examples between Geraldton and Bunbury. The stromatolites of Lake Thetis are recognised as a Threatened Ecological Community (TEC). Another TEC, a small clay pan in Bashford Nature Reserve, is one of a cluster of damplands on the edge of the IOD study area.

At 30% of the project study area, the existing sources of vegetation map cover do not currently provide a finer scale regional alternative to Beards vegetation extent. However, a review of the available maps and data can inform how future mapping work can deliver information that can be more effectively incorporated into regional and local planning by contributing a coherent regional vegetation dataset and map coverage.

## Background

### *1.1. Purpose*

The purpose of this project is to report on the existing vegetation and flora data and to identify further requirements needed to assist land use planning in the Jurien Bay area and along Indian Ocean Drive. This is one of the outputs for the Regional Local Government Biodiversity Conservation Project, delivered by the Local Biodiversity Program (LBP) with funding through the State Natural Resource Management (NRM) Program 2012-2014.

The Local Biodiversity Program is delivered by the Western Australian Local Government Association (WALGA) in partnership with the Department of Planning, Department of Parks and Wildlife (DPaW) and support from Local Governments and the South West Catchment Council

The aim of the program is to increase the capacity of priority Local Governments to effectively use land use planning mechanisms to conserve priority natural areas, resulting in increased levels of biodiversity retention and protection.

With the announcement of Jurien Bay as one of the Super Towns, or priority regional centres and the increased demand for development along the Indian Ocean Drive, the Department of Planning is seeking to better understand the quality of existing vegetation mapping, the relative significance of mapped vegetation types and flora information within areas potentially affected by land use changes and identify any gaps in the current information.

### *1.2. Study area*

The study area extends through the Shire of Gingin and the Shire of Dandaragan (Figure 1), covering lands west of the Indian Ocean Drive, from north of Conservation Reserve R49994 to the northern extent of the Shire of Dandaragan boundary. The eastern boundary is within the 5km buffer of the Indian Ocean Drive except in the Jurien Bay area where it extends to Cockleshell Gully Road and Munbinea Road between the Hill River Nature Reserve and the Lesueur National Park.

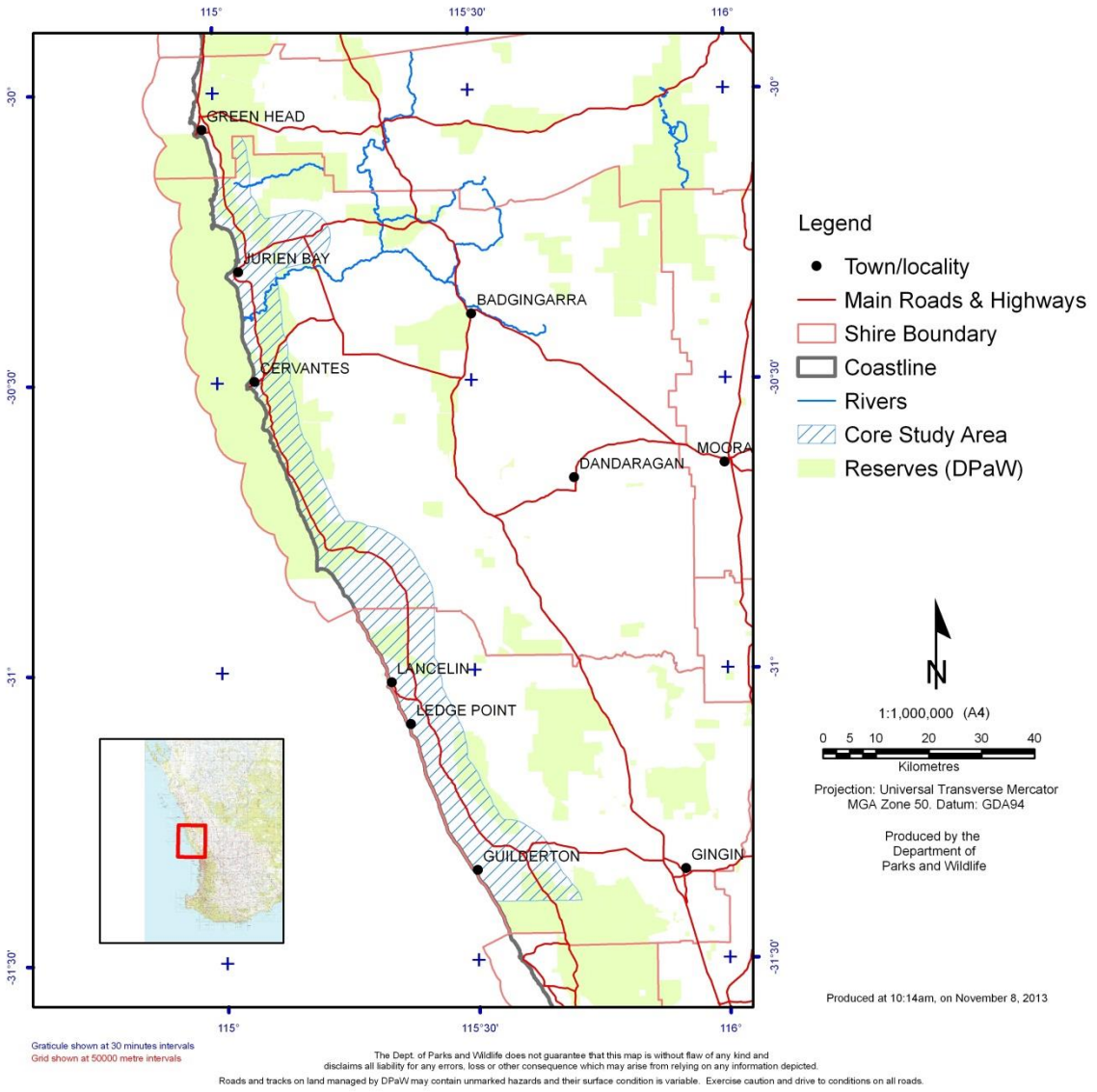



**Figure 1 Study area spatial envelope in relation to tenure, shire boundaries and main roads in particular Indian Ocean Drive**

### *1.2.1.Geomorphology*

Physiographically the study area is in the northern Swan Coastal Plain (Playford *et al.* 1976) which consists of the Quindalup, Spearwood and Bassendean dune systems (McArthur and Bettenay 1960).

Inland just east of Beekeepers Reserve and including the Hill River below the scarp is the very northern tip of the Bassendean dunes (Playford *et al*. 1976).

The very northern extent of Bassendean sands is near Diamond of the Desert Spring in the Lesueur NP (Landform Map 3.3 in Burbidge *et al.* 1990).

The coastal geomorphology for the study area has been mapped and presented in a report by Elliot *et al.* (2012) (refid 075) as part of a strategic assessment of land use along the coast of Gingin and

Dandaragan shires. For information sources examined in this project, mapped vegetation units have been assessed with reference to the geomorphology units presented by Eliot *et al.* (2012).

### *1.2.2.Regional Vegetation*

Previous regional vegetation surveys covering the Shires of Dandaragan and Gingin (Figure 2) were undertaken by Beard at scales of 1:250,000 (Beard, 1979a, b) and 1:1,000,000 (Beard, 1981). The original 1:250,000 maps by Beard, were digitised as a State-wide coverage, summarised at the 1:3,000,000 scale (Beard et al., 2013). Electronic versions of the relevant explanatory notes are included with this project. Although these maps and their associated vegetation data are valuable sources of baseline information, their coarse scale limits their usefulness where finer scaled information is required for decision making. Also caution must be exercised when these vegetation layers are intersected with a finer scale, more precise, remnant vegetation layer to calculate the area of vegetation associations remaining or in conservation reserves as the regional mapping was not designed for this purpose.

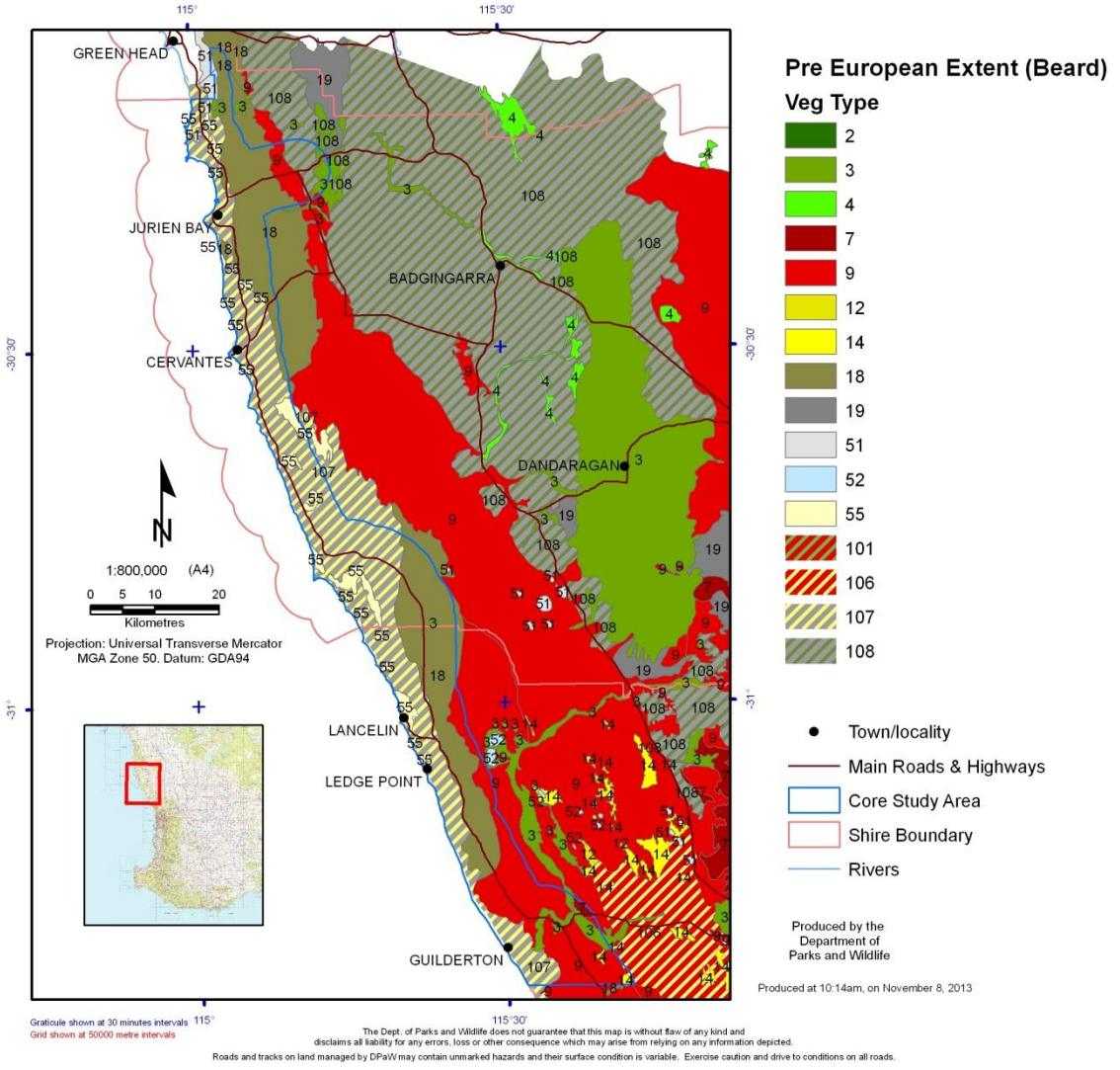



**Figure 2: Beard's vegetation types in relation to the Indian Ocean Drive between Guilderton and Jurien (see Table 1 for vegetation association descriptions)**

**Table 1 Regional Vegetation Types and Beard Vegetation associations present in the Core Study area**

| VT | Vegetation type | BVA | Map code |
|---|---|---|---|
| 2 | Forest | n/a | |
| 3 | Woodland; mainly marri wandoo | 4 | e3,5Mi |
| | | 1008 | e3Mr |
| | | 998 | e4Mi |
| | | 1011 | e4Mr |
| | | 1032 | e3,5,45Mi/dZc |
| 4 | Woodlands other; flooded gum | 1009 | e3,18Mr |
| | | 1028 | e18Mi |
| 7 | Low woodland banksia (may include tuart) | 949 | bLi |
| | | 1030 | b1,2Li |
| | | 1012 | e4Mr/bLi |
| 9 | Medium open jarrah marri woodland with low banksia woodlands | n/a | |
| 12 | Open marri woodland over teatree thicket | n/a | |
| 14 | Tea tree thickets | 37 | mSc |
| 18 | Mixed scrub-heath | 377 | x6SZc/e44Lp |
| | | 1029 | x9SZc |
| 19 | Heath | n/a | |
| 51 | Salt lakes | 125 | sl |
| 52 | Freshwater lakes | n/a | |
| 55 | Dune sand | 129 | ds |
| 101 | Mosaic of jarrah woodland and low banksia woodland | n/a | |
| 106 | Mosaic of low banksia woodland and teatree thickets | 1014 | bLi/mSc |
| 107 | Mosaic of heath with patches of thicket | 1007 | a26,m4Sc/a23,32Zc |
| | | 1026 | a23,32m3Sc/a26m4Zc |
| 108 | Mosaic of mixed scrub-heath and heath | 1031 | hSZc/dZc |

**n/a = not in core study area**

**SPECIES CODES: a23 =*Acacia rostellifera* (summer-scented wattle), a26 =*Acacia lasiocarpa* (panjang), a32 =*Acacia cyclops* (coastal wattle), b=*Banksia* spp., b1=*Banksia attenuata* (slender banksia), b2=*Banksia menziesii* (firewood banksia), d=*Banksia* spp. (dryandra), e3 =*Corymbia calophylla* (marri), e4 =*Eucalyptus gomphocephala* (tuart), e18=*Eucalyptus rudis* (flooded gum), e44 =*Eucalyptus erythrocorys* (illyarrie), e45 =*Eucalyptus accedens* (powderbark wandoo), e5 =*Eucalyptus wandoo* (wandoo), h=*Hakea* spp., m3=*Melaleuca raphiophylla* (paperbark), m4 =*Melaleuca systena* (coastal honeymyrtle), m=*Melaleuca* spp. (tea tree), x6=Mixed scrub-heath in Lesuer (?) System, x9=Mixed scrub-heath in Jurien System ,**

### *1.3. Comparability of Vegetation Mapping*

Finer scale vegetation maps are often produced as specific 'fit for purpose' products and not necessarily to inform broader regional objectives. For this reason the sources of data supporting such products vary enormously in methods and scale of data capture, analysis, interpretation, mapping and graphic outputs. Although broad guidelines are available (EPA, 2004; Walker and Hopkins, 1990), there is no prescribed set of standards to which vegetation surveys may refer for regional consistency and comparability. For this reason, it is important that the methods used for vegetation survey, data capture, analysis and interpretation are well documented and referenced. Variation in the way vegetation is described for such heterogeneous data sources requires a

standard frame of reference for interpreting this information at some comparable and meaningful level. At the very least there needs to be a standard descriptive terminology to compare vegetation descriptions as nominally equivalent attributes for units across all maps being examined. The National Vegetation Information System (NVIS) provides a set of useful guidelines that help achieve this (ESCAVI, 2003). NVIS also provides a set of hierarchical structural and floristic criteria with which to assess the compatibility and consistency of vegetation attributes from different sources.

### *1.4. Mapping Scale*

Scale has traditionally been determined and specified by the cartographic standards that dictate what can be practically depicted on a map at a specified scale. Thus at a scale of 1:100 000, the minimum recommended area for polygons is about 5 mm width on the map which equates to a ground area of 20 ha. (Neldner et al., 2012) . The resolution of mapping is also often set by the imagery used (and available) for mapping. Image interpretation is often the primary means by which vegetation units are initially established for subsequent refining from survey ground truthing. The final scale of a map in this context can be considered to be double the scale of the interpretive material (air photo, satellite image), for example a 1:25,000 scale aerial photography produces a final map scale of 1:50,000.

Scale not only controls the linework/mapping unit details, it also has a strong bearing on the level of vegetation attribute detail that may be resolved. Vegetation attributes with a low level of detail interpretable at NVIS level I to III (see Table 4) can be resolved at small (coarse) scales. Those vegetation attributes with a higher level of structural and floristic detail (NVIS level VI), more likely to represent smaller vegetation units, will support a larger scale of mapping such that they can be resolved as discrete entities in mapping where more spatial and attribute detail is required.

This scalar relationship is often reflected in the heterogeneity of a map unit; map units representing mosaics are often the result of spatially defining vegetation associations that are too small an area to be resolved at the scale used. There is also a scale relationship with the level of sampling intensity used to gather data from a vegetation survey. This data may be analysed to determine species turnover or classified into floristic groups used to inform the attribution and spatial interpretation of map units. Difficulties arise where information captured at different scales has to be compared or reconciled. If the sources of information can be interpreted according to some common level in a consistent hierarchical frame of reference, such as NIVS, then there is the opportunity for reconciliation, but only at the lowest common level of the hierarchy or broadest/coarsest/smallest scale. Such is the case where attempts are made to reconcile large scale maps, representing a high level of attribute detail covering a small area, with a smaller scale set of broader generalised regional vegetation units.

Difficulties also arise where information sources do not state the scale of interpretative materials or remote sensing imagery that may have been used to inform the scale or level of vegetation data sampling intensity. In many cases where maps are reproduced as part of derivative reporting processes such as environmental impact assessments and proponent development reviews, comprehensive information about scale parameters becomes detached such that often only a scale embedded with a printed map remains (i.e. a stated ratio or scale bar).

For vegetation mapping in particular, generation of mapped units can also involve a significant component of subjective expert interpretation involving a distillation of experience and familiarity with local and regional vegetation characteristics lending greater veracity to the mapping product. This aspect of mapping information is difficult to define for scale as in many cases subjective interpretation can provide a level of insight that effectively informs a higher resolution of map unit attribution.

*1.4.1 Defining fine scale:*

For spatial vegetation information in Western Australia, reference to 'fine' scale mapping is often made relative to that of Beard's vegetation system associations. Often there is some confusion over the term 'large' and 'small' scale. Large does not mean 'large area', rather it can be viewed as meaning a 'large amount of detail' or higher resolution, in other words it is the equivalent of 'fine'. Beard's vegetation mapping is therefore viewed as 'small' scale in relation to the larger scale of information resolution required for evaluating vegetation characteristics required for biodiversity and impact assessment at a scale of local significance.

*1.4.2 Appropriate scale*;

The notion of an appropriate or relevant scale for capturing and mapping spatial vegetation data depends on the structural and floristic complexity of the vegetation, its distribution across the landscape and the scale of land use impact processes or management/assessment units being considered (Table 2 & Table 3)

**Table 2 A general summary of the orders of vegetation mapping scale in relation to the extent of interpretative applications (Brocklehurst et al., 2007)**

| Scale | Significance |
|---|---|
| ≤ 1:50 000 | local |
| 1:100 000-1:250 000 | regional |
| 1:1 000 000 | national |

**Table 3 Summary of the scale of spatial resource data in relation to various kinds of assessment applications**

| Land resource survey class | Typical scales | Area (ha) shown by 1 cm² of map | Minimum area shown* | | Recommended uses |
|---|---|---|---|---|---|
| | | | Uniform occurrence (ha) | Elongated occurrence (ha) | |
| Very high-intensity | 1:5000 | 0.25 | 0.05 | 0.07 | Horticultural research and production areas, agricultural research areas, pasture research areas, forestry research areas, irrigation implementation, urban development, waste disposal, highway planning, mine site rehabilitation, engineering uses, property planning. |
| | 1:10 000 | 1 | 0.2 | 0.27 | |

| Land resource survey class | Typical scales | Area (ha) shown by 1 cm² of map | Minimum area shown* | | Recommended uses |
|---|---|---|---|---|---|
| High-intensity | 1:20 000 | 4 | 0.8 | 1.1 | Agricultural production areas, pasture research areas, forestry production areas, irrigation implementation, urban development, waste disposal, highway planning, mine site rehabilitation, engineering uses, management of small catchments, shire planning (agricultural areas), conservation management. |
| | 1:25 000 | 6.25 | 1.2 | 1.7 | |
| Medium-intensity | 1:50 000 | 25 | 5 | 6.7 | Agricultural production areas, pasture production areas, forestry areas, irrigation feasibility, management of small catchments and conservation reserves, shire planning (agricultural areas). |
| Low-intensity | 1:100 000 | 100 | 20 | 27 | Agricultural feasibility studies and production areas, pasture production areas, forestry production areas, irrigation feasibility studies, management of large catchments, shire planning (pastoral areas), conservation management. |
| Reconnaissance | 1:250 000 | 625 | 120 | 170 | Agricultural development potential, pasture production areas, national or regional resource inventory, conservation management. |
| | 1:500 000 | 2 500 | 500 | 675 | |
| Synthesis | 1:2 000 000 | 40 000 | 8 000 | 11 000 | National resource inventory, teaching, global planning. |

** Assumes that uniform occurrence is circular, with a diameter of 5 mm in the map, and elongated occurrence is rectangular with sides of 3 and 9 mm in the map. Source: Adapted from (Reid, 1988).*

## 2. Project Approach

Existing vegetation maps, descriptions and site based surveys were sourced from published documents, the grey literature (such as unpublished hard copy reports), and documents associated with the Environmental Impact Assessment (EIA) process. In some cases, particularly with Public

Environmental Review (PER) documents, the primary survey reports are sometimes un-appended documents which may be difficult to locate or are of restricted access.

Information sources were examined to ascertain their content and relevance to the project. A key component of this scoping was the development of a reference database and spatial extent overview of information sources. This spatial overview or 'map of the maps' represented the georeferenced spatial 'footprints' of those sources interpreting vegetation information as mapped units: This overview layer was useful in helping to:

- Understand the spatial relationships of potential map information sources and their prioritisation for further evaluation.
- Creating 'spatially aware' (georeferenced) map boundaries for more efficient digitising of vegetation units into the project GIS.
- Assessing spatial relationships of data sources such as coverage gaps, overlay and configuration of mapped areas.

It was also important to:

- Understand the relative characteristics and comparability of each spatial data source.
- Assess the congruency of source vegetation unit attributes with the NVIS.

The congruency of vegetation unit attributes with NVIS was examined, through translating examples of vegetation descriptions from selected sources.

The project also provides information about data inconsistencies and deficiencies that hinder standardisation. As a result of these findings, guidelines for data collection have been developed to inform the future data collection at the local government level.

In assessing and comparing sources of existing vegetation, particularly for data interpreted as mapped units, two previous regional spatial data integration DPaW initiatives were helpful in informing the current project:

1. the Avon Native Vegetation Map Project (ANVMP) to address an information gap identified for the Avon Natural Resource Management Region (Richardson et al., 2007)and
2. the Great Western Woodlands (GWW) Map Project (Bishop et al., 2013) to identify gaps in the vegetation mapping of the GWW.

**The general approach followed by these initiatives as adapted to the IOD project is outlined below and represented in**

Figure 3.


**Figure 3: Approach used to consolidate existing vegetation information for Indian Ocean Drive in the shires of Dandaragan and Gingin (modified from Bayliss (2011)**

### *2.1. Data Search*

A literature and spatial vegetation data search was carried out to locate sources of existing fine-scale vegetation maps and vegetation attribute data relevant to the project, this included contextual data sources such as related to soil landforms and coastal geomorphology. Spatial data interpreted as mapped units were generally sourced as hard copy map images from the 'grey' literature mostly generated through the Environmental Impact Assessment (EIA) process and consultants reports appended to development proponents evaluation documents. Source information was obtained from the DPaW Conservation Science Library and the Department of Planning. Reports were scanned into PDF format and maps extracted as digital images to be georeferenced and rectified in a Geographic Information System (GIS).

All collated source reports were entered into the bibliographic data base, EndNote, and a relational database was developed in Microsoft Access to store summaries of the source documents with particular reference to vegetation and related themes. This information included details about scale, area covered, number of maps and general comments about the map compilation and site data, if available (Figure 4). The reference identification (refid) number in EndNote was the key identifier. This 'refid' number is carried through to identify and relate all scanned maps, GIS spatial layers (shapefiles), data summaries and report files. A list of all source documents is presented in Appendix A and the summaries of each report are contained in the attached report summary database.

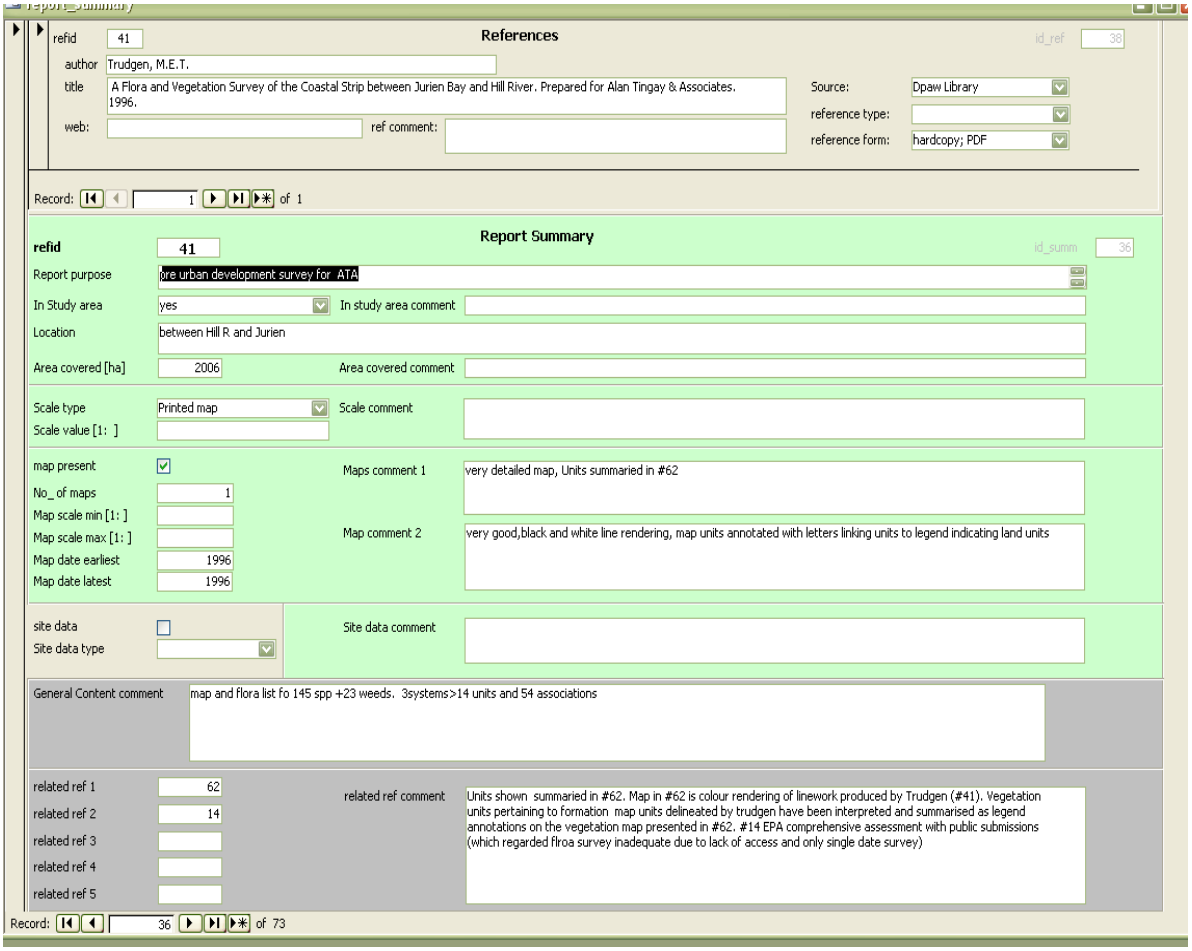



**Figure 4 Database form view of report summaries.**

Additional spatial data relevant to the mapping of vegetation patterns was also considered. These data included maps/layers relating to geomorphology, wetlands, soil landscapes and soils.

### *2.2. Scoping Information sources*

Scoping was undertaken to understand the content, quality and relationships between the collated information sources. An assessment was made to determine which information sources were relevant and suitable for contribution to the project objectives based on the following considerations.

- Map properties:
    - Vegetation units should be displayed or interpretable as unbroken closed boundaries (polygons)
    - Map unit line work should be clear and unambiguous
    - Explicitness of map unit annotation or attribution. Each mapped polygon comprising a map vegetation unit should be clearly labelled according to the vegetation type described. Some maps used properties such as colour or shading to link map units with a described vegetation type. This relationship needs to be clearly rendered.

- Adequacy of geographic referencing. That is, presence of important information needed to define the maps geographic properties and location, such as a datum, projection and coordinate reference grid. Other useful displayed reference information includes documented reference cadastral boundaries, such as reserve or property boundaries. Coastline features obtained from topographic data layers Aerial orthophotography is also useful depending on the date, image source and scale.

- Survey sites need to be unambiguously cited with georeferenced locations in the reporting document.

➢ Requirements for consistency and comprehensiveness of the original vegetation descriptions;

- Consistency and comprehensiveness of information relating to structural and floristic parameters such as height, cover, and species dominance are required. In particular whether vegetation is described according to consistent criteria such as that of the National Vegetation Information System (NVIS) or to a known structural classification system (e.g. Muir, (1977), that can be related to NVIS.

- Correlation with any previous or adjacent mapping should be documented.

➢ Importance of spatial representation and configuration. This includes the relative extent of the mapped area i.e. whether this represents a small or large area; a compact or long and narrow form such as a road corridor alignment. Large compact nonlinear mapped areas are preferable in that, as well as potentially providing greater coverage, they are more likely to appropriately represent regional vegetation patterns. Small areas mapped in fine detail may not capture the contextual features of the units described. Similarly, for narrow mapped corridors regional vegetation patterns may be inadequately represented.

The ability for vegetation descriptions from different information sources to be interpreted according to NVIS terminology has been used as a measure of their comparability and the comprehensiveness with which fundamental floristic and structural vegetation parameters have been captured. As part of the source information assessment process for this project, selected vegetation descriptions were interpreted using NVIS as a standard frame of reference. This exercise highlighted and helped determine how feasible the comparative interpretation of source descriptions could be with each other at a local scale and with Beard's vegetation coverage at a regional scale. Vegetation descriptions varied with some being closely NVIS compliant in that they consistently used a recognised classification scheme for descriptions (for example (ESCAVI, 2003; Keighery, 1994; Muir, 1977); whereas others, although detailed, defined vegetation units informally using nonstandard descriptive terms rather than those of a consistent classification system. In some cases vegetation descriptions were deficient in essential floristic and structural information required by NVIS criteria, or represented a complex mosaic that could not be resolved as NVIS interpretable attributes for the associated map unit. For vegetation data interpreted as mapped units, where attributed vegetation descriptions did not refer to a defined vegetation classification system, but

contained i) sufficient structural and floristic information or ii) other contextual source information (e.g. site data), descriptions could sometimes be usefully interpreted according to NVIS terminology.

### *2.3. Processing spatial data: creation of the spatial extent overview layer (map 'footprints'):*

The majority of source maps were only accessible in hard copy format with few available directly in a GIS compatible digital format. This meant that hardcopy maps had to be manually scanned, and the map images made 'spatially aware' (georeferenced and rectified) so they could be viewed in a GIS. The boundaries of these georeferenced map images were then digitised as polygon features representing the 'foot print' of the map.[†]

Much of the source information reflected the pattern of development activities along the IOD corridor. These activities are usually subject to EIA assessment for which the reporting required of proponents usually involves collection and presentation of vegetation data. Inevitably, such sources of information vary in the quality, scale, methods of capture, interpretation and description of mapped vegetation. Additionally, mapped areas can overlap in time and space and have differing or incongruent boundaries.

To understand these map information characteristics, creating a spatial extent layer to identify the distribution and extent or 'footprints' of existing vegetation maps was an essential component of the project.

The spatial extent layer represented a 'map of the maps' combining the disparate map images to reveal their location, relative size, configuration, and spatial overlap. This layer was a useful overview tool for evaluating:

- How the various maps related to each other;
- Potential overlap and clashes of incongruent information; and
- The area represented by the source from which information was derived.

### *2.4. Processing vegetation attribute data (descriptions) – the National Vegetation Information System (NVIS)*

The NVIS framework (ESCAVI, 2003) facilitates the compilation of a nationally standardised vegetation dataset. It provides a comprehensive means of describing and representing vegetation information based on establishing relationships between structural and floristic data. The NVIS framework consists of 6 hierarchical levels based on increasing complexity of structural and floristic

[†] All 'hard copy' map images, as well as electronic formats such as PDF, have no inherent geographic reference or 'spatial awareness' enabling representation in a Geographic Information System (GIS). A GIS enables integration and analysis of such images not possible otherwise. Spatially unaware images, such as scanned maps from a report therefore need to be made 'spatially aware' or georeferenced. To create the spatial extent layer, boundaries of georeferenced hardcopy maps images displayed in a GIS viewer were digitised with a standard geographic frame of reference allowing display and query in a GIS.

components (Table 4). Collectively, the different levels in the classification provide a description of vegetation that can be directly related to precise spatial areas on a vegetation map.

| ↓ ↓ ↓ INCREASING COMPLEXITY ↓ ↓ ↓ | Hierarchical Level | Description | NVIS structural/floristic components required |
|---|---|---|---|
| | I | Class* | Dominant growth form for the ecologically or structurally dominant stratum |
| | II | Structural Formation* | Dominant growth form, cover and height for the ecologically or structurally dominant stratum. |
| | III | Broad Floristic Formation** | Dominant growth form, cover, height and dominant land cover genus for the upper most or the ecologically or structurally dominant stratum. |
| | IV | Sub-Formation** | Dominant growth form, cover, height and dominant genus for each of the three traditional strata. (i.e. Upper, Mid and Ground) |
| | V | Association** | Dominant growth form, height, cover and species (3 species) for the three traditional strata. (i.e. Upper, Mid and Ground) |
| | VI | Sub-Association** | Dominant growth form, height, cover and species (5 species‡) for all layers/sub-strata. |
| | * (Walker and Hopkins, 1990)<br>** NVIS (defined for the NVIS Information Hierarchy) | | |

**Table 4**: The NVIS Information Hierarchy with levels recommended for data compilation.

Although integration of vegetation data for this project does not involve submitting vegetation data to a national dataset, NVIS provides a guide to standardising terminology across sources that do not always uniformly describe or define vegetation. Appendix B contains a summary of general NVIS concepts and a West Australian example of a Muir to NVIS translation for a Salmon Gum Woodland description Bayliss (2011).

NVIS represents a nationally recognised vegetation classification framework that can be related to frequently used structural vegetation classification schemes (e.g. Muir, 1977; Keighery, 1994), For this reason NVIS can be used to standardise existing vegetation descriptions associated with maps captured for the IOD. Appendix B provides a comparative table showing the way NVIS and classifications can be related. This table is a useful tool for other similar projects and applications seeking to interpret vegetation descriptions according to a common NVIS terminology.

Although NVIS is a valuable framework for defining vegetation data standards in relation to information from different sources, there are issues relating to specific vegetation types in South Western Australia. For example, NVIS does not accommodate Scrub-heath (present in the study area) or Mallee-heath vegetation types as each of these types encompasses a range of strata and has no obvious dominant species. Also on simplifying levels 5 and 6 to level 4 in the NVIS hierarchy and reducing the representative dominant taxon from species to the rank of genus, there is a significant loss of information which could be overcome if a dominant species component was

‡ Although NVIS specifies five species to define the floristic elements of a Level 6 description, for some floristically rich communities more than five may need to be noted.

incorporated into the NVIS level 4 sub-formation descriptions. It is generally considered for WA that floristic modification is necessary to include dominant species, rather genera, as there are many Eucalyptus and Acacia that characterise a vegetation community. For the current project, selected vegetation descriptions have been interpreted to accommodate these considerations and help generate a more comprehensive and consistent map unit annotation coding.

### *2.5. Project Output*

The project package contains:

- Report
- The GIS spatial layers for vegetation maps and sites based surveys with appropriate meta data
- GIS spatial layers for relevant available contextual features.
- The database containing summaries of all source references.
- EndNote bibliographic data base.
- PDF files of most references.
- PDF files of Appendix B A summary of NVIS general concepts and description coding, Appendix C: Relationships between the National Vegetation Information System (ESCAVI 2003) and Muir (1977) Vegetation Structural Classification Systems and Appendix D Conditions of Supply of information pertaining to Rare and threatened species of plant and animals, Appendix E Spread sheet of vegetation statistics for Dandaragan and Gingin shires

## 3. Findings

### *3.1. Data coverage and characteristics*

Around seventy information sources were examined for vegetation information. Eighteen sources provided spatial information about native vegetation, either interpretable as mapped units (polygons) or as site (point) related information (Table 6). The spatial foot prints for these sources are shown in Figure 5 and Figure 8. Discussion concerning the methods, quality and validity of vegetation and related information in the source reports are presented below in section 3.4 and 3.5. In particular the representation and interpretation of vegetation attributes is noted with reference to spatially and temporally overlapping data sources.

The scale information was variable and not always clearly defined (Table 5) with most sources indicating scale simply as a scale bar and page size dependent ratio on a printed map within a document. Based on these indicators, scale varied from 1:200 000 (regional) to 1:8600 (local) ( Table 5. Several sources presented site data only according to stated coordinates and did not provide any clear estimate of information scale. Only three sources indicated the scale of interpretative imagery used to inform mapping units or site data capture. None of the sources gave any direct indication of site density or an explicit analysis of information scale parameters (see section 1.4) other than by generalising as regional or local. Currency of information captured or survey date ranged from 1989 to 2010. For information interpretable as defined area coverage, i.e. mapped units, the representation of source extent within the study area ranged from 352 to 19179 ha (see table 6)

**Table 5 Summary of information source scale range.**

| Source (refid) | Map id | Data type | Area (ha) | Scale | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | map scale ratio (1:n) | map scale type | printed map size | imagery scale (1:n) | site density |
| 007 | 008 | polygon | 3107 | 75000 | bar/ratio | A3 | not stated | not stated |
| 013 | 002 | polygon | 8289 | 100000 | bar | A4 | not stated | not stated |
| 016 | 000 | point | 2421 | 10000 | bar/ratio | A4 | not stated | not stated |
| 022 | 000 | point | na | na | na | na | 20000 | not stated |
| 033 | 003 | polygon | 163 | 10000 | bar/ratio | A3 | not stated | not stated |
| 033 | 004 | polygon | 189 | 10000 | bar/ratio | A3 | not stated | not stated |
| 041 | 049 | polygon | 2421 | 35000 | bar/ratio | A4 | not stated | not stated |
| 047 | 029 | polygon | 682 | 36000 | bar/ratio | A4 | not stated | not stated |
| 049 | 000 | point | na | 200000 | bar/ratio | A4 | not stated | not stated |
| 071 | 011 | polygon | 11302 | 142857 | bar | A4 | not stated | not stated |
| 073 | 000 | polygon | 3038 | 20000 | bar/ratio | A3 | not stated | not stated |
| 074 | 000 | point | na | na | na | na | na | na |
| 076 | 000 | point | na | 8600 | bar | A3 | not stated | not stated |
| 083 | 000 | polygon | 19179 | 50000 | bar/ratio | 50k topo base mapsheet | 25000 | not stated |
| 084 | 006 | polygon | 14228 | 200000 | bar | A3 | 25000 | not stated |
| 084 | 007 | polygon | 872 | 30000 | bar | A4 | 25000 | not stated |
| 084 | 008 | polygon | 236 | 14705 | bar | A5 | 25000 | not stated |
| 086 | 000 | polygon | 14228 | na | na | na | na | not stated |

Initial scoping revealed fragmentation of information across government agency and private industry commissioned survey reports as well as across reporting stages associated with assessment protocols such as the public environmental review (PER) process. This was reflected in the overlap of many information sources and required some form of overview to help comprehend their spatial and temporal relationships as well as identify regional gaps in data coverage.

A spatial extent layer or set of data 'footprints' for vegetation related information sources was created to help provide such a spatial overview of information sources Table 6. The 'foot print' map of survey extents for the nine main sources which interpreted vegetation information as mapped units is shown in Figure 5. The area of more intensive and fragmented survey activity and reporting is displayed at a larger scale in Figure 6. The four surveys capturing and presenting site only data are shown in Figure 8. One information source, ATA Environmental (2001) (refid 016), represented a survey of small coastal wetlands for which the total area mapped was low (~10ha) relative to the extent of the region surveyed (~2000ha). The survey extent boundary for this information source shown in Figure 5 is essentially the same as that for refid 041. For this reason, refid 016 is omitted from summary area calculations for the project given in Table 7 and Table 8

Differences between information sources were apparent in their methods of mapping and vegetation interpretation. These differences sometimes gave rise to spatial and attribute incongruities. Resolution of such incongruities is often complex, particularly if assumptions have to be made in the absence of a stated vegetation structural classification system. Structural classification systems, define the key parameters of height, cover and growth form with which vegetation structure is interpreted and described Appendix B. Where various data sources use different but consistently applied and documented classification systems for interpreting and describing vegetation, often this information can then be compared with reference to their respective classification systems.

A regional reconciliation of spatial and attribute incongruities between mapped data from different sources is beyond the scope of this project; rather spatial datasets are presented as independent spatial layers in the project GIS data set. Areas of significant spatial overlap can be examined by drilling down through the data layers to compare the different ways vegetation is defined for a given area by different sources. It may then be possible for further interpretation and regional reconciliation of these data to be performed as more information or opportunities for additional survey data collection become available.

In general source documents represented spatial vegetation data interpreted as either mapped units (polygons) or as site based information (points). Sometimes information for both spatial types was presented by the same source. Site information may be mathematically analysed to identify vegetation types as species assemblages grouped according to likelihood of geographic co-occurrence or relationship with other environmental variables. Although the sites from which data is collected may be geographically defined in the source report, the vegetation groups identified from floristic site data analysis may not necessarily be interpreted as mapped units (for example Griffin, 1993)

**Table 6: Sources of survey information interpreted as mapped vegetation units and according to sites only.**

| Refid | Author | Title |
|---|---|---|
| | | INFORMATION SOURCES INTERPRETING VEGETATION AS MAPPED UNITS |
| 007 | Ecologia | Cervantes- Jurien Coastal road Consultative Environmental Review for Main Roads and Shire of Dandaragan. 1997, Main Roads and Shire of Dandaragan: Perth, W.A. |
| 013 | Burbidge, A.H. & Boscacci, L.J. | A spring reconnaissance survey of the flora and fauna of the Southern Beekeepers Reserve. 1989, Dept. of Conservation & Land Management: Perth, W.A. |
| 033 | Coffey Environments | Spring Flora and Vegetation Assessment Marine Fields and North Cervantes Study area. 2011, Prepared for Ardross Group of Companies: Perth. p. page 48 in Ref 32. |
| 041 | Trudgen, M.E.T. | A Flora and Vegetation Survey of the Coastal Strip between Jurien Bay and Hill River. Prepared for Alan Tingay & Associates. 1996. |
| 047 | Bennett Environmental Consulting Pty Ltd | Effects of Water Drawdown on Vegetation near Jurien Bay prepared for Kellogg Brown & Root. 2004: Perth, WA. |
| 071 | Crook, I.G., Williams, A.E. & Chatfield, G.R. | 1982. Nature reserves of the Shire of Dandaragan, Volume 1, Department of Fisheries and Wildlife, Perth, WA. |
| 073 | Grey, C. | 2005. Flora and vegetation survey near Fatfields Jurien Bay. ATA Environmental. |
| 083 | Thomas, J.F., McArthur,W.M. & G.A.Bartle | Land use and management in the Defence Training Area at Lancelin. Report No. 90/10, November 1990. |
| 084*<br>085*<br>086* | Halpern Glick Maunsell | 2000. Lancelin to Cervantes Coastal Road Public Environmental Review for Main Roads Western Australia, Perth. |
| | | SITE VEGETATION INFORMATION SOURCES |
| 022 | Griffin, E.A. | Flora of the Quindalup Dunes between the Swan and Irwin Rivers, Western Australia. . 1993: Unpublished report to Coastal Planning Branch, Department of Planning and Urban Development, and the Heritage Council of W.A. |
| 049 | Bennett Environmental Consulting Pty Ltd | Comparison of Vegetation at Lakes in the Jurien Bay prepared for Kellogg Brown & Root. 2006: Perth, WA. |
| 074 | Langley, M.A. | 1999. West Midlands Survey. Perth, 1998 - 1999. |
| 076 | Keighery, B.J., Keighery, G.J. & Longman, V.M | 2003. Vegetation and flora of Sappers and Cowalla Road between Nilgen Nature Reserve and the Moore River. Unpublished report for Wildflower Society of Western Australia and WA Landskills Inc. Wildflower Society of W.A, Perth. |
| 016 | | ATA Environmental, (2001). Turquoise coast development Jurien Bay: wetland survey. Unpublished report 2001/92. 2001, Unpublished report prepared for Ardross Estates Pty Ltd. Perth, W.A. |

**The site information and coordinates for the GIS polygon layers is under Refid 084, however the site related information is under Refid 086. Refid 086 is the document that has both sets of information. Refid 085 has detailed information for Wedge and Grey settlements.*

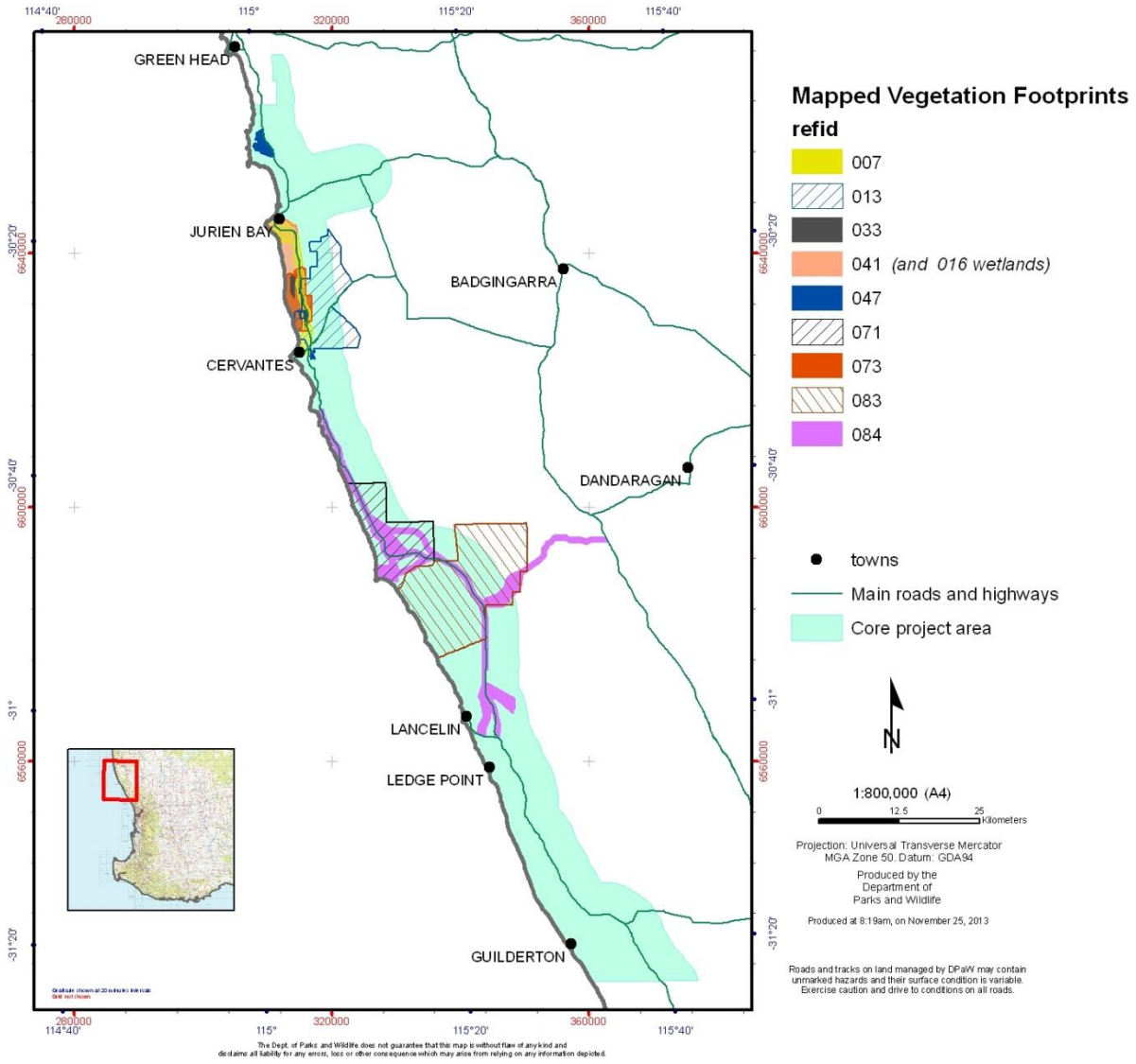



**Figure 5: The extent of vegetation mapped (see Table 6 for references)**

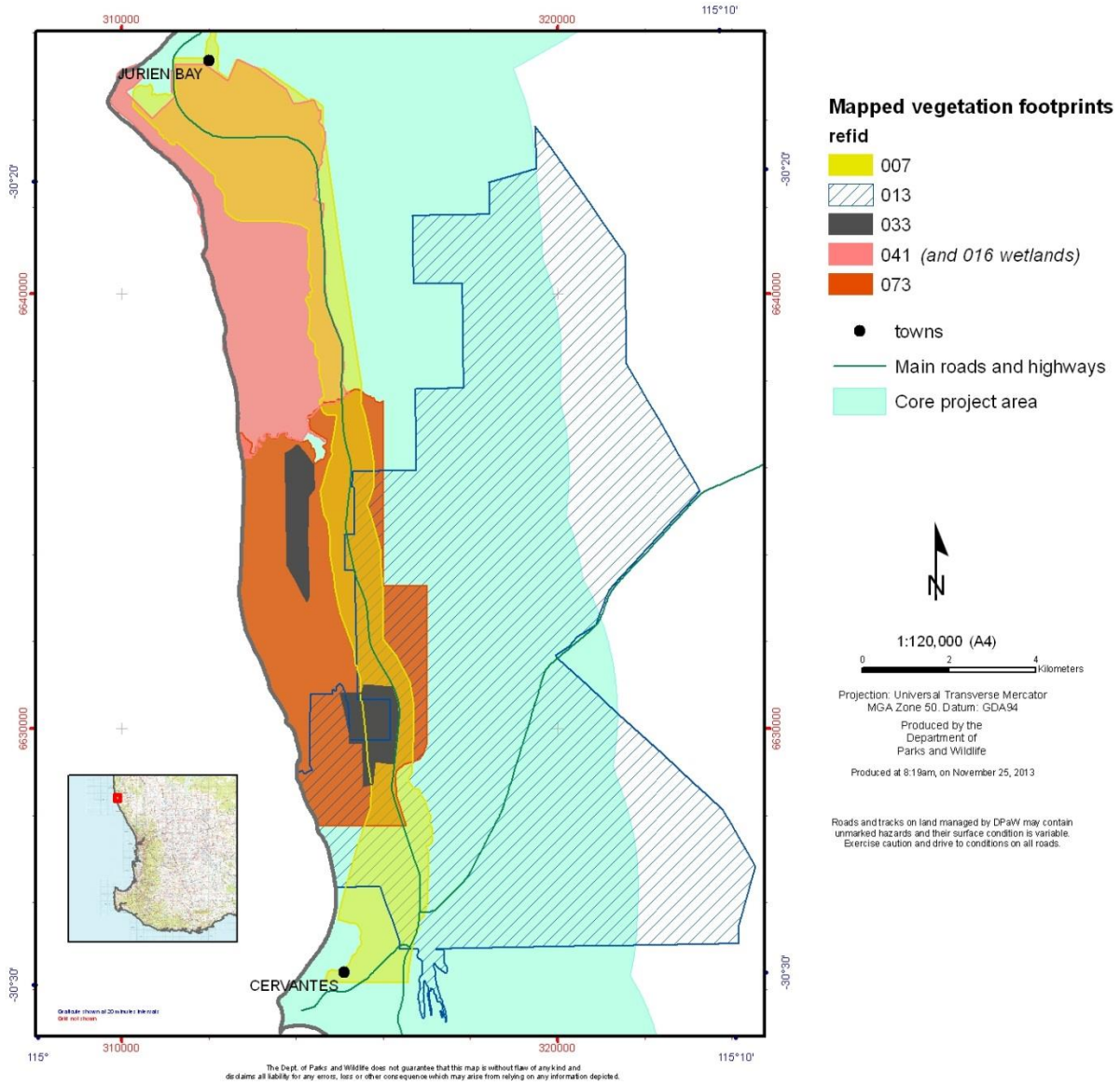



**Figure 6: Extent of vegetation mapped (detail of area between Jurien and Cervantes)**

**Table 7: Area mapped within core study area by listed reference sources.**

| refid | Mapped area (ha) |
|---|---|
| 007 | 3107 |
| 013 | 8289 |
| 033 | 352 |
| 041 | 2421 |
| 047 | 682 |
| 071 | 11302 |
| 073 | 3038 |
| 083 | 19179 |
| 084 | 12987 |
| Total | 61358 |

**Table 8 Mapped area statistics relative to the core study area.**

| | |
|---|---|
| Amount of overlap (ha) between mapped areas | 11920 |
| % of mapped area within core study boundary representing overlap | 24 |
| Core study area (ha): | 156106 |
| % core study area mapped (all map areas - no overlap) | 32 |

From the map spatial extent overview layer area statistics were calculated for each of the contributing information sources in relation to the project study area (Table 7 and Table 8), and the following information was highlighted:

- Total of areas represented by each of the vegetation maps within the core study area boundary is 61358 ha
- Of this total mapped area, 24% represents map overlap of the same areas by different information sources.
- Excluding overlap, the total proportion of the core study area mapped by one or more sources is 32%

**Table 9 Mapped area statistics relative to remnant vegetation extent.**

| | |
|---|---|
| Core study area (ha) as remnant vegetation*: | 120533 |
| % core study area as remnant vegetation: | 77 |
| Area (ha) of remnant vegetation mapped for core study area*: | 47859 |
| % core study area mapping representing remnant vegetation: | 97 |

*figures derived from AGFWA/DPaW GIS data overlay (data derived from AGFWA data processed to meet the departments CAR requirements as at 2012)

Figure 7 shows the mapped vegetation footprint in relation to the remnant vegetation extent. Of the mapped vegetation extent within the study area, 97% represents remnant vegetation, (Table 9)

Vegetation mapping tended to conform to linearly aligned polygons defined by the IOD corridor service, utilities and survey lines, or were confined to public lands and land development parcels .

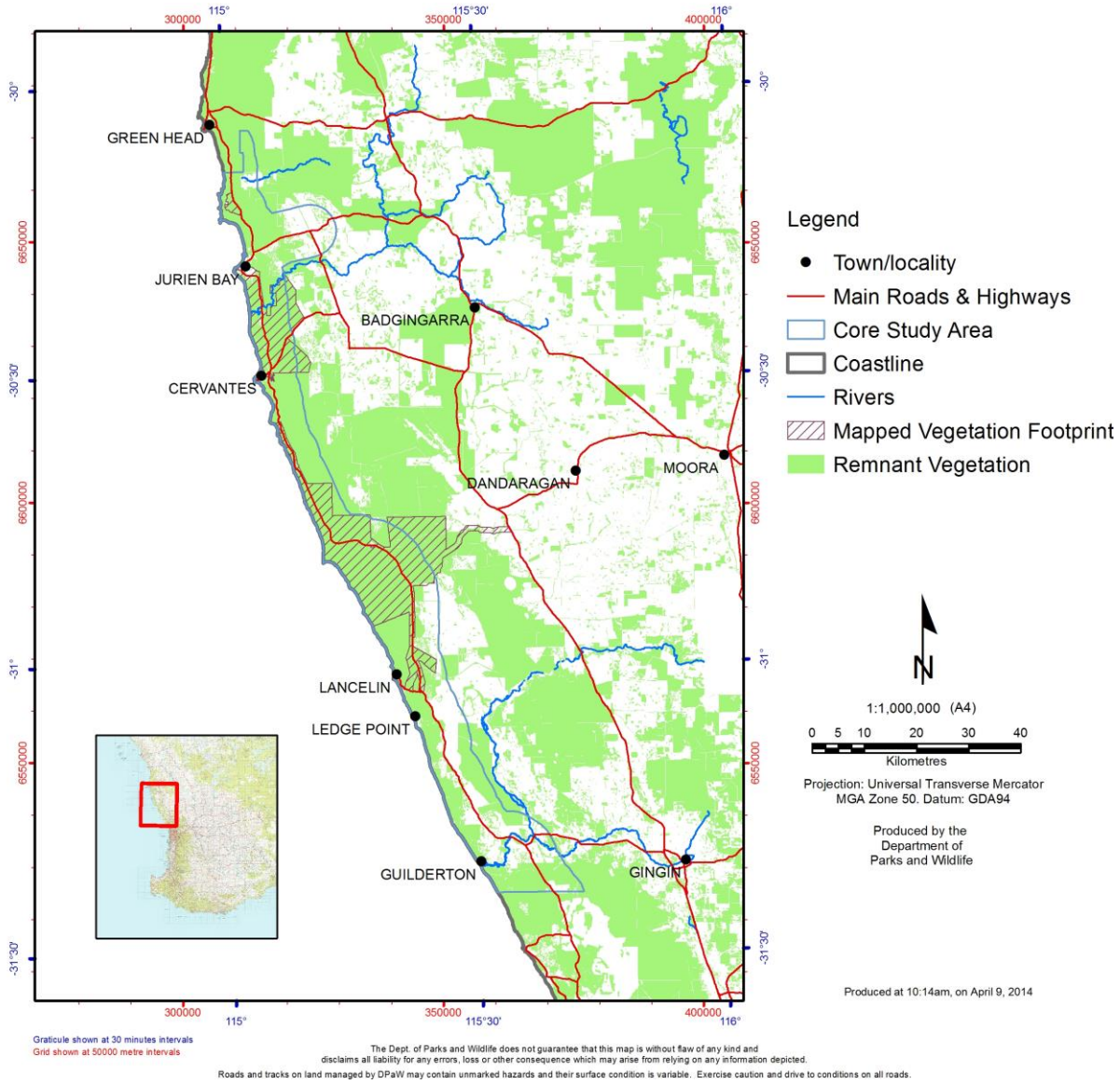



**Figure 7 The footprint of vegetation mapped in relation to remnant vegetation extent**

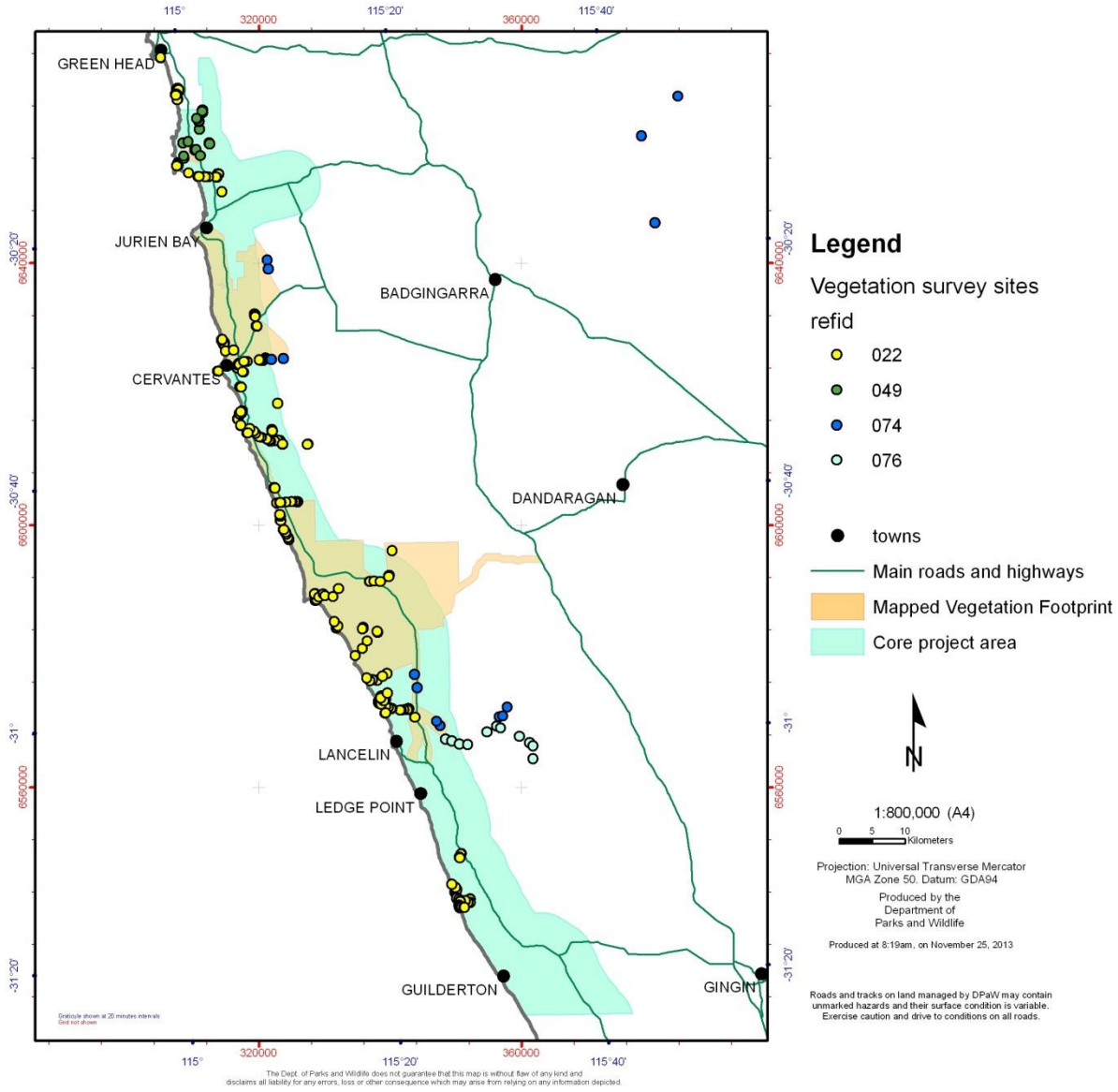



**Figure 8 Vegetation survey sites (see Table 6 for references)**

### *3.2. Spatial (map) coverage gaps and data variability.*

There are considerable gaps in vegetation data interpreted as mapped units along the coast between Guilderton and Cervantes. These gaps would be partly filled if Nilgen and Nambung Nature Reserves (NR) and the Defence Training Area (DTA) were mapped. Although the DTA was surveyed and mapped according to 'landform-soil-vegetation complexes' in 1989 by Thomas *et al.* (1990) (refid 083) there is a need for more current vegetation map information over this area. Halpern Glick and Maunsell (2000) (refid 086), reported that map information produced by Ecologica for the DTA was in preparation as at August 2000. However Ecologia Environment have only been able to find records of an unpublished report to the Department of Defence documenting a survey carried out in 1998 for the DTA for which no vegetation units appear to have been interpreted (Ecologia, 1998; Refid 097)

It was apparent from early project scoping that the source information was variable in terms of the nature and quality of the spatial data (vegetation maps) and associated vegetation descriptions. Factors that were noted in relation to variability of data characteristics include:

- The relative extent and configuration of area covered by the mapped area (i.e. small vs. large area, compact vs. a narrow linear configuration);
- Comprehensiveness and consistency in documenting and describing vegetation map units, ease of standardisation and translation of the original vegetation descriptions according to a consistent set of criteria such as those of NVIS;
- Correlation between delineated map units and documented vegetation descriptions;
- Quality of map annotation such as clarity of map unit delineation, explicitness of map unit annotation or attribution, and adequacy of geographic referencing such as statement of datum, projection, presence of a map reference grid and documented cadastral reference boundaries.

In addition heterogeneity of map annotation and vegetation unit coding can make it difficult to cross reference and reconcile map units in relation to spatially overlapping sources and regional comparison of units representing comparable vegetation types, particularly where this involves an initial 'eyeballing' across the non-standard vegetation codes used for map annotation.

### *3.3. Site data in relation to map unit interpretation.*

Amongst the information sources, some site-based information such as floristic data collected from quadrats or relevès was analysed and classified into groups of likely co-occurrence but not spatially interpreted as geographically mapped vegetation units. For other sources site-based data was collected to inform the interpretation of spatially defined map units and their attributes. In particular cases sources produced vegetation maps that included the locations of such sites but did not give site descriptions, or only mentioned them generally in the document text. Without accurate site locations and associated species lists it is difficult to verify map unit interpretation and for the data to be used to inform future surveys and analyses.

### *3.4. Summary of source reports with vegetation information interpreted as mapped units*

Summaries of surveys and vegetation information from these reports are given below in chronological order. These vary greatly in the survey methods, classification system and Purpose of survey. Surveys for existing rural subdivisions associated with the Marine Fields stage 1, 2, 3 & 4 and Hill R Heights developments could not be located.

**Beard 1979a, 1979b (refid 021 & refid 071)**

Regional vegetation maps at the scale of 1:250,000 were compiled by John Beard in the late 1970s. These maps were digitised as Beard vegetation associations (BVA) in the 1990s. Later these BVAs were intersected with Beard's Systems and systems associations (BSA) and described according to level 6 in the NVIS hierarchy. Descriptions for the relevant BVA and BSA in the two shires are given in Appendix F. The BSA descriptions are not simply linked to the spatial layer, there are sometimes

many descriptions for one polygon and several polygons in different systems can have the same 'general' description. There are 41 BVA and 58 BSA in the two shires. The vegetation statistics for the Shires of Dandaragan and Gingin can be extracted from the State-wide Vegetation Statistics (Government of Western Australia, 2013) https://www2.landgate.wa.gov.au/web/guest/downloader and include the proportions of the BSAs remaining overall as well as in reserves. In the course of this study errors in the digital linework, attribute tables and questionable mapping were revealed.

**(Crook et al. 1982) (refid 071)**

The vegetation maps for this source were prepared as part of management plans for reserves in the southern part of the Dandaragan Shire: Reserves 23934, 25254 (Jam Hill), 26248 (Wongonderrah), 27216, 27219 (Minyulo), 27394 (Eneminga), 27993, 28558 (Namming) and 37695 (Wanagarren). Wanagarren NR is the only nature reserve in the current study area which was reported on by Crook *et al.* (1982), and for which vegetation units were mapped. Although somewhat schematic, the Wanagarren map exemplifies a clear and unambiguous attribution of delineated map units with described vegetation associations. Vegetation descriptions also follow a consistent structural nomenclature using the Muir (1977) structural classification system enabling interpretation according to the NVIS hierarchy. The map has the potential to be refined using the soil subsystems (McArthur and Bettenay, 1960; Schoknecht et al., 2004). For example, although the reserve is entirely in the Quindalup System, the unit, 'coastal variable heaths' could be resolved to distinguish the soil subsystems Qu_4 (Fore dune complex adjacent to the coast and beach, with parabolic dunes and trailing arms of various ages) and Qu_8 (Calcareous dunes overlying Tamala limestone complex, calcareous dunes dominant). Subsystem Qu_4 also occurs in north-south bands, visible on orthophoto maps and interspersed throughout Qu_13 (Limestone outcrop; shallow calcareous sands and remnants of parabolic dunes, limestone dominant). These subsystem patterns were not reflected in the vegetation map of Crook et al.

**refid 013 (Burbidge and Boscacci, 1989)**

This survey of the southern Beekeepers NR was carried out between 23rd and 28th of August 1985 and gathered information relevant to an assessment of the conservation value of the Reserve and recommendations for appropriate vesting. The survey, which focussed on fauna habitat, produced a vegetation map limited to seven units representing formations determined subjectively to correspond with marked changes in vegetation structure and/or floristic composition. Three of these formations are described only by structural names on the map legend. Two units, 'Tuart Woodland' and 'Low Woodland of Banksia spp.' indicate some dominant floristic component in the map unit label. The other units are essentially geomorphic: 'Foredunes' and 'Mobile Dunes' with a group of several unlabelled polygons assumed to be wetland features associated with that labelled 'Dingo Swamp' on the map. This map is not as detailed as the more recent overlaying mapping of (Grey, 2005) (see refid 073 below). Vegetation descriptions for the five trap line sites were provided with their locations indicated on the map. At each trap line, vegetation was classified and described according to Muir's (1977) system of nomenclature and coding. In addition to these trap line sites, four 10m x 10m quadrats on the southern boundary of the reserve were scored for vascular species presence; however the vegetation was not described as for the trap sites. Exact locations or species lists for these quadrats were not provided in the source document.

As the vegetation units were essentially described through structural formation labels, they can only be interpreted to NVIS level 2. The trap site vegetation descriptions in Appendix 1 can be interpreted to NVIS level 5 or 6, however as these descriptions could not be related to the mapped units, interpretation was not carried out. No information was available from the quadrat sites to interpret.

Although not explicitly mapped, the occurrence of *Eucalyptus rudis* fringing the Hill River was indicated in the fauna descriptions from the source report. *Eucalyptus gomphocephala* was also documented but unmapped and together with the occurrence of *E. decipiens* is near its northern limit of distribution.

**Refid 083 (Thomas, J.F., McArthur,W.M. and G.A.Bartle, 1990)**

This Report to the Department of Defence was commissioned by the Australian Army to examine the environmental impacts of Defence land use activities in the Defence Training Area (DTA) between Wedge Point and Lancelin, and inform on management implications for the DTA. Some vegetation descriptions were included in the of the soil unit attributes.

The survey examines defence force training activity impacts on coastal dune geomorphology and vegetation. This includes impact of vehicular activity on dune stability, erosion and potential for pathogen dispersal. This information may be regionally useful for assessing, planning and managing the environmental impact of civil works and development impacts for other areas within the IOD project area having similar landforms and vegetation.

Survey field work was conducted in the DTA between August and October 1989. Landform-Soil-Vegetation complexes were mapped to provide a basis for management planning. The Report documents and summarises evidence of environmental impact on the area from military as well as other uses. Observations of army exercises provided the basis for recommendations for future management. Detailed vegetation surveys involving specimen collection from transects or quadrats were not undertaken. The fauna information including, species lists for the DTA, were summarised from sources such as WA Museum records. No specific fauna surveys were undertaken.

Vegetation mapping exists as a component of the Landform –Soil-Vegetation Complexes. These complexes have been delineated on a 1:50 000 scale topographic base compiled by the Department of Land Administration (DOLA) with the complexes described in the map legend. Although the base map was an output of DOLA, the complex unit map was produced for Defence operations distribution only and not available in digital form. For the IOD project, given the extent of line work, the relevant sections of the source map have been scanned and rectified but not digitised as a GIS vector data layer. The Landform-Soil-Vegetation-Complex descriptions include a vegetation component describing the dominant shrub stratum structure and dominant species. Where an upper stratum is included this is usually described structurally indicating dominant species over a floristically undefined shrub layer. Descriptions are generally interpretable to NVIS level 5; however these are problematic in cases where a non-dominant upper stratum is described structurally and floristically to NVIS Level 5 over a dominant shrub stratum defined only by structure, and thus limited to an NVIS level 2 interpretation.

Although the report is one of the older sources examined and vegetation descriptions are of a general nature, the mapped complexes are of value in that they:

1. Fill a significant spatial information gap in the project area between Wanagarren and Nilgen Nature Reserves.

2. Provide a regional context for the narrow road alignment corridor vegetation mapping of Baimbridge (in, Halpern Glick and Maunsell, 2000: refid 086 and 084) which passes through the DTA. (For refid 086, its authors indicated that to some degree information from the DTA report of Thomas et al (1990) was used to assist in documenting the communities present within the survey area. Further, reference is also made to sources of biological data relevant to the area that could not be utilised, this included a survey of the DTA by (Ecologia, 1998) which could not be obtained before the report by Halpern Glick and Maunsell, (2000) could be finalised.

**refid 041 (Trudgen, 1996)**

This document was originally produced for inclusion in a report by ATA Environmental (2000) (refid 062). Trudgen's vegetation map and report of the area between Hill River and Jurien, is very detailed and largely follows the complex geomorphological features of the region, particularly in the area of variously aged dunes and interdunal plains. This congruence is evident from an overlay of the geomorphological map units presented in (Eliot *et al*. 2012) (refid 075) and orthophoto imagery in the GIS data frame. Trudgen's recognition of the geomorphic units in his vegetation unit descriptions also highlights the relationship.

The boundary between the Quindalup and Spearwood soils fringed by lower slopes, with siliceous sand surface agrees with Beard and the geomorphic map units presented in Eliot *et al.* (2012).

Trudgen (1996) mentions the location of 54 vegetation 'stands' as examples of the vegetation units however the geographic coordinates and descriptions for these stands are not included in the source document and numerical analysis was not carried out on them. Because of this, the validity of the map units cannot be checked and further use of the stand data is not possible.

The report does not indicate what, if any vegetation classification system was used in relation to the descriptive terminology employed; although there appear to be similarities to terms associated with several existing structural vegetation classifications (Aplin, 1979; Keighery, 1994; e.g. Muir, 1977). The informal term 'High' is consistently used – presumably in place of 'Tall' (as used in other standard classifications) as the logical counter point to 'Low' (the term usually opposite to 'Tall' in other classifications). It is also not clear as to what the structural descriptors 'Scrub' and 'Open Scrub' refer. Although these terms are used by Muir (1977) his classification terminology is not consistently used throughout Trudgen's descriptions. Despite this, the key floristic and structural parameters documented are such that the vegetation descriptions can be somewhat subjectively interpreted to NVIS Level 6.

Overall, nineteen units have been mapped and geomorphically grouped by Trudgen: Quindalup Dunes (with 15 units), Spearwood Dunes (two units) and Hill River (two units). Each unit is associated

with one or more vegetation descriptions as follows: unit A=6 descriptions; B=4; C=10; D=4; E= (no descriptions); F=3; G=1; H=1; I=6; J=5; K=1; L=(no descriptions); M=(no descriptions); N=(no descriptions); O=3; P=1; Q=(no descriptions); R=6; S=2; total descriptions = 53. In many cases vegetation units therefore represent a 'mosaic' in relation to the attributed vegetation descriptions, where the proportion and distribution of mosaic elements are not spatially defined.

Trudgen's vegetation map has been reproduced in the report by ATA Environmental (2000) (refid 062) where units have been identified by colour rendering rather than annotated codes. Map unit rendering is correlated with abbreviated vegetation descriptions in the map legend for refid 062. These descriptions represent the dominant stratum component for those of Trudgen's; comparison of both maps shows a few differences between them in interpretation. Polygons comprising map units labelled as 'N' ('Older Dune?') by Trudgen in refid 041 appear to be rendered by ATA in refid 062 as equivalent to Trudgen's unit 'O' ('Q3 [Some Q4?] Dunes That Appear to Have Been Partially Destabilised'); Orthophotography for these areas show what appears to be regeneration after disturbance or partial clearing. Trudgen's map Unit 'B' is associated with one additional vegetation association according to refid 062, which is not described in refid 041: 'high open *Conostylis sp., Opercularia spermacocea* (coastal form) open herbland to herbland'. For Map unit 'C' the associations described by Trudgen in refid 041 as i) '*Melaleuca cardiophylla, Acacia rostellifera (*to *Acacia rostellifera/Melaleuca cardiophylla*) high shrubland to open scrub over *Acanthocarpus preissii, Rhagodia baccata* low open shrubland to open shrubland over *Austrostipa sp. A* open grassland' and ii) '*Melaleuca cardiophylla, Acacia rostellifera* (to *Acacia rostellifera, Melaleuca cardiophylla)* high shrubland to open scrub over *Melaleuca acerosa* open shrubland over *Acanthocarpus* preissii low open shrubland to low shrubland over *Conostylis sp., Austrostipa sp. A, Stipa* (small perennial) herbland/grassland' are both summarised as the same vegetation association in refid 062 despite the difference in lower strata.

A map unit polygon (feature 041_049_64 in the GIS spatial layer: 041_049), in the vicinity of the Hill River mouth was undefined by Trudgen but rendered by ATA as equivalent to unit 'O' in Trudgen's schema. However orthophoto coverage indicates this area has more similarity to adjacent areas coded and rendered as 'P: Sedgelands at the Mouth of Hill River'. This polygon (feature 041_049_64 ) coincides with a wetland identified as '45' and described by (ATA Environmental, 2001) (refid 016) as one of six wetlands adjacent to the Hill River Estuary and supporting a dense stand of *Juncus pallidus* with some *Halosarcia halocnemoides.* (See discussion relating to refid 016 below and the GIS spatial layer 016_004). It is recommend in the report by ATA Environmental (2001) that wetland '45' be protected in an extension of existing reserves. Also of note is Trudgen's mapped vegetation unit 'F: Seasonal Wetlands' which is comprised of one polygon corresponding with wetland '62' identified and assessed by ATA Environmental (2001) as a wetland of good condition outside of reserves.

Vegetation mapping carried out by Trudgen (1996) was stated by Grey (2005) (refid 073) and Coffey Environments (2011) (refid 033), as informing their respective work. These more recent sources share a similar system of vegetation coding and an attempt was made to interpret Trudgen's vegetation descriptions according to these codes to facilitate an initial comparative 'eyeballing' of all three information sources. However the vegetation codes from refid 073 and refid 033 often did not indicate dominant species characterising the vegetation type or describe the lower strata which

made summarising difficult; the absence of such floristic and structural parameters limited comparison of the vegetation units between the respective sources to a lower level in the NVIS hierarchy than that achievable with Trudgen's descriptions alone.

**refid 061 (V & C Semenuik Research group, 1994)**

This broad scale survey of wetland suites included several in the core study area: I Hill River Estuary, III Jurien, IV Cervantes, V Thetis and VI Leeman (north of Jurien); XX Hill River and XII Mimegarra (east of Jurien); and the western end of XVI Nambung where the river descends underground, (**Error! Reference source not found.**). Descriptions of geomorphology, stratigraphy, water quality nd levels, wetland types and vegetation are given for multiple sites within each suite and are presented in the report by (V & C Semenuik Research group, 1994)(refid 061, Tables 1 and 2). Vegetation descriptions are simple and have not been translated into NVIS.

**refid 007 (Ecologia, 1997)**

This survey along the IOD between Cervantes and Jurien in September 1996, describes thirteen vegetation associations. The map delineates ten named vegetation map units and also shows the location of thirty flora survey sites. The vegetation information is supplemented by good descriptions of geology, hydrology, geomorphology, soils, wetlands, vegetation condition and fauna.

The ten vegetation map unit names are not the same as those used for the thirteen described vegetation associations. However with several exceptions the map units can be related to the vegetation associations. The map unit rendered as 'Coastal Scrub *Acacia cyclops* over *Melaleuca spp.*' has been shaded and annotated on the map where disturbed. These map unit variants correlate with the described Associations: '6', 'Coastal scrub on dunes' and '7', 'Coastal scrub disturbed'. Vegetation Associations: '9', '*Melaleuca hamulosa* low scrub' and '10', '*Melaleuca cardiophylla* thicket' are not directly correlated as rendered map units in the source vegetation map or map legend. These two associations are described as occupying the ridges (Association 9) and higher ground (Association 10) "surrounding the playa lake". This playa lake is not identified as such on the source map but is presumably the wetland feature annotated as 'Dingo Swamp' on the map. No other water body is delineated apart from the Hill River Channel.

As the survey was limited to a strip along the IOD road alignment it is difficult to assess the regional significance of the vegetation. For example a small mapped unit may represent a small area within the survey area but may occur extensively outside the road survey corridor; conversely a regionally uncommon vegetation unit may happen to be extensively represented within the survey area through its alignment with the road corridor.

No botanist is named in the report and the descriptions of the thirty sites are not included. This mapping correlated well with the boundary between the Quindalup and Spearwood soils north of the Hill River however there were errors through poor recognition of the major soil boundary (Beard, 1979a; Eliot et al., 2012) South of Hill River. East of IOD and south of Hill River the polygon

mapped as 'Coastal scrub Acacia *cyclops* over *Melaleuca* spp.' should be '*Dryandra sessilis* scrub heath' similar to the area north of Hill River and east of IOD. Also an area mapped as grazed looks well vegetated and is mapped as such by Trudgen (1996) (refid 041). As no site data were given or numerical analysis carried out the validity of the communities could not be checked.

The map from Trudgen's report shows locations of the thirty flora sites but no descriptions are included in the document.

**refid 086 (Halpern Glick Mausell, 2000a)** .

This report is summarised in the Public Environmental Review document, (Halpern Glick Mausell, 2000b) (refid 084) and is the subject of comments from the EPA in refid 081 (EPA, 2002). Refid 081 (Halpern Glick and Mausells, 2001) specifically documents the larger scale biological investigations of Wedge and Grey summarised in refid 081, 084 and 086. Michael Braimbridge surveyed the Grey and Wedge areas in spring 1999 and autumn 2000, which are not the best seasons for optimum flowering and species determination. The report documents the methodology and numerical analysis behind the information given in refid 085 and summarised in refid 084. All raw data is included in the report so that analyses may be repeated using other classification methods, as well as enabling the original data to be supplemented or combined with other datasets if necessary. For the Wedge and Grey areas documented in refid 085, vegetation has been mapped at a larger scale and the fourteen vegetation associations described in more detailed than those presented in refid 086 for the smaller scale road corridor assessment. .

The report includes comprehensive descriptions for 119 sites and 19 vegetation communities. Location coordinates (geographic coordinate system AGD 84) and detailed descriptions were given for all sites according to a standard set of categories including: descriptive summary name for vegetation represented; physiographic information such as landform, topography and soil; vegetation condition; a detailed listing of species grouped according to life form, height and cover using NVIS compatible structural classes. Survey sites were comprised of 10m x 10m quadrats within which all vascular flora present were recorded. The Bushland Plant Survey Recording Sheet of Keighery (1994) was used as the primary data collection format. Vegetation condition was also assessed.

Analysis of species cover by sites was undertaken using TWINSPAN to find the relationship between sites and identify diagnostic indicator species for each community.

In an attempt to interpret the vegetation units in a broader context beyond the road corridor, the vegetation map was compared with the soil landscape units (Schoknecht et al., 2004) developed by the Department of Agriculture and Food (DAFWA). There were close correlations in some areas, particularly along the boundary between the Quindalup and Spearwood systems and in relation to dune blow outs. Other boundaries attributed to old and young inland dunes did not correlate with the soil subsystems.

Of note, as discussed under section 4.2, refid 086 identifies a vegetation Unit 'Eucalyptus gomphocephala woodland ('Mi-02a') grouped under 'Wetland/Dampland Vegetation' This unit is represented by a single polygon (project GIS layer feature '084_006_12') within the IOD corridor and is coincident with a geomorphic wetland feature identified as a 'Dampland'. There is a local cluster of these Damplands that includes 'Mi-02a' as well as one occurring within Bashford NR. The Bashford NR Dampland is identified as a claypan Threatened Ecological Community (TEC) (DPaW, Species and Communities Unit) and is also identified by refid 086 as being associated with similar E. gomphocephala woodland as 'Mi-02a'. These woodlands are described as having a very restricted distribution on the coastal plain and of high conservation significance. Report refid 086 and PER refid 084 do not appear to identify any threatened flora or communities associated with the local Dampland cluster.

Report refid 085 mentions a survey report of the Defence Force (DF) Training area being prepared by Ecologia. However Ecologia have only been able to locate records of an unpublished report to the Department of Defence documenting a survey and environmental profile carried out in 1998 for the DTA. This survey examined vegetation through a set of monitoring quadrats but does not appear to have interpreted any mapped units (Ecologia, 1998; Refid 097)

**refid 016 (ATA Environmental, 2001)**

ATA Environmental carried out this wetland survey of an area between Hill River and Jurien in response to EPA recommendations concerning the Turquoise Coast Estate Development. The survey was conducted between the 26$^{th}$ and 27$^{th}$ June 2001 and involved a comprehensive assessment of landforms including depressions, river flats and wetlands, although no numerical analysis of vegetation survey data was carried out. Based on digital contour information, areas of less than 2m Australian Height Datum (AHD) were interpreted as potential wetland sites for investigation. Sixty two sites were surveyed with twenty identified and evaluated as wetlands and mapped at a larger scale (1:10000, A4) than the investigation sites (1:21000, A4). Two of these polygons represented inundated excavations or dams. Data sheets for each of the investigation sites were presented in an Appendix to the report by ATA (2001). Location coordinates were given as site centroids; however the geographic coordinate system (i.e. datum and projection) was not defined. Site data included a vegetation description, an assessment of vegetation condition, surrounding landscape and vegetation, soil type, connection to groundwater as well as wetland status and area. No data sheet was provided for site J62; however, this was described elsewhere in the report as a large wetland identified by Trudgen (1996) as 'Unit F, Seasonal Wetlands: *Gahnia trifida*, *Baumea juncea* closed sedgeland over *Sarcocornia blackiana*, *Sporobolus virginicus* herbland/grassland.' Trudgen's unit 'F' is represented by the polygon feature '041_049_2' in the project GIS spatial layer '041_049'. The report recommended adjusting boundaries of the coastal reserve (Crown Reserve 19206, Victoria Location 12008) to include coastal wetlands and a buffer of 50m. These recommendations included identifying all possible wetlands within the Turquoise Coast estate development and a recommendation for protection (Table 10).

**Table 10 Recommended Protection of Wetlands on the Turquoise Coast Development Site***

| Wetland No. | Geomorphic unit | Reservation status | Vegetation Condition | Recommendation |
|---|---|---|---|---|
| J3 | Quindalup Dunes | In proposed Foreshore Reserve (FR) | Very good | Protected |
| J8 | Beach Ridge Plain | Outside of reserves | Poor | Not protected |
| J9 | Beach Ridge Plain | Outside of reserves | Poor | Not protected |
| J24 | Beach Ridge Plain | Outside of reserves | Poor | Not protected |
| J27 | Quindalup Dunes | Outside of reserves | Very good | Not protected |
| J30 | Beach Ridge Plain | Outside of reserves | Poor | Protected |
| J62 | Beach Ridge Plain | Outside of reserves | Very good | Protected |
| J3 I | Quindalup Dunes | Partly in proposed FR | Very good | Protect in extended FR |
| J32 | Quindalup Dunes | In proposed FR | Very good | Protected |
| J33 | Quindalup Dunes | In proposed FR | Very good | Protected |
| J34 | Quindalup Dunes | In proposed FR | Very good | Protected |
| J38 | Quindalup Dunes | In proposed FR | Very good | Protected |
| J43 | Hill River Estuary | In proposed reserve | Very good | Protected |
| J45 | Hill River Estuary | In proposed reserve | Very good | Protect in extended reserve |
| J47 | Hill River Estuary | In proposed reserve | Very good | Protected |
| J55 | Hill River Estuary | In proposed reserve | Very good | Protected |
| J56 | Hill River Estuary | in proposed reserve | Very good | Protected |
| J57 | Hill River Estuary | In proposed reserve | Very good | Protected |

**refid 016: ATA Environmental, Turquoise coast development Jurien Bay: wetland survey. Unpublished report 2001/92. 2001, Unpublished report prepared for Ardross Estates Pty Ltd. Perth, W.A.*

**refid 073 (Grey, 2005)**

The survey for this report was carried out by Botanist Cassyanna Grey on the 10th and 11th March for ATA Environmental (now Coffey Environmental) over a coastal area referred to as 'Fatfields', south of and adjacent to Hill River and north of Cervantes. Two locations within this area were subsequently resurveyed and mapped in greater detail by Coffey Environmental (2011) (refid 033). Although both reports used similar vegetation coding for the mapped vegetation units, floristic and structural elements were ordered differently. Vegetation descriptions in each case appeared to use the same terminology following a structural classification adapted from Muir (1977) and Aplin (1979). A table defining the class intervals used for vegetation classification by ATA Environmental (2005) and Coffey Environmental (2011) was only provided in the latter report.

Although the survey by Grey was not conducted at the best time of year for vegetation assessment and collection of plant material, ten plant communities comprised of forty six species (including only two weeds) were identified and assigned a condition rating. It should be noted that this condition rating incorrectly interpreted burnt areas as degraded.

Several vegetation communities are described too broadly in relation to stratum structure to be easily interpreted according to NVIS criteria. These criteria require a defining height and cover class interval for each stratum.

Grey indicated that vegetation type delineation from aerial photography was supplemented with plot based floristic sampling from 10x10m quadrats located in representative vegetation types. However no coordinates or map of plot locations were provided; neither were specific plot data or species lists presented and there did not appear to be any numerical analysis of plot data.

Although the vegetation maps appear to be contiguous and share the same vegetation unit and condition codes, some discontinuities in map unit polygons and their attributes were apparent when edge matching the two maps; for example between the units 'TsArMh' and 'TsArMhMC' along the coast and between units 'TOSAr' and 'TSArMhMc' further inland, there is an abrupt boundary at the junction of the two maps. Although 'TsArMh' is annotated on the map, this unit is not linked to any description in the map legend or document text. Similarly the delineated map unit annotated as 'LSMsAIPs' is not linked by this code to any vegetation description in the source map legend or document text. These undescribed codes may be typographic errors or variants of the described codes, 'LSMsLpAl' and 'TSArMhMc', however no such variants are documented by Grey. Conversely there is an apparently superfluous boundary between two polygons sharing the same attributes. (Project GIS layer 033_000, polygons 033_000_2 and 033_000_19)

Grey generally followed the condition assessment protocol of Keighery (1994), however this protocol recommends no assessment be given to vegetation less than five years after fire. For this reason Grey's assessment of the burnt area as 'degraded' is misleading and as it is surrounded by vegetation of excellent condition, is very likely to recover.

The map units generally do not correlate well with the coastal geomorphological units of (Eliot et al., 2012) and do not pick up the significant wetland depression east of the road south of Molah Hill.

The report makes reference to interpreting and extrapolating from the work by Trudgen (1996) (refid 041) in assessing values of the Fatfields area, however this relationship was not discussed further and there does not seem to be an obvious correlation with Trudgen's information.

Photographs and brief descriptions provided of the eleven vegetation map units do not appear to be directly related to any of the listed sites.

**refid 033 (Coffey Environmental, 2011)**

Botanist Clinton Van Den Berg surveyed two small areas (Marine Fields and north Cervantes) between Hill River and Cervantes. This is a very good quality survey but too localised in itself to identify vegetation units of regional significance. Mapped vegetation units are directly related to vegetation types described according to the vegetation structural classes adapted from Muir (1977) and Aplin (1979); a structural classification table is provided. Site descriptions include map grid coordinates (MGA z50), site photographs, a species list as well as information relating to aspect, soil, rock type, vegetation description and condition. The flora list is inadequate due to it being a poor flowering season involving only one survey visit. No numerical analysis was conducted. A table, summarising survey limitations is presented which could be applied as a useful template for assessing and informing future surveys (refid 033 Table 5 p 12).

The map units presented by refid 033 do not correlate well with those comprising the overlapping broader interpretation carried out between Hill River and Cervantes (Grey, 2005) (refid 073) for ATA Environmental or those north of the Hill River interpreted by Trudgen (1996) (#41 Trudgen, 1996) .

Refid 033 mentions that 'Marine Fields Rural/Residential Estate has been the subject of a number of studies extending over a long period' (p4). It is assumed that this refers to the survey by Grey (2005) but it is unclear whether this also refers to previous surveys done for Marine Fields stages 1, 2, and 4 and Hill River Heights. Pages relating to references, conclusions and a disclaimer (pp. 27 – 30) were missing from the source document copy so previous surveys cited were not able to be identified.

*3.5. Summary of reports documenting site based vegetation surveys without interpreted map units.*

**refid 22 (Griffin, 1993),**

This extensive site based survey of vegetation on Quindalup dunes between Perth and Dongara has over 250 of the 545 sites occurring within the core study area. Co-ordinates were supplied by Griffin as a tabulated extract from his personal database. Species cover data was collected from temporary 10m x 10m relevès; however this information was not included in the database extract. Sites were allocated with reference to 1:20,000 colour 1990 aerial photography and classified by Griffin using PATN© analysis (Belbin and Collins 2006). Although the resulting groups were described in terms of structure, dominant and constant species, these descriptions cannot be interpreted according to NVIS as the dominant taxa are listed separately from the structural description and therefore unidentifiable with a particular stratum.

Griffin concludes in his report that "Lake Thetis is saline and highly significant due to the occurrence of stromatolites. Griffin notes that Hill River is as a "perennial fresh water system" and that " South of the present mouth are shallow but well defined old drainage channels containing brackish or even fresh water, suggesting that "these once may have been part of Hill River"; he concludes that "the seasonally free water is undoubtedly an expression of ground water *en route* to the coast." (Griffin, 1993 pg 89). He also discusses at length the formation and composition of dunes in the area.

**(Bennett Environmental Consulting Pty Ltd, 2004, 2006)** (**refid 047 ); (refid 049)**

Both reports document surveys of sites associated with the CSR Jurien Gypsum mining lease M70/1161.

Bennett Environmental Consulting Pty Ltd (2004) refid 047: This report documents an assessment of vegetation surrounding a lake near Sandy Point, north of Jurien Bay, in the Southern Beekeepers Reserve (C 24496). Potential impacts of water drawdown from gypsum mining on vegetation surrounding the lake and lease area were examined. A survey was undertaken on 27th and 28th October 2003 and the dominant vegetation units within the lease area and the immediate surrounds were described and mapped. No delineated study area boundary or scale defined the extent of vegetation types. This resulted in several unclosed features and in some cases vegetation types were defined on the source map by annotation only with no delineation of units. For example, units 'Bp' and 'MhGa' were undelineated in the source map and their extent implied by code annotation only

such that they could not be spatially defined or easily interpreted. Site descriptions representative of vegetation units were generally clearly defined structurally with dominant species identified according to class intervals compatible with NVIS. However map units 'Co' and 'Hal' were not represented by any described site. No geographic coordinate system was stated but is assumed to be MGA 94 zone 50 which appears to give coordinates the correct location except for unit 'MhAr'. As the area surveyed was relatively small (682 ha) with vegetation units ambiguously defined, spatial interpretation of the vegetation descriptions according to NVIS was not pursued. In addition, the gypsiferous, saline nature of the focal wetland feature is uncharacteristic of those occurring within most of the study area. However Information concerning responses to hydrological changes may have application to similar vegetation types occurring in other parts of the IOD study area.

Bennett Environmental Consulting Pty Ltd (2006) refid 049: The report examines lakeside vegetation communities, selected to provide a comparative regional context for areas around a lake impacted by the gypsum mine expansion proposal. The field survey was conducted during October and November 2005. Thirty one quadrat sites (3 permanently marked) were sampled from vegetation associated with nine of twelve lakes nominated for assessment. Quadrat site descriptions covering physiographic and vegetation parameters are summarised according to site numbers in the report document with location coordinates given as GPS coordinates. Although the coordinate system was not stated it was assumed to be either WGS 84 or GDA 94 datum with MGA 94 zone 50 grid coordinates. Vegetation parameters assessed included: condition using the classification of Keighery (1994), weed rating, and vegetation height and cover percentage for all species as well as dominants encountered in the quadrat. Although the characteristics of the vegetation units varied considerably amongst the lakes a classification analysis of site data indicated there were 5 major categories:

1. Casuarina obesa Woodlands

2. Melaleuca taxa Shrublands

3. Halosarcia taxa Low Shrublands

4. Other taxa Shrublands

5. Sedgelands

Most of Bennett's discussion relates to interpretation of information relevant to Lake 'CSR01' as the subject of gypsum mining proposals. Condition of vegetation in the three permanent quadrats associated with this lake was considered very good to excellent. This was considered unlikely to be compromised with the proviso that regulatory guidelines were adhered to and monitoring maintained at the quadrat sites. It was noted that vehicular activity on and around some of the other lakes examined had resulted in some degradation and for one wetland (CSR 11) in particular, death of *Casuarina obesa*.

**refid 076 (Keighery et al., 2003)**

The most western three sites of a survey of ten sites along Sappers and Cowall road verges, which link Nilgen Reserve and Moore River are included in the core study area. This survey was carried out using methods outlined in (Keighery, 1994). Each site has a vegetation description which often names two or more strata against a suite of species so cannot be directly interpreted according to NVIS level 6 descriptions. There is also a detailed species list given for each stratum but does not identify the dominant species required for the NVIS level 6 sub association description.

### *3.6. Comparison with Beard's mapping*

Generally Beard's mapping is too broad to explicitly relate to the other finer scale vegetation data sources examined for this project. However, vegetation boundaries of Beard's that correspond to the Quindalup and Spearwood systems show consistency with maps from other sources reflecting soil related units such as that of the Defence Training Area by Thomas et al (1990) (refid 083) and data sources interpreting geomorphological parameters . This congruency with Beard's boundaries through physiographic relationships is also reflected in some of the vegetation units interpreted by Trudgen (1996) (refid 041) and Ecologia (1997) (refid 007).

Coastal vegetation is mapped by Beard in the north (Hill River map sheet) as a mosaic comprised of: i) Shrublands; *Acacia rostellifera* and *Melaleuca cardiophylla* thicket and ii) Shrublands; Acacia lasiocarpa and *Melaleuca acerosa* heath (BVA1026). To the south this mosaic adjoins another comprised of i) Shrublands; *Acacia rostellifera* and Acacia cyclops thicket and ii) Acacia lasiocarpa and Melaleuca acerosa heath (BVA1007) which has a very detailed set of NVIS level 6 descriptions (see Appendix B).

According to recent aerial orthophotography, between Cervantes and Jurien, two small areas originally mapped by Beard as sand dune are now vegetated: one in a bow of Hill River and the other to the north-west. A sand dune to the south of Molah Hill currently appears as originally mapped by Beard. In general sand dunes delineated by Beard correlate with those mapped by Crook *et al.* (1982) (refid 071).

West of IOD a polygon located on Quindalup sands in the Guilderton System is identified on Beard's map as 'scrub heath on limestone' and may have been a fire scar at the time of Beards mapping as it is not discernible from recent aerial orthophotographs . This area on the orthophotographic coverage does not appear to be similar to the large area to the east on the Spearwood dunes (Jurien System) and described by Beard as 'Shrublands; scrub-heath Dryandra-Calothamnus association with Banksia prionotes on limestone in the northern Swan Region'; Trudgen (1996) also does not mention any of these species in the vicinity of Beard's 'scrub heath on limestone' polygon.

## 4. Significant vegetation and flora of the study area

### *4.1. Vegetation*

The study area occurs in the most northern extent of Beards Drummond Botanical Sub-district which largely equates with the Swan Coastal Plain IBRA region and comprises the north western part of the Darling Botanical District

The coastal vegetation on the Quindalup dunes forms a gradient of communities from the beach/foredunes, through young to older dunes with pockets of exposed limestone, low woodland and wet depressions. The dunes, many of which are unstable, provide sheltered areas where the vegetation occurs as thickets. The pockets of low limestone identified by Coffey Environmental (2011) refid 033 and Grey (2005) refid 073 are floristically rich and have shallow soils which are generally low in weeds. Medium woodland patches of Tuart (*Eucalyptus gomphocephala*), Flooded Gum (*E. rudis*) and low woodlands of mature *Acacia cyclops* and *A. rostellifera* and *Allocasuarina lehmanniana* are prominent emergents from the shrublands.

Vegetation of the Spearwood Dune system is mainly scrub heath with a high diversity of shrubs of varying heights partly determined by the. Soil depth over limestone

Low Banksia woodlands with mixed understorey is the dominant vegetation of the Bassendean Dune System which is at its northern limit, occurring east of Jurien and in the south east corner of the study area.

Also to the north of the study area and, east of Jurien, is the Gardner Botanic system with a rich mosaic of shrublands often with Hakea and Dryandra species that extend to the Mt Lesueur National Park.

Vegetation condition in the study area is generally very good except in disturbed areas where weed species are prevalent. The coastal vegetation between Hill River and Jurien Bay has not been burnt for many years and now provides very good habitat for birds.

Wetlands and depressions in the project study area have unique individual communities as exemplified by the threatened ecological community of Lake Thetis (see section 4.2 below). Notably, between Geraldton and Bunbury the Hill River is associated with the last remaining tracts of intact riparian vegetation and relatively undisturbed river mouth.

A list and descriptions of Beard Vegetation associations (BVAs) and System Vegetation Associations (BSAs) for the study area is presented in Appendix E Table 1. A summary of small and poorly represented units is listed in Table 2. Further discussion about the poorly represented units is also present in Appendix E of this report.

Of particular note are those units which have limited remaining extent or represent small areas that are poorly conserved. These units include:

- areas of open tuart woodlands (BVA1011) and open tuart and banksia woodlands (BVA1012) along the Moore River,

- a small patch of Tuart woodland north east of Lancelin which falls into refid 086 (Halpern and Glick), and
- riverine rivergum or flooded gum woodlands along Cockleshell Gully and Hill river which may not accurately report all that exists in these narrow corridors.

The most northerly occurrence of BSA 1010.1 (e3,4,Mr) is in the study area where it is not represented in any reserves. However this BSA is in the Bassendean system and may be more common to the south of the study area.

A full set of vegetation statistics for the whole of Dandaragan and Gingin shires is attached as Appendix E. This includes the remaining extent of the system associations and the percentage in reserves (Government of Western Australia, 2011).

- There are 6 BVAs with more than 50% of their remaining regional extent within the core area
    - 1012 (88%), Tuart and banksia, small, and unreserved and regionally significant as a northern occurrence of tuart and banksia woodland. It may actually be similar to other tuart only or banksia woodland only units further south.
    - BVA 129 (84%) Sand dunes which are poorly captured in the remnant vegetation layer and may have expanded or contracted.
    - 1007 (53%), Mixed coastal heath mosaic, similar to 1026 further north
    - 1026- 86%, Similar mixed coastal heath unit to 1007 further south so needs to be considered in conjunction with 1007,
    - 1029 (70%) Jurien scrub-heath. There could be less remaining as polygon in Guilderton System is questionable whether it exists.

- While only about 5% of the remaining vegetation in the core area is within land uses with limited opportunities for vegetation retention/protection, there are some regionally significant BVAs which do not have any portion of their current extent in land uses with good opportunities for vegetation protection/retention:
    - BVA4, Marri and wandoo woodland near Mt Lesueur 22% in reserve and 44% remaining.
    - 37 Teatree or paper bark thicket represent a coastal limit with more existing to the east,
    - 1012 Northern tuart and banksia unit mentioned above.
    - 1031 coastal edge of a much larger inland unit of mixed scrub-heath and heath

- While most are represented to some level in the conservation estate outside core area, BVA 1012 is not and all the remaining extent in the core area is on land zoned General Rural or within road reserves. Clearly this BVA should be a priority for consideration for conservation especially considering that at IBRA level <30% and <17% is protected and 88% of the remaining extent in IBRA is within the core study area. This is spread over several properties along the Gingin Brook Road NE of Guilderton.

- BSAs in the vicinity of the IOD not represented in any DPaW Reserves in the Shires of Gingin or Dandaragan are,
    - 37.4 Tea tree or paperbark thickets ,
    - 949.1, Banksia woodlands in the Jurien System

- 949.2 Banskia woodlands in the Northern Bassendean system (Carnaby's cockatoo food source) ,
- 998 Northern tuart woodland in the Jurien System, small limited extent.
- 1011 Small patch of open tuart woodland in the Jurien System. Should be considered in conjunction with 998,
- 1008 Coastal and riverine (Moore River) marri woodlands. Limited extent remaining,
- 1012 Small area, northern extent near banks of Moore River. Grazed (Beard 1979),
- 1029 Mixed scrub-heath in Guilderton System. Not obvious on orthophotos or mentioned in mapping by Trudgen, may be a fire scar (questionable unit).

For more details see Appendix E attached spread sheet.

### *4.2. Threatened ecological communities*

A significant threatened ecological community (TEC) represented in the project study area is the stromatolite formations of Lake Thetis south east of Cervantes. There is also a cluster of TECs at the southern end of the study area which is shown in detail in Figure 10, Table 11 lists the TECs occurring within or immediately adjacent to the IOD study area. One of these TECs is identified with a claypan occurring within Bashford Nature Reserve (R 39221). This claypan is one several wetland features comprising a local group adjacent Indian Ocean drive identified as 'Damplands' in the DPaW Geomorphic Wetlands spatial data set (DPaW, 2010). The other Dampland features in this local group do not appear to be identified with TECs. However a survey report by Halpern Glick and Maunsell (2000) identifies one of the Dampland features within this local group, together with the Bashford Reserve wetland as significant in being associated with Tuart (*Eucalyptus gomphocephala*) woodland ('occasional woodlands associated with drainage sumps'). These Tuart woodlands are described by Halpern Glick and Maunsell as having a very restricted distribution on the coastal plain and of high conservation significance. From the DPaW TEC records there appear to be a cluster of nine TECs within two kilometres of Indian Ocean Drive and are identified as 'Endangered, Limestone ridges (SCP 26a)' (Table 11) The other six occurrences of these TECs are immediately outside the southern border of the study area.

Conditions relating to the supply of information about threatened species and communities are given in Appendix D. This issue has been discussed in relation to local government biodiversity planning information resource requirements in the Northern Extension Project (PBP, 2010).

**Table 11 Vegetation and status of Threatened Ecological Communities associated with the IOD study area.**

| TEC ID | TEC Name | Status |
|---|---|---|
| Limestone ridges (SCP 26a) | *Melaleuca huegelii* - *Melaleuca acerosa* (currently M. systena) shrublands on limestone ridges (Gibson et al. 1994 type 26a) | Endangered |
| Thetis-microbialite | Stromatolite community of stratified hypersaline coastal lake - Lake Thetis | Vulnerable |
| Claypans with shrubs over herbs | Claypans with mid dense shrublands of *Melaleuca lateritia* over herbs | Priority 1 |
| Coastal Saltmarsh | Subtropical and Temperate Coastal Saltmarsh | Priority 1 |

| TEC ID | TEC Name | Status |
|---|---|---|
| SCP29b | Acacia shrublands on taller dunes | Priority 3 |
| SCP29a | Coastal shrublands on shallow sands | Priority 3 |

### *4.3. Flora*

As the core study area falls within the most northern extent of the Darling botanical district there are several species which are near or at the limits of their distribution as indicated by species distributions derived by querying the DPaW NatureMap website.

For example species at the northern limits of their distribution are:

- Tuart *Eucalyptus gomphocephala* with nine records in the study area near Jurien Bay. (Beard's most northern mapped stand is south east of Wedge in reserve 1978).
- *E. decipiens* with seven records along the study area coast.
- *E. petrensis* just north of Jurien Bay, with three records near Lancelin and additional occurrences around Seabird.
- *E. rudis occurs with* fringing vegetation along the Hill River and according to records queriable on Naturemap has an isolated occurrence north of the core study area.
- *Allocasuarina lehmanniana* (Dune Sheoak) in dunes and winter wet depressions is near its northern limit apart for isolated populations as far north as Kalbarri.

Species occurring in the study area representing the southern limits of their distribution are:

- E*. erythrocorys,* for which a record exists for (Illyarrie) just south of Jurien or 15 km north of Cervantes but none of the survey reports examined for the project recorded this species.
- *Olax aurantia* and *Caladenia crebra* (Arrowsmith Spider Orchid) for which collections by Burbidge and Boscacci (1989) within the study area currently stand as the most southerly occurrence according to records queried from NatureMap as at 15/11/2013).

### *4.4. Rare and threatened plants*

A requirement of all surveys is to ascertain from the DPaW Species and Communities Branch (SCB) what threatened and priority flora (TPFL) species may be in the survey area so a targeted search can be undertaken. Table 12 summarises species lists derived for the core study area from:

- The DPaW Species and Communities Branch
- The WA herbarium database
- Those species mentioned in the relevant surveys examined (denoted in the table by their reference identifier).

For conservation code definitions and details on the conditions concerning the supply of information about particular threatened species by name and location see Appendix D).

Table 12 **Rare and threatened plants mentioned in source survey reports.**

- **CC = conservation Code**
- **RefID = survey source reference.**
- **TPFL* = Threatened and Priority Flora database, Species and Communities Branch.**
- **WAHERB = Western Australian Herbarium records database.**

| Species | Conservation codes | | Sources | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | RefID | | | | DPaW | |
| | CC | WA rank | 7 | 33 | 41 | 86 | TPFL* | WAHerb** |
| Acacia plicata | 3 | | | | | | | y |
| Baeckea sp. Limestone | 1 | | | | | | | y |
| Banksia fraseri var. crebra | 3 | | | | | | | y |
| Banksia dallanneyi subsp. pollosta | 3 | | | | | | y | y |
| Beyeria cinerea subsp. cinerea | 3 | | | | y | | y | y |
| Caladenia speciosa | 4 | | | | | | | y |
| Chamaescilla gibsonii | 3 | | | | | | | y |
| Chorizema varium | T | EN | | | | | y | y |
| Conostylis bracteata | 3 | | | | | | y | y |
| Conostylis pauciflora subsp. euryrhipis | 4 | | | y | | y | y | y |
| Dampiera sp. Jurien (G. Lullfitz s.n. 10/7/1986) | 2 | | | | | | | y |
| Dampiera tephrea | 2 | | | | | | | y |
| Dodonaea hackettiana | 4 | | | | | | y | |
| Eleocharis keigheryi | T | | | | | | y | y |
| Eucalyptus zopherophloia | 4 | | | | | | | y |
| Eucalyptus angularis | 2 | | | | | | y | |
| Eucalyptus argutifolia | T | VU | | | | | y | y |
| Eucalyptus x mundijongensis | 1 | | | | | | y | y |
| Eucalyptus crispata | T | | | | | | | **y** |
| Gratiola pedunculata | 2 | | | | | | y | y |
| Grevillea olivacea | 4 | | | | | | | y |
| Grevillea evanescens | 1 | | | | | | y | y |
| Guichenotia alba | 3 | | | | | | | y |
| Haemodorum loratum | 3 | | | | | | y | y |
| Haloragis foliosa | 3 | | | | | y | | y |
| Hensmania stoniella | 3 | | | y | | | | y |
| Hibbertia spicata subsp. leptotheca | 3 | | | | | y | y | y |
| Isotropis cuneifolia subsp. glabra | 2 | | | | | | y | y |
| Jacksonia anthoclada | 3 | | | | | y | | |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Lepyrodia curvescens | 2 | | | | | | | y |
| Leucopogon sp. Yanchep (M. Hislop 1986) | 3 | | | | | | | y |
| Marianthus paralius | T | CR | | | | | y | y |
| Pimelea calcicola | 3 | | | | | | | y |
| Sarcozona bicarinata | 3 | | | | | | y | y |
| Stenanthemum limitatum | 2 | | | | y | | | |
| Stylidium inversiflorum | 4 | | | | | | | y |
| Stylidium maritimum | 3 | | | y | y | y | y | y |
| Stylidium torticarpum | 3 | | | | | | | y |
| Synaphea lesueurensis | 2 | | | | | | | y |
| Tetratheca pilifera | 3 | | | | | | y | y |
| Thryptomene sp. Lancelin (M.E. Trudgen 14000) | 2 | | | | y | | | y |
| Thysanotus sp. Badgingarra (E.A. Griffin 2511) | 2 | | | | | y | | |
| Trithuria australis | 4 | | | | | | y | |
| Xanthosia tomentosa | 4 | | | | | | | y |

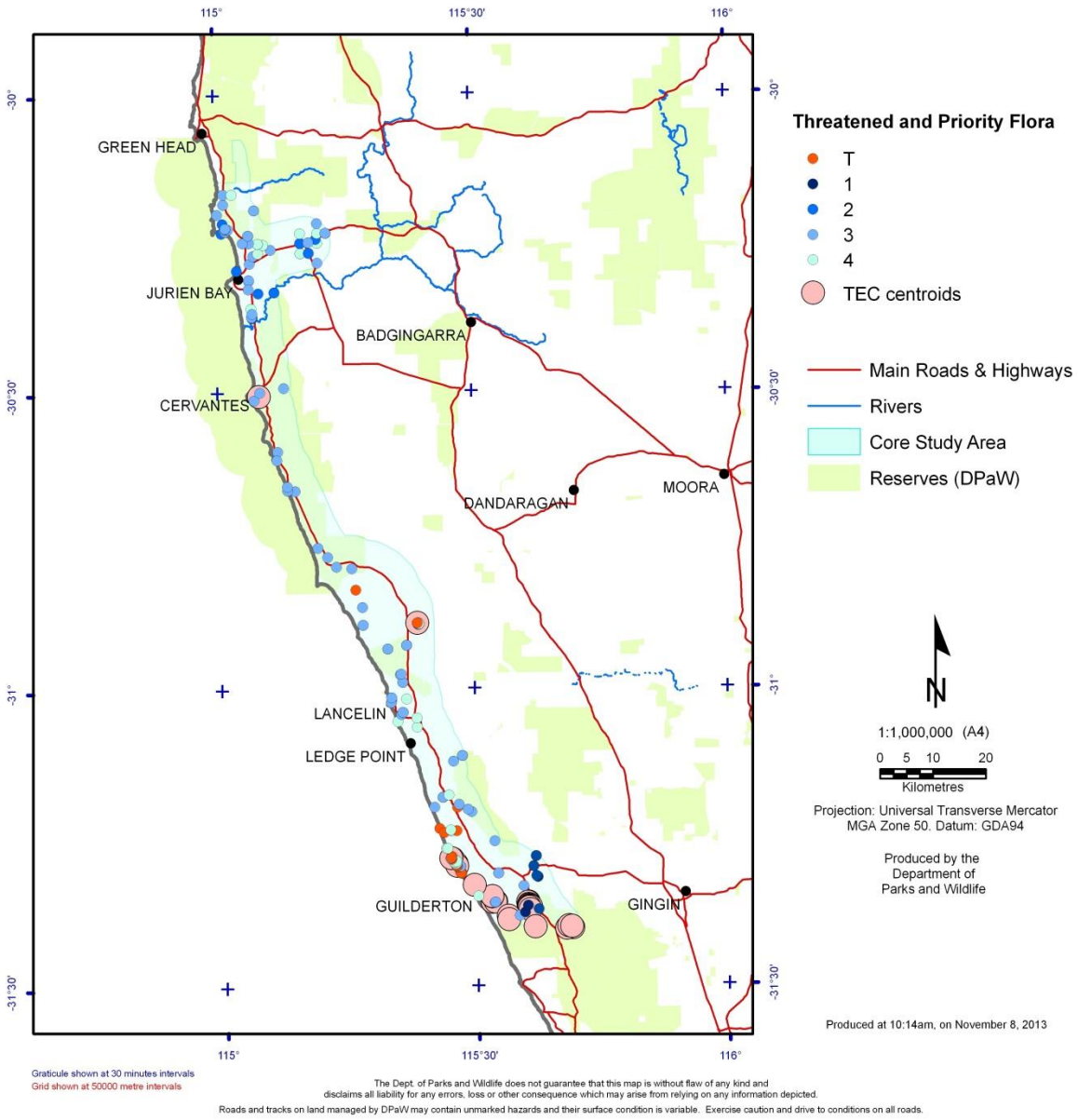
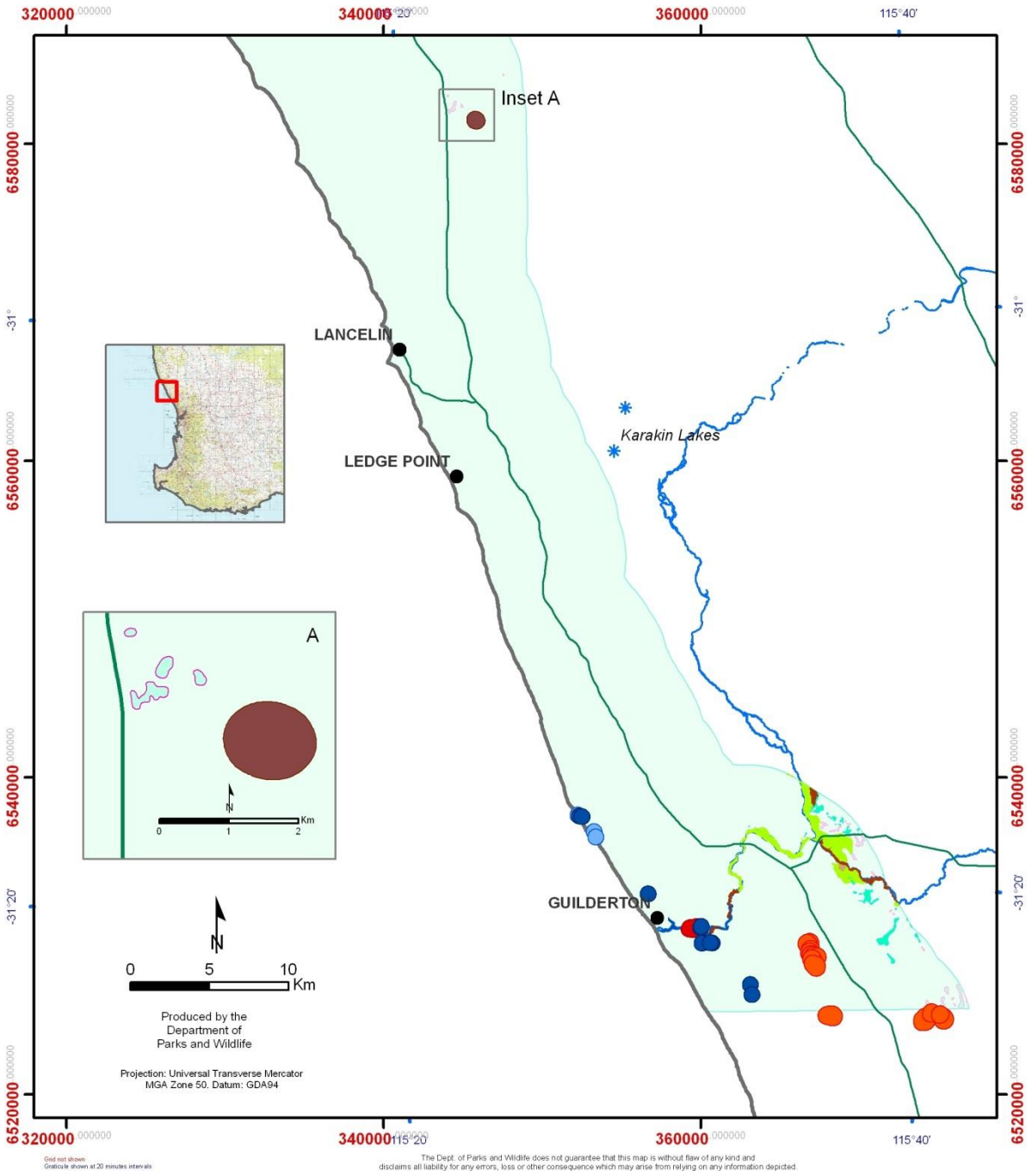



**Figure 9 Location of rare and threatened flora and threatened ecological communities**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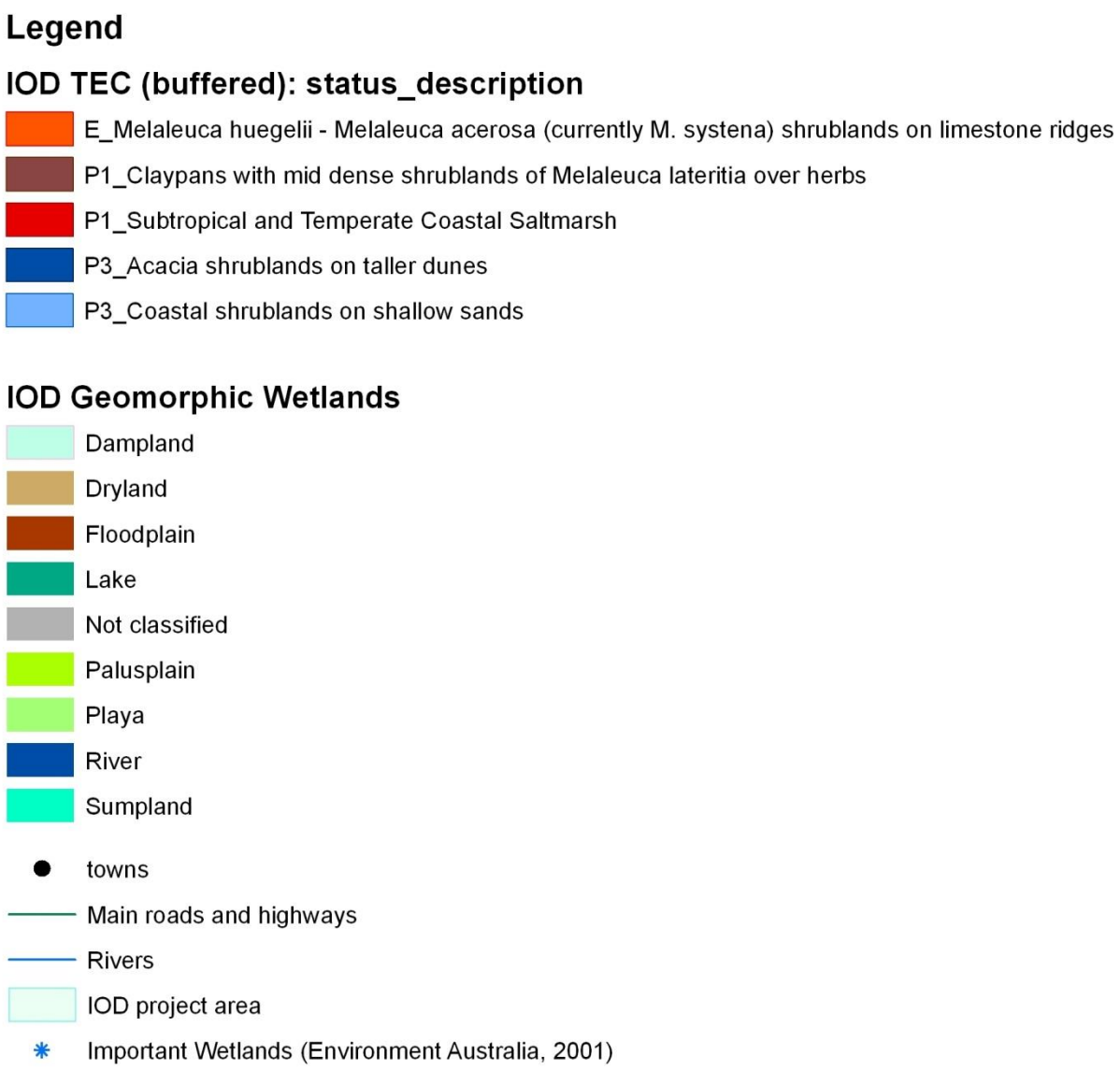



**Figure 10 Status and description of Threatened Ecological Communities in relation to the Geomorphic Wetlands coverage.**

### *4.5. Wetlands*

The wetlands, sumplands and damp depressions in the study area are varied and scattered. The V and C Semeniuk research group (1994) undertook a survey between the Moore and Irwin rivers and nine out of twenty consanguineous (of similar origin) suites of wetlands occur in the study area, (Figure 11). This survey provided a basis for the detailed survey between Hill River and Jurien by ATA Environmental (2001) (refid 016). Of particular significance is the undeveloped mouth and lower reaches of the Hill River (ATA Environmental, 2001; Eliot et al., 2012; Griffin, 1993; V & C Semenuik Research group, 1994). For a summary of recommendations for protection of wetlands by ATA environmental for the 2000ha of coastal land between the existing Jurien Bay town site and Hill River comprising the 'Turquoise Coast' Development site see Table 10 under the previous report summary (refid 016. Immediately west of the intersection of Jurien and Munbinea roads is an area,

identified by Semenuik (1995) as an example of the 'Mimegarra' (12) consanguineous wetland suite, (Figure 11). Semenuik describes this suite as locally significant "in that it contains seasonal freshwater sumplands and damplands in an otherwise water deficient area" and notes that these wetlands are uncommon regionally. This particular occurrence of the Mimegarra Suite is substantially contained within a proposed development land parcel comprised of four freehold lots (see section 5 for a more detailed discussion of this development area.)

Lake Thetis, near Cervantes, is the only wetland cited in the Directory of Important Wetlands in Australia (Environment Australia, 2001), within the project study area. Lake Thetis is also a Threatened Ecological Community (TEC) (DPaW, Species and Communities Branch) (see section 4.2) Karakin lakes are just outside the eastern margin of the study area. No currently listed Ramsar wetlands occur within the project study area.

Bashford NR, approximately 1km east of IOD is identified as a TEC associated with a claypan. The Bashford NR claypan is one of a cluster of geomorphic wetlands identified as 'Damplands' in the Geomorphic Wetlands spatial data layer (DPaW, Swan Coastal Plain – Classification [layer metadata statement], 2013). However although (Halpern Glick Mausell, 2000a) (refid 086) have identified one of these Damplands as being associated with a Tuart (Eucalyptus gomphocephala) woodland of significance (section 3.4) no other threatened flora or communities have been noted for these Damplands.

North of Jurien, Bennett examined a number of wetlands including , a contextual survey of lakeside vegetation (Bennett Environmental Consulting Pty Ltd, 2004, 2006). (refid 049) (Figure 11) and a survey assessing impacts of water drawdown from gypsum mining on vegetation surrounding a salt lake (Bennett Environmental Consulting Pty Ltd, 2004, 2006) (refid 047) (Figure 5) See also report discussions for these sources given in section 3.4.

The Moore River from the junction with Gingin creek runs through the far southern extent of the study area.

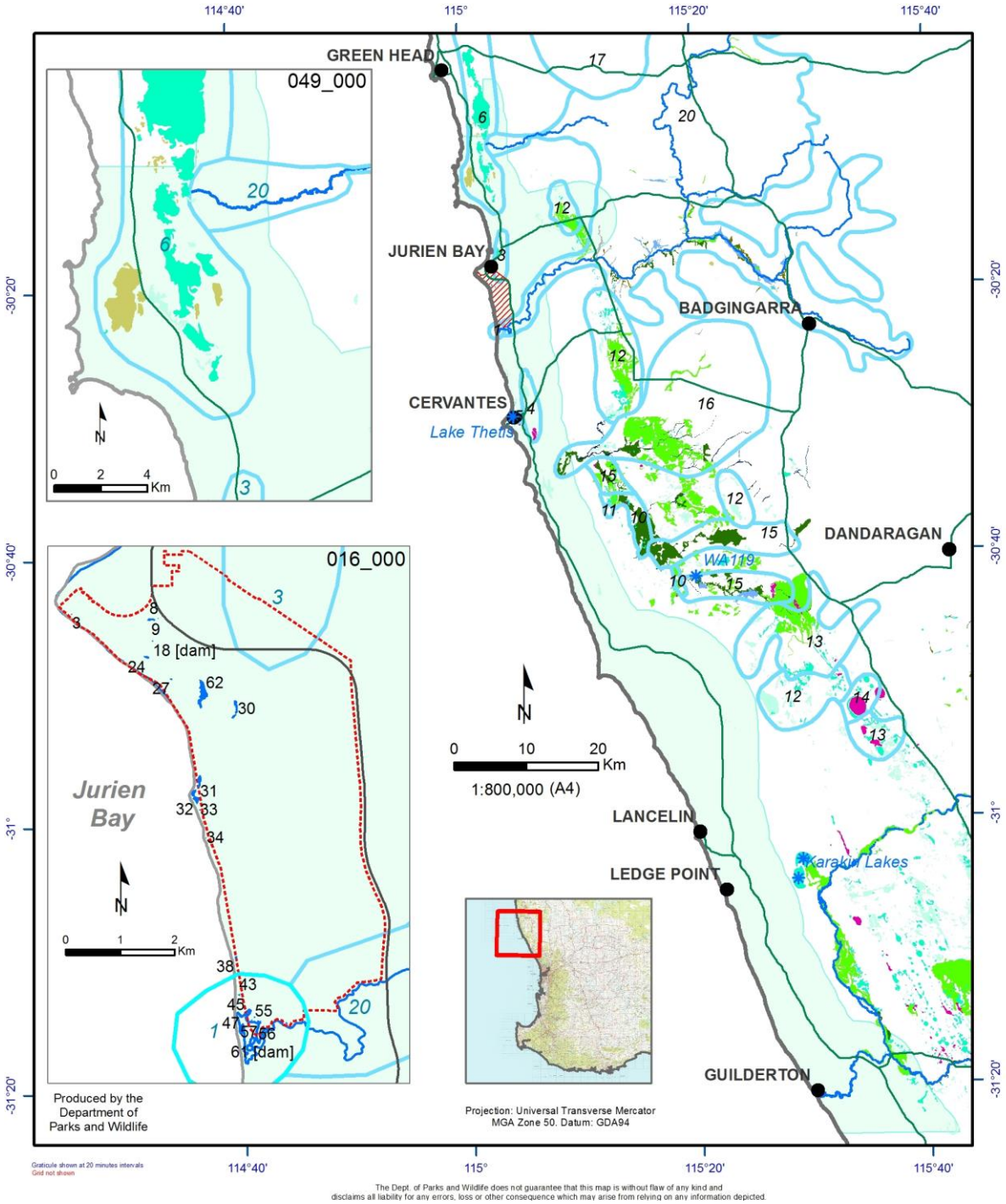
Representation of Geomorphic Wetlands in the study area (Figure 11).

These wetland units represent a dataset interpreted from information relating to the location, boundary, geomorphic classification (wetland type) and, for the Swan Coastal Plain, management category of wetlands in South Western Australia. The geomorphic wetland classification system is based on the characteristics of landform and water permanence defined by Semeniuk and Semeniuk 1994. Most of these wetland units occur to the east of the project study area with incursions associated mainly with the Moore, Nambung and Hill River systems, (Figure 11). At the northern extremity of the study area occur areas defined as 'playas' and 'sumplands' comprising the Leeman (6) consanguineous wetland suite of Semenuik. Immediately east of the town site is the Jurien suite (3) and is the only one associated with the Quindalup Dune System in Semenuik's schema and noted for its local importance as well as "rarity and unusualness of habitat" (Semenuik and Semenuik, 1995, p24). Given its proximity to Jurien, much of the wetland suite appears to be impacted by associated townsite and transport infrastructure and development. In particular, immediately north east of Jurien town site, an area of sumpland identified in the geomorphic wetland spatial data set appears to be subject to considerable track and infrastructure development. According to cadastral

records (State Cadastral Database, 2013) the sumpland largely occurs on land designated as town development lots and road reserve. To the south east of Cervantes several water bodies defined as 'lakes' are identified adjacent to Indian Ocean Drive, Lake Thetis to the west and two to the east of the road. All these wetlands are in nature reserves, the former is a TEC and the latter group in Nambung NP. Also near Cervantes, to the north east, between Indian Ocean Drive and the Cervantes Road, is an area defined as a "Dampland" and includes several lake bodies including one known as 'Dingo Swamp' which is referred to in a report by (Ecologia, 1997) (refid 7) as a 'playa lake'. The Dampland area and associated lake bodies occur largely within the Beekeepers Reserve, however Dingo Swamp appears to be associated with a freehold enclave within the reserve and accompanied by considerable vehicular track disturbance visible from aerial orthophotographic imagery. The wetlands in the vicinity of Cervantes and east of Indian Ocean drive comprise the Cervantes suite (4) defined by Semenuik. Immediately west of the intersection of Jurien and Munbinea roads, occupying an eastern lobe of the study area are occurrences of palusplain and sumplands associated with the Mimegarra Wetland Suite of Semenuik discussed previously in relation to a development land parcel.

It appears that only a small proportion of the project study area is associated with these geomorphic wetlands as defined by the dataset parameters (DEC, 2007). However it is apparent from studies such as those of ATA Environmental (2001) (refid 016) that, with closer examination of relevant landscape elements, wetland features may be revealed at a scale not resolved by regional wetland criteria. The characteristic geomorphology of the coastal dune systems comprising much of the study area would suggest that although there may be little surface area expression of wetlands, there may be much more extensive subsurface hydrological connectivity. For example, water from Nambung River flows directly into the caves at the eastern margin of the limestone and contributes to the karst aquifer. The Nambung River replenishes Warrup and Kinchela Pools and transports relatively fresh water into both the coastal groundwater and surface water systems (Kern 1993 in Semenuik, 1994 p30)

Therefore it is important that any land use proposals within the study area need to consider possible impacts at a scale fine enough to identify wetland features of local significance too small to appear in regional inventories. In addition the impacts on subsurface flows and hydrological connectivity in relation to dependent biota, including vegetation, need to be considered.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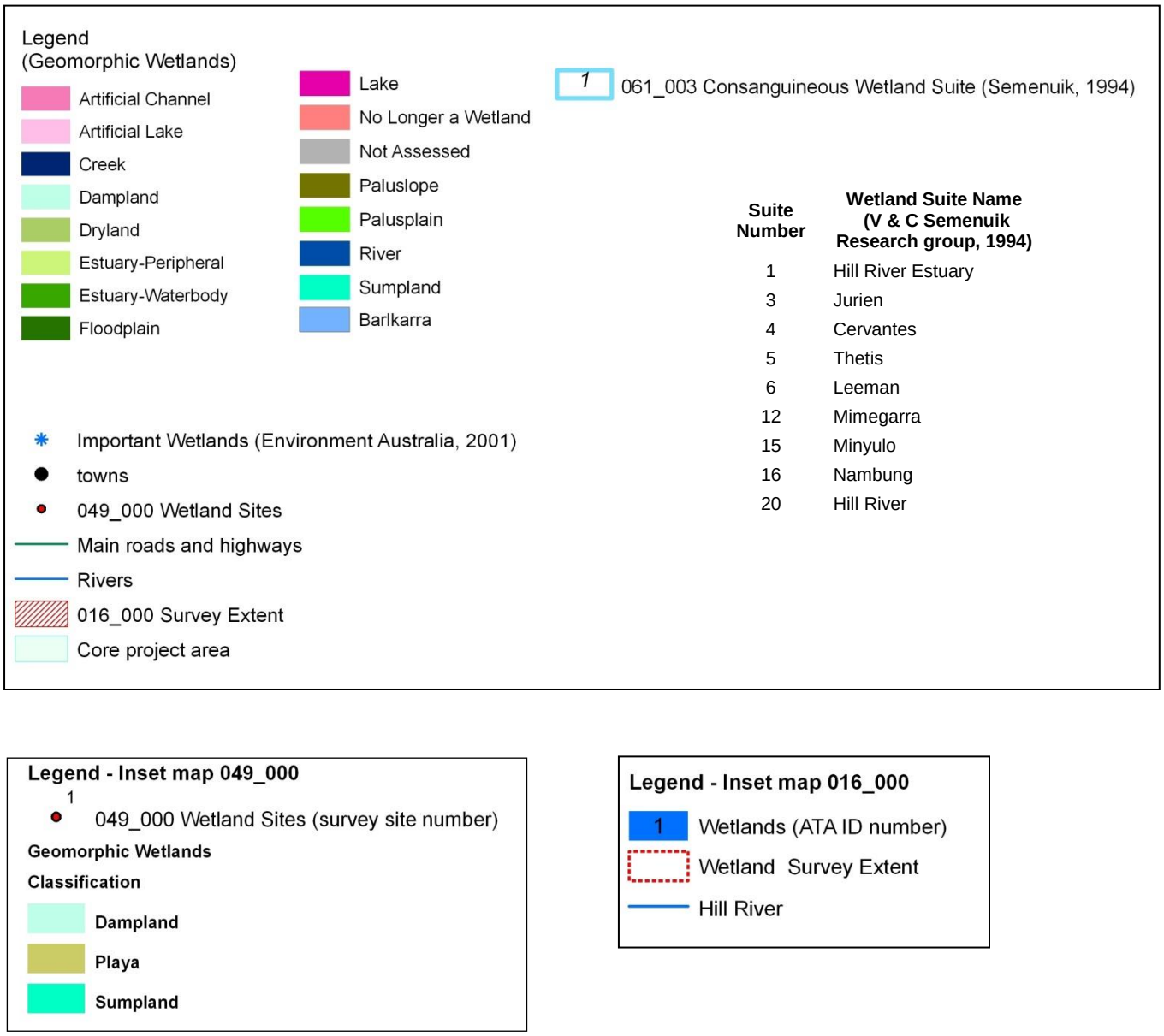


**Figure 11 Location of Wetlands**

### *4.6. Threatened and priority fauna and habitat*

A list and locations of threatened and priority fauna in the study area were obtained from DPaW Species and Communities Branch (Figure 12, Table 13). For details on the conditions in respect to the supply of information concerning locations and species names see Appendix D. The DPaW corporate spatial data base does have general locations of breeding and roosting areas of Carnaby's Cockatoo and shows potential foraging areas within remnant vegetation based on relevant Beard vegetation associations.

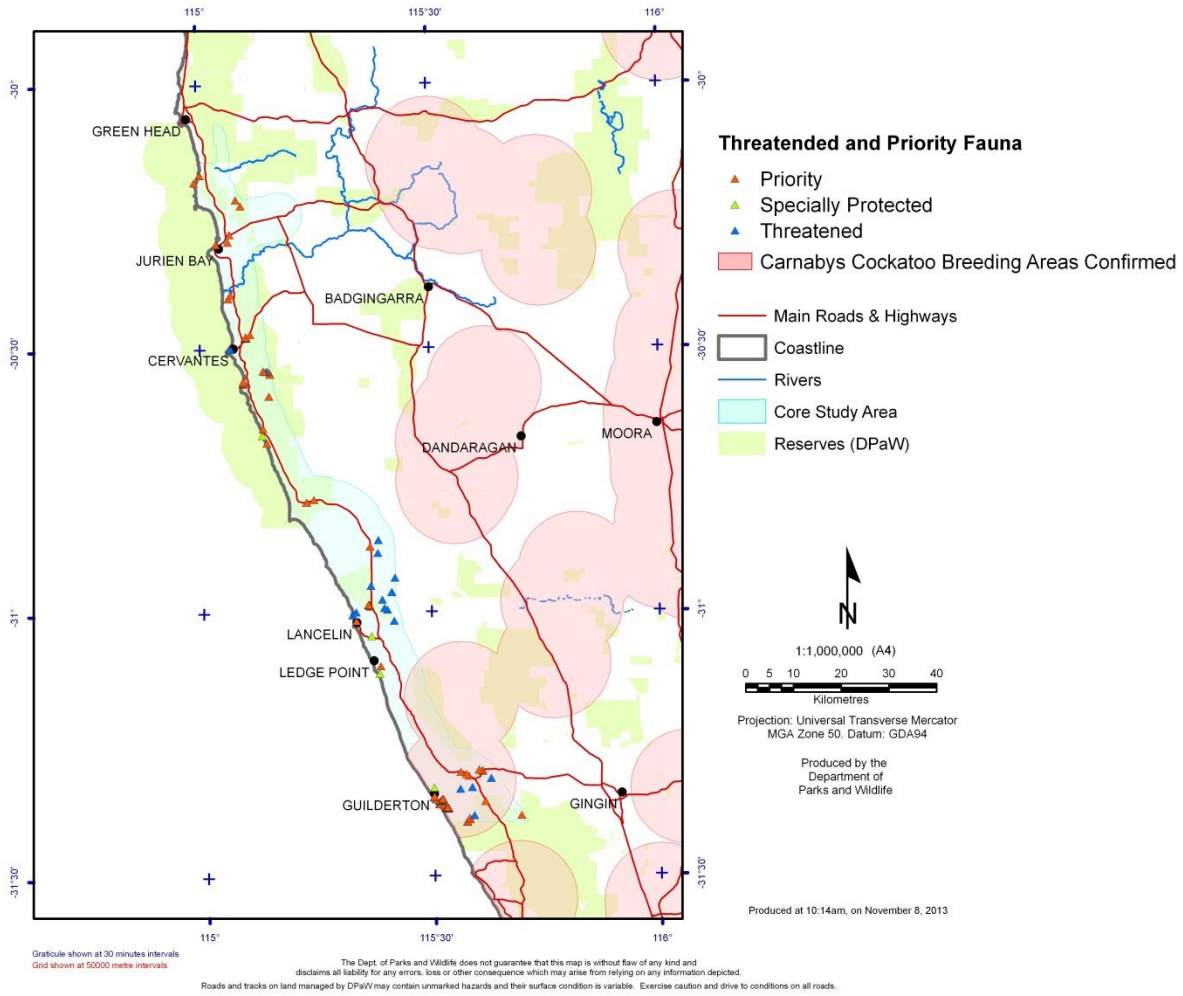


**Figure 12 Threatened and Priority Fauna recorded in the study area and confirmed Carnaby's Cockatoo breeding areas in the general vicinity. (Note: locations are approximate only.)**

**Table 13 Threatened fauna species summarised for the core study area. From records extracted from the DPaW Threatened Fauna Database.** ***See Appendix 6, Conservation Codes definitions for Flora and Fauna***

| NAME | NAME_ID | VERNACULAR | CONSV_CODE | CLASS |
|---|---|---|---|---|
| Bettongia penicillata subsp. ogilbyi | 24162 | Woylie, Brush-tailed Bettong | T | MAMMAL |
| Calidris ferruginea | 24784 | Curlew Sandpiper | T | BIRD |
| Calidris tenuirostris | 24790 | Great Knot | T | BIRD |
| Calyptorhynchus baudinii | 24733 | Baudin's Cockatoo (long-billed black-cockatoo), Baudin's Cockatoo | T | BIRD |
| Calyptorhynchus latirostris | 24734 | Carnaby's Cockatoo (short-billed black-cockatoo), Carnaby's Cockatoo | T | BIRD |
| Charadrius mongolus | 25576 | Lesser Sand Plover | T | BIRD |

| NAME | NAME_ID | VERNACULAR | CONSV_CODE | CLASS |
|---|---|---|---|---|
| Ctenotus lancelini | 25051 | Lancelin Island Ctenotus, Lancelin Island Skink | T | REPTILE |
| Dermochelys coriacea | 25346 | Leatherback Turtle | T | REPTILE |
| Malurus leucopterus subsp. edouardi | 24547 | Barrow Is. White-winged Fairy-wren | T | BIRD |
| Falco peregrinus | 25624 | Peregrine Falcon | S | BIRD |
| Falco peregrinus subsp. macropus | 24475 | Australian Peregrine Falcon | S | BIRD |
| Morelia spilota subsp. imbricata | 25240 | Carpet Python | S | REPTILE |
| Actitis hypoleucos | 41323 | Common Sandpiper | IA | BIRD |
| Anous stolidus | 25634 | Common Noddy | IA | BIRD |
| Apus pacificus | 25554 | Fork-tailed Swift | IA | BIRD |
| Ardea modesta | 41324 | Eastern Great Egret | IA | BIRD |
| Arenaria interpres | 25736 | Ruddy Turnstone | IA | BIRD |
| Calidris acuminata | 24779 | Sharp-tailed Sandpiper | IA | BIRD |
| Calidris alba | 24780 | Sanderling | IA | BIRD |
| Calidris canutus | 25738 | Red Knot | IA | BIRD |
| Calidris melanotos | 24786 | Pectoral Sandpiper | IA | BIRD |
| Calidris ruficollis | 24788 | Red-necked Stint | IA | BIRD |
| Calidris subminuta | 24789 | Long-toed Stint | IA | BIRD |
| Chlidonias leucopterus | 41332 | White-winged Black Tern | IA | BIRD |
| Egretta sacra | 41336 | Eastern Reef Egret, Eastern Reef Heron | IA | BIRD |
| Haliaeetus leucogaster | 24293 | White-bellied Sea-Eagle | IA | BIRD |
| Limosa lapponica | 30932 | Bar-tailed Godwit | IA | BIRD |
| Merops ornatus | 24598 | Rainbow Bee-eater | IA | BIRD |
| Numenius phaeopus | 25742 | Whimbrel | IA | BIRD |
| Onychoprion anaethetus | 41347 | Bridled Tern | IA | BIRD |
| Plegadis falcinellus | 24843 | Glossy Ibis | IA | BIRD |
| Pluvialis fulva | 24382 | Pacific Golden Plover | IA | BIRD |
| Pluvialis squatarola | 24383 | Grey Plover | IA | BIRD |
| Sterna dougallii | 25640 | Roseate Tern | IA | BIRD |
| Tringa brevipes | 24803 | Grey-tailed Tattler | IA | BIRD |
| Tringa glareola | 24806 | Wood Sandpiper | IA | BIRD |
| Tringa nebularia | 24808 | Common Greenshank | IA | BIRD |
| Bothriembryon perobesus | 34057 | land snail | 1 | INVERT |
| Hemisaga vepreculae | 33976 | cricket | 3 | INVERT |
| Neelaps calonotos | 25249 | Black-striped Snake | 3 | REPTILE |
| Ardeotis australis | 24610 | Australian Bustard | 4 | BIRD |

| NAME | NAME_ID | VERNACULAR | CONSV_CODE | CLASS |
|---|---|---|---|---|
| Charadrius rubricollis | 24376 | Hooded Plover | 4 | BIRD |
| Hydromys chrysogaster | 24215 | Water-rat | 4 | MAMMAL |
| Macroderma gigas | 24180 | Ghost Bat | 4 | MAMMAL |
| Macronectes giganteus | 24690 | Southern Giant Petrel | 4 | BIRD |
| Macropus irma | 24133 | Western Brush Wallaby | 4 | MAMMAL |
| Synemon gratiosa | 33992 | Graceful Sunmoth | 4 | INVERT |
| Westralunio carteri | 34113 | Carter's Freshwater Mussel | 4 | INVERT |
| Isoodon obesulus subsp. fusciventer | 24153 | Quenda, Southern Brown Bandicoot | 5 | MAMMAL |
| Macropus eugenii subsp. derbianus | 24131 | Tammar Wallaby (WA subsp) | 5 | MAMMAL |

## 5. Investigation area east of Jurien.

The project study area includes an area east of Jurien along Jurien Road, west of Cockleshell Gully Road and Munbinea Road, to incorporate Lots 1, 500, 10600 and 10601 where potential for land use change has been investigated (Figure 13). This land parcel is associated with an area of relatively complex physiography compared to the adjacent coastal margin of the study area dominated by northern extents of both the Spearwood and Bassendean soil systems.

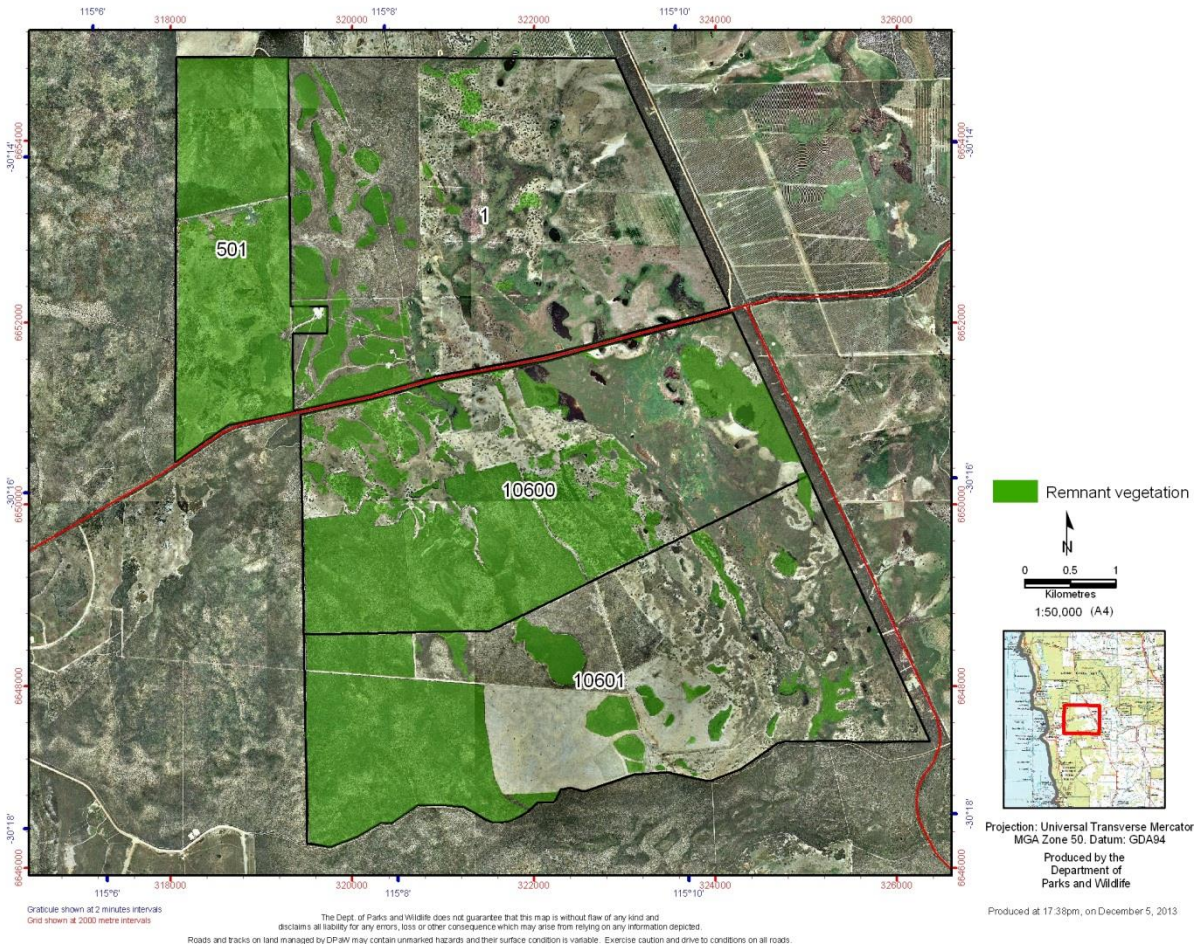


**Figure 13 Overlay of Lots 1, 500, 10600 and 10601 on aerial orthophotography (2010?) showing complexity of land forms and vegetation. Clearing patterns are shown with the remnant vegetation cover highlighted DEC/AGFWA, April 2012)**

Table 14 shows remnant vegetation extent calculated for lots comprising the investigation area. Spatial data is derived from the DPaW version of the AGFWA remnant vegetation layer used for the annual CAR reserve process. (DPaW, April 2012)

**Table 14 Area statistics for land parcel lots and proportion of remnant vegetation cover (as calculated from the DEC version of the AGFWA remnant vegetation layer used for the annual CAR reserve process. April 2012)**

| lot no. | total lot area (ha) | area remveg (ha) | % remveg |
|---|---|---|---|
| 1 | 1429 | 184 | 13 |
| 501 | 529 | 497 | 94 |
| 10600 | 1309 | 702 | 54 |
| 10601 | 1496 | 508 | 34 |
| total | 4763 | 1891 | 40 |

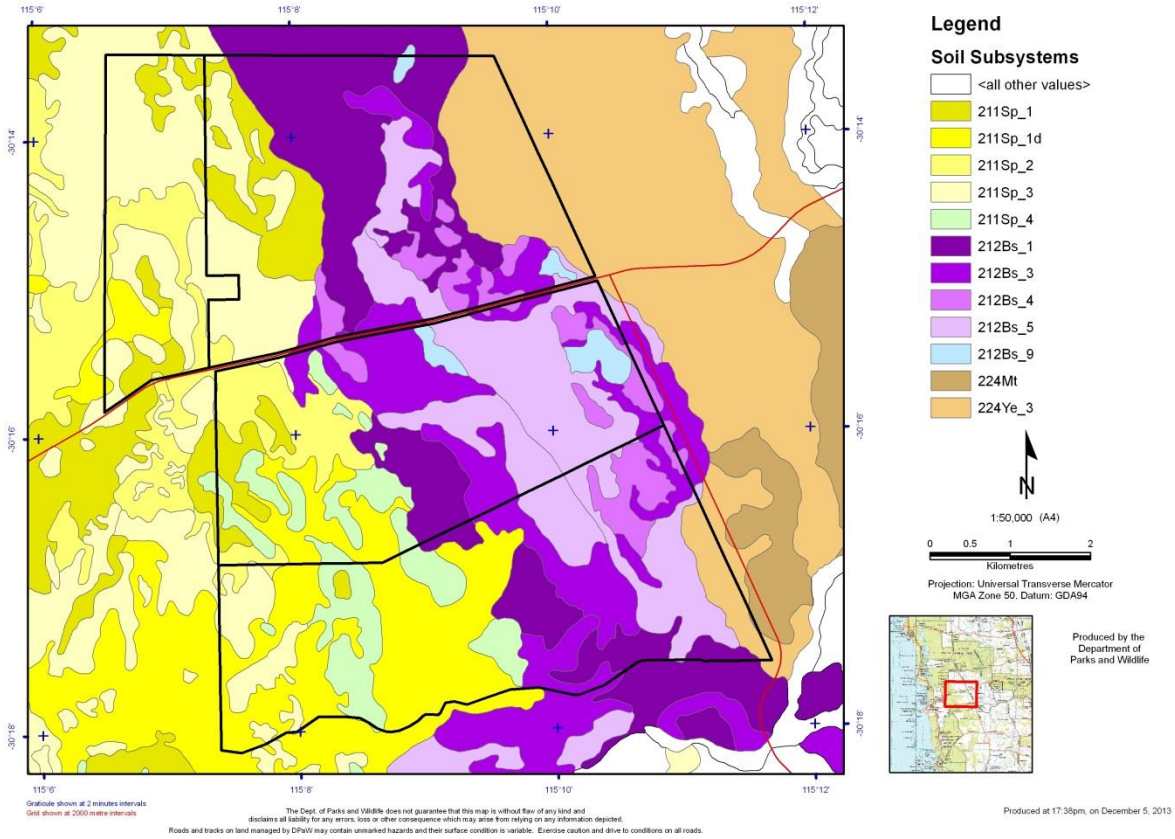


**Figure 14 Soil Landscape sub systems covered by Lots 1, 500, 10600 & 10601**

As shown in Figure 14, the four investigation area lots are associated with a complex soil land system comprised of eleven soil subsystems (Table 15). Five of these subsystems occur within in the Spearwood system and five within the Bassendean system. One in the Yerramulla system encroaches on the eastern edge of the investigation area. Overlay of the remnant vegetation extent indicates that most of the Bassendean and Yerramulla systems have been cleared with uncleared areas predominantly remaining on the Spearwood system.

**Table 15 Soil landscape sub systems for Lots 1, 500, 10600 and 10601**

| Code | System | Subsystem description |
|---|---|---|
| 211Sp_1 | Spearwood 1 Subsystem | Deep yellow sands |
| 211Sp_1d | Spearwood 1 dune Phase | Bleached sands over yellow sands and limestone |
| 211Sp_2 | Spearwood 2 Subsystem | Limestone outcrop/; shallow soils (pockets of deeper sands) |
| 211Sp_3 | Spearwood 3 Subsystem | Complex of deep yellow sands and shallow sands, no limestone outcrop |
| 211Sp_4 | Spearwood 4 Subsystem | Limestone outcrop |
| 212Bs_1 | Bassendean 1 Subsystem | Undulating to flat sandplain and minor swamps; pale to yellow deep sands |
| 212Bs_3 | Bassendean 3 Subsystem | Low dunefields; deep, pale grey or white sands |
| 212Bs_4 | Bassendean 4 Subsystem | Plain, often poorly drained; semi-wet soil, pale shallow sands over pan, sandy duplexes, wet soil |

| Code | System | Subsystem description |
|---|---|---|
| 212Bs_5 | Bassendean 5 Subsystem | Complex pattern of dunes or low sandy rises, poorly drained plains, (Complex of Bs1, Bs4 and Bs6; Bs4 or Bs6 dominant); saline depressions and swamps.. |
| 212Bs_9 | Bassendean 9 Subsystem | Permanent or semi-permanent swamps |
| 224Ye_3 | Yerramullah 3 Subsystem | colluvial slopes and some plateau remnants, very gently to gently inclined hillslopes and sand filled minor valleys; pale and yellow deep sands, pale sandy gravels, shallow gravel over duricrust, some sandy duplexes and sandy earths |

As noted in section 4.5 , the extent of the regionally uncommon Mimegarra wetland suite comprised of dampland and sumplands (Table 16) (#61 V & C Semenuik Research group, 1994) (refid 061) is almost entirely represented within the investigation area. However, most of the area within the land parcel representing the Mimegarra suite appears to have been cleared. However Semenuik states that this suite is locally significant in that it contains seasonal freshwater sumplands and damplands in an otherwise water deficient area. He also emphasises the importance of the associated water bodies as nodes for local biotic diversity.

**Table 16 Semenuik's descriptions of seven sites in the Mimegarra wetland suite**

| Site | Large Scale geomorphology | Small scale stratigraphy | Water quality Water levels | Wetland type | Vegetation |
|---|---|---|---|---|---|
| a) | Bass. | quartz sand (sl. peat)<br>orange/dk. brown ms<br>quartz sand buff ms | W.T.=>-300cm<br>no water | dampland | Maculiform Low scrubland- *Melaleuca rhaphiophylla, K. ericifolia, Acacia. saligna, Acacia* sp. *Heath - Hypocalymma. angustifolium* |
| b) | | grey peat<br>quartz sand | W.T.=>-170cm<br>no water | dampland | Maculiform Scrubland - E. rudis<br>*K. ericifolia, Melaleuca teretifolia*<br>*M. rhaphiophylla*,<br>Heath -*A. saligna* |
| c) | | dk grey humic sand<br>grey quartz sand | W.T.=-48cm<br>pH=7.6<br>TDS=0.47ppt | sumpland | Maculiform Shrubland - *M. rhaphiophylla*<br>Shrubland -*A. saligna* |

| Site | Large Scale geomorphology | Small scale stratigraphy | Water quality Water levels | Wetland type | Vegetation |
|---|---|---|---|---|---|
| d) | | grey humic sand<br>grey quartz sand<br>cream/orange ms | W.T.=-150cm<br>pH=8.9<br>TDS = 4.8ppt | sumpland | Paniform<br>Scrubland - *M. rhaphiophylla* |
| e) | | black peat<br>black peaty sand<br>calcrete | W.T.=+20cm<br>pH=8.6<br>TDS=0. 71ppt | sumpland | Maculiform<br>Scrubland - *M. rhaphiophylla*<br>*Banksia littoralis*, *M. hamulosa*<br>Heath - *M. incana, M. lateritia*<br>*Viminea. juncea, A. saligna*<br>*H. angustifolium, M. hamulosa*<br>Sedgeland - *G. trifida,*<br>*Lepidosperma gladiatum* |
| f) | res.<br>qtz.<br>sand | black humic ms<br>black med. qtz sand<br>grey ms (clay min.)<br>buff quartz sand | W.L.=>+30cm!<br>W.T= -65cm<br>pH=7.2<br>TDS=1.0ppt<br>PO4=2.5ppm | sumpland | Heteroform<br>Open woodland - *Eucalyptus. rudis*<br>Shrubland - *A. saligna*<br>Sedgeland - *Typha. orientalis* |
| g) | res.<br>qtz.<br>sand | black peat<br>grey quartz sand | W.T.=-10cm!<br>pH=6. 3<br>TDS=1.0ppt<br>Po4=6. 0ppm | sumpland | Maculiform<br>Low forest - *E. rudis*<br>Shrubland - *M. huegelii*<br>*M. rhaphiophylla, M. hamulosa*<br>*A. fascicularis*<br>Sedgeland-*G. trifida* |

.

**Table 17 Approximate vegetation cover (%) of investigation area lots east of Jurien**

| Lot No. | Banksia low woodland (%) | Scrub-heath with B. prionotes (%) | Approx Vegetation Cover (%) |
|---|---|---|---|
| 1 | 80 | 20 | 15 |
| 501 | nil | 100 | 90 |

| Lot No. | Banksia low woodland (%) | Scrub-heath with B. prionotes (%) | Approx Vegetation Cover (%) |
|---|---|---|---|
| 10600 | 60 | 40 | 50 |
| 10601 | 30 | 70 | 60 |

As indicated in figure 13 and Table 14 the investigation area is about 60 percent cleared. Most of the cleared area is in the eastern half of the land parcel associated with the Bassendean Soil Subsystems and Low woodlands of *Banksia attenuata* & *B. menziesii* representing Beard's system association 1030.2 (Table 17). Remnant vegetation occupying most of lot 501 and the western sectors of lots 10600 and 1061 is associated with the Spearwood Soil subsystems and Shrublands comprised of scrub-heath with *Banksia prionotes* representing Beard's system association 1029.1. As both these vegetation types represent significant feeding habitat for Carnaby's cockatoo, further clearing of vegetation remnants needs to give consideration to this relationship.

The investigation area needs to be comprehensively surveyed to adequately assess the significance of the vegetation, flora and fauna. Although the remnant vegetation extent spatial data suggests that much of the area has been cleared, the actual extent and viability of native habitat can only be assessed from the ground. For example low vegetation such as sedgeland is not always clearly represented in the remnant vegetation layer.

## 6. Information Gaps and Guidelines

### *6.1. Spatial Data Gaps*

There are two main areas within the project study area for which spatial vegetation data exists as some form of surveyed and interpreted set of map units: 1) between Cervantes and Jurien and 2) the area north and south of Wedge Island represented by Wanagarren Nature Reserve and the Defence Training Area in the Shire of Dandaragan. There is a significant gap in spatial vegetation information for the area between Lancelin and Guilderton for which little data exists or at least has been interpreted as mapped units. Similarly there is a surprising lack of such data for the area encompassed in Nambung National Park between Cervantes and Wanagarren NR; although a survey by Ecologia (1997) (refid 007) has interpreted vegetation units along the Indian Ocean Drive corridor north of Wanagarren N.R. to Hangover Bay. There exist other sources of vegetation survey data that cover the spatial gaps outlined, most notably the extensive survey of the Quindalup dunes by Griffin (1993) (refid 022). However, although such sources represent valuable information about vegetation, plant communities, their, physiographic relationships and vulnerability to land use impacts, these site derived data have not been interpreted as mapped units.

The vegetation maps along the IOD in the Shires of Gingin and Dandaragan are too narrow to ascertain significant or uncommon vegetation types. There are no mapped areas between Guilderton and Jurien in the Shire of Gingin.

It is difficult to assess what is significant vegetation outside the DPaW lands as there are no vegetation maps of Nambung National Park (NP) or Nilgen Nature Reserve and more recent vegetation mapping is required for the Defence Training Area. All the available vegetation maps are attributed in such a variety of ways that it is difficult to comprehensively identify unusual vegetation communities. Relating all these maps to soils landscape mapping and or geomorphology may assist with this process, but would be a complex process.

### *6.2. Gaps in reserves*

Habitat connectivity provided by the continuous corridor of remnant vegetation along the study area coast is not reflected in the reserve system. This is an issue which is pertinent in the context of habitat connectivity, climate change and possible movement of fauna and plant dispersal.

Connectivity of core green belt regions through native vegetation linkages has been identified as important in planning for local biodiversity conservation (PBP, 2010). Such information is important to help recognise opportunities for connectivity of core green belt regions through native vegetation linkages. This connectivity was highlighted as a significant asset of the substantially uncleared species rich western margin of the Avon Arc sub region strategy study area. This habitat rich area of remnant vegetation overlapped the NEP study area in the Gingin Shire PBP (PBP, 2010).

It is important to maintain a continuous corridor of vegetation from Dongara to Lancelin (and preferably further north) and to maintain east-west corridors, for example from Southern Beekeepers NR to the coast as other reserves such as Lesueur NP are not directly linked to the coast.

There are also gaps in the conservation estate between Hill River and Drovers Cave NP. The rezoning of the Defence Training Area into a conservation reserve would represent a significant contribution. Despite there being remnant vegetation in the area, there are only two relatively small Recreation and Conservation Reserves vested in the Shire of Gingin (R21 473 & R17949) along over 50 kms of the coast west of the IOD between conservation Reserve 49994 south of Guilderton and conservation reserve R 31 781 north of Lancelin.

The regional vegetation mapping of Beard does not capture the fine scale mosaic of dune and inter dune vegetation along the coast or the transition from beach to limestone dunes. BVA 1007 and 1026 generalise this patterning (see Appendix E Table 2 for descriptions). Further detailed mapping is required to effectively represent this patterning.

## 6.3. Survey Guidelines

Although vegetation surveys and the vegetation units interpreted from them may be required to inform a variety of specific objectives, they all generally depend on addressing fundamental structural and floristic parameters. For example structure may be considered the critical vegetation parameter to capture for fire management mapping; however species composition is also an important consideration in fire response.

Often sites based surveys such as those carried out by Griffin refid 022, refid 042 are based on full species composition. However without cover information to indicate the dominant species, the vegetation community cannot be adequately described and interpreted in conjunction with other mapping resources.

A range of survey methods are available and it is important to state the methods used for collecting field data (e.g. Keighery 1994).

Vegetation descriptions of mapped units need to state what classification has been used to define structure(height), growth form and cover classes e.g. (Keighery, 1994; Muir, 1977). These descriptions need to be interpretable to NVIS (level 6) as part of a standardisation process that enables ecologically recognisable communities to be summarised. Exploring this standardisation process in relation to the selected information sources indicates that a regionally relevant reclassification is a complex task and beyond the scope and time available for this project.

One of the problems contributing to difficulties with summarising vegetation descriptions is the variation in map unit annotation coding. We propose a code derived with reference to NVIS level 6 for use in map legends. This replaces the scientific name with a commonly used code based on the first three letters of the genera and species names with two extra letters for subspecies.

Mapping of small areas should consider the regional context. For example the small pockets mapped in refid 033 (Coffey Spring Flora and Vegetation Assessment Marine Fields and North Cervantes Study area) is very detailed but the relationship to the surrounding area is not taken into account. Similarly the linear mapping along the IOD corridor does not capture the regional extent of the vegetation units.

Surveys should include permanently marked and georeferenced quadrats. Site species lists and or data sheets should be included as electronic appendices. Survey data should go into a standard database such as TURBOVEG (see Mucina and Daniels 2013) or that of Griffin and Trudgen (pers. comm.) so that the data can be verified, updated, and used for other purposes. Data are required to undergo classification (EPA, 2004). For example Griffin refids 022, 031, 042 used methods in the PATN Package and refid 085 (Baimbridge) used TWINSPAN. Including analysis of soil samples will assist with the reconciliation with soil spatial layers.

It would be advisable to include a form (Coffey Environmental, 2011) to document the quality and limitations of each survey (refer to Table 18). This should include the names and credentials of the botanists.

**Table 18 Botanical Survey Limitations form**

| Potential Limitation | Constraints (Yes/No); | Comment |
|---|---|---|
| Competency/experience of the consultant conducting the survey | | |
| Proportion of flora identified | | |
| Sources of information (historic/recent/new or anecdotal) | | |
| Proportion of the task achieved and further work that may need to be undertaken | | |
| Timing/weather/season/cycle | | |
| Intensity of survey (e.g. in retrospect was the intensity of the survey adequate) | | |
| Completeness (e.g. was relevant area fully surveyed) | | |
| Resources (e.g. degree of expertise available for plant identification) | | |
| Remoteness and/or access problems | | |
| Availability of contextual (e.g. bioregional) information of the survey area | | |

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### *6.4. Data collation*

This and future projects would benefit substantially from access to a central data repository of spatial and site based vegetation data. Environmental survey data and reports generated through the EIA process are often concerned with local and project specific impact assessments as part of a 'fit for purpose' product such as is commissioned by a proponent. Such products are generally not readily accessible beyond the agencies involved in these specific purpose assessments. A requirement to submit standardised, spatially referenced of mapping products and site based vegetation data would enable wider access and utilisation. The challenge is to develop the standard methods and databases that current practitioners will agree to use and databases that can accommodate historical data. The formation of a Vegetation Information System through a coordinated central interagency arrangement has been raised and discussed at various times amongst government and non-government stakeholders. For example, the recently initiated WA Biodiversity Research Institute has *Informatics* as one of its four key themes. Recent policy decisions by Government will help facilitate the expeditious development of such a spatial data repository. Centralised/coordinated spatial referencing of vegetation information would provide a framework for enhanced data access and standards for data collection, interpretation, documentation and quality. This would potentially benefit Government, Industry and Community stakeholders, facilitating ongoing strategic planning and policy decisions.

## **7.** Recommendations

The efficiency and comprehensiveness of information capture could be greatly improved through a spatially referenced interagency registry of vegetation information. This would provide a single point of inquiry enabling a search by geographic criteria for any vegetation mapping, quadrat based surveys or reporting that exists for an area of interest.

Given the variable nature of information sources, standard protocols for spatial and attribute data collection, interpretation, documentation and quality would enhance future regional data reconciliation. This includes consistent and comprehensive capture of floristic site data to enable their interpretation for developing vegetation maps and associated models depicting vegetation patterns at bioregional scales. In addition it would also help with the assessment of areas of local significance in a regional context.

Other spatial data layers for geology, soils and in particular landforms are included and relevant for assessing vegetation maps and potential extrapolation into adjacent areas. The vegetation mapping at the 1:250 000 scale by Beard should not be the sole basis for assessing extent remaining and conservation significance of local vegetation communities, but rather a guide for on ground surveys.

It is recommended that to enhance regional comparability of data, future fine scale vegetation mapping should be consistently informed by soil landform mapping and geomorphology. These themes can provide a congruent reference base for resolving vegetation units at a scale relevant to local biodiversity conservation as well as enable reconciliation at regional planning scales.
Vegetation information also needs to:

1. Acknowledge previous or concurrent mapping that may be spatially coincident.
2. Be unambiguously interpreted as geographically defined mapped units
3. Follow a defined vegetation structural classification with a consistent descriptive nomenclature.
4. Interpret vegetation units according to key floristic and structural parameters, with the dominant species in all strata recorded along with the height, cover and dominant growth form of each stratum (NVIS Level 5) or substratum (NVIS Level 6).
5. Be compatible with NVIS and preferably, able to be described to the level of Sub Association (6) (this is contingent on items 2 to 4.)

Broad guidelines are provided by the EPA (2004). Appendix G provides an example of a more prescriptive approach to standardising vegetation assessment and mapping methods outlined in an unpublished document that includes suggested parameters relevant to surveys of WA Wheatbelt reserves (Beecham, 1998).

The project results and recommendations can be used as a base for future work to improve and further consolidate vegetation mapping of the IOD. Obvious gaps identified were the lack of mapping of vegetation within DPaW reserves. This is needed to provide suitable reference for

mapping outside reserves and thus be able to evaluate the adequacy of conserving representative examples of all vegetation types and habitats

The project has identified the extent of existing vegetation mapping, identified significant issues in standardising vegetation maps from various sources and provides guidelines for standardised data collection to streamline and enhance the development of a regional vegetation map for the Shires of Dandaragan and Gingin.

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Glossary

**attribute data:** "what things are" as distinct from "where things are" (**spatial data**). (GIS: information about what a spatial feature represents)

**bioregion:** Bioregions are relatively large land areas characterised by broad, landscape-scale natural features and environmental processes that influence the functions of entire ecosystems. They capture the broad-scale geophysical patterns across Australia. These patterns in the landscape are linked to fauna and flora assemblages and processes at the ecosystem scale, thus providing a useful means for simplifying and reporting on more complex patterns of biodiversity. Bioregions have been defined for Australia according to The Interim Biogeographic Regionalisation for Australia (Thackway & Cresswell 1995, Environment Australia 2000, Commonwealth of Australia 2004) IBRA categorises the Australian continent into regions of like geology, landform, vegetation, fauna and climate. There are 80 such regions throughout Australia, and 26 occur in Western Australia. http://florabase.dpaw.wa.gov.au/help/ibra/

**cadastral boundaries:** geographically defined jurisdictional boundary of tenure, ownership or management e.g.: property boundary

**fine scale:** Equivalent to "large scale" (i.e.: for the same size map, features on a small-scale map (1:1,000,000) will be smaller than those on a large-scale map (1:1,200). A fine scale map is more likely to represent a higher spatial resolution of vegetation information. (However simply "zooming in" on a small scale map will not increase the resolution of vegetation information it represents.)

**floristic data:** information about the occurrence of plant species in a location, species composition.

**geographic coordinate system:** a set of values that define a location on the earth surface (e.g. latitude and longitude). A geographic coordinate system is defined by its datum and projection which mathematically interprets the earth's curved surface as a flat grid for a particular region.

**geographic datum: (see Geographic coordinate system)**

**geographic projection: (see Geographic coordinate system)**

**georeference:** defines where something is on earth according to "real world coordinates" such as Latitude and longitude

**GIS (Geographic Information System):** A computer based tool for representing and analysing things that can be defined by their position on earth. A GIS links geographic (spatial) information (where things are) with attribute information (what things are). This Information is organised into, and viewed as "layers". GIS layers are made up of the same feature types such as polygons representing a theme (for example vegetation associations). Each layer carries a table (the attribute table) listing attributes for all features. One or more layers can be combined and displayed graphically or printed out as a "map"

**grey literature:** literature that is unpublished**,** informally published or published in non commercial form, e.g.: technical reports, reviews or briefing documents from government agencies, scientific research groups or industry, commissioned consultants reports, maps, policy statements, issue papers, fact sheets, newsletters and bulletins.

**map units:** A map unit is a spatial category which contains a vegetation type or group of co-occurring vegetation types. The map unit is commonly an item in a map legend and is delineated on the map by means of one to many **polygons**.

**map**: a graphical representation of geographically defined spatial and attribute information or data (see **map units**). Attribute information is often displayed via a map legend. To be useful a map needs to have some kind of geographic reference to place it in the "real world". A geographic reference is usually expressed according to a defined **geographic coordinate system**

**polygon:** a flat shape with more than 3 sides. A polygon is a feature type used in a **GIS** to represent something that has area as well as a position on earth - eg: an area of a particular vegetation type. A polygon also has topological properties of an "inside", "outside" and adjacency (to other polygons).

**reconciled:** (vegetation map) : reinterpreting spatial units from different sources so that they are congruent (represent the same thing or attribute) and "match up" across adjoining mapped areas. Ideally map data from different sources are not only reconciled with each other but also with the broader bioregional context.

**rectify:** transforming a digital map image to fit a defined **geographic coordinated system**. This is often done by identifying features in the map image which can be matched with known coordinates and then "warping" the source map image to fit these coordinates. (see also **georeferencing)**

**spatial data:** information that has a defined location or position on earth. Information about "where thing are" as distinct from "what things are" (**attribute data**)

**spatial layer:** A collection of features of the same feature type (e.g. polygon), sharing the same attribute table and theme in a GIS.

**spatial Viewer:** a means by which digital spatial data can be viewed and queried such as through a GIS or web based facility such as NatureMap.

**Structural classification (vegetation):** a classification of vegetation according to growth form, height and cover. Height and cover value ranges are usually grouped into class intervals for given types of growth forms. (e.g. Muir 1977).

**structural data (vegetation):** Information about the spatial arrangement (vertically and horizontally) of plants within a community.

## Appendices

**Appendix A: List of collated source documents**

| refid | Author | Title |
|---|---|---|
| **1** | Richardson, J., Langley, M., Meissner, R. and Hopkins, A. | Biodiversity assessment and vegetation mapping of the northern agricultural region, Western Australia. 2005, Perenjori, W.A.: Northern Agricultural Catchments Council. 106. |
| **2** | DPUD | Central coast regional profile: incorporating parts of the shires of Irwin, Carnamah, Coorow, Dandaragan & Gingin 1994: Department of Planning and Urban Development. |
| **3** | WAPC | Central coast regional strategy: a strategy to guide land use in the next decade: final 1996, Perth WA: Western Australian Planning Commission. |
| **4** | Landvision | Coastal plan incorporating structure plan & design guidelines for coastal development & management. 1999: Shire of Dandaragan. |
| **5** | Chalmers, C.E. and S.M. Davies | Draft coastal management plan: Jurien Bay. 1983, Department of Conservation and Environment Perth, WA. |
| **6** | Ecologia | Coastal road Jurien to Green Head Consultative Environmental Review for Main Roads, Shires of Dandaragan and Coorow. . 1995. |
| **7** | Ecologia | Cervantes- Jurien Coastal road Consultative Environmental Review for Main Roads and Shire of Dandaragan. 1997, Main Roads and Shire of Dandaragan: Perth, W.A. |
| **8** | EPA | Cervantes-Jurien Coastal Road, Shire of Dandaragan: Main Roads Western Australia: report and recommendations of the Environmental Protection Authority, EPA Bulletin 881. 1998, Environmental Protection Authority: Perth, W.A. . |
| **9** | Griffin, E.A. | Floristic survey of remnant vegetation in the Dandaragan area, Western Australia. 1990, E.A. Griffin and Associates Consultant botanist in association with the Department of Agriculture: South Perth W.A. |
| **10** | Griffin, E.A. | Restricted species of the northern sandplain between the Moore and Irwin rivers. 1981, Dept. of Fisheries & Wildlife: Perth, W.A. p. 394. |
| **11** | DEC | Hidden treasures of the Northern Agricultural Region: last stands: Unpublished field survey report. 2008, Dept. of Environment and Conservation: Geraldton, W.A. |
| **12** | Burbidge, A.A., S.D. Hopper, and S. van Leeuwen | Nature Conservation, Landscape and Recreation values of the Lesueur area EPA Bulletin 424. 1990, Environmental Protection Authority: Perth, W.A |

| refid | Author | Title |
|---|---|---|
| **13** | Burbidge,.H. and L.J. Boscacci | A spring reconnaissance survey of the flora and fauna of the Southern Beekeepers Reserve. 1989, Dept. of Conservation & Land Management: Perth, W.A. |
| **14** | EPA | Turquoise Coast development, Jurien Bay : Ardross Estates Pty Ltd, Report and recommendations, EPA Bulletin 1031. 2001, Environmental Protection Authority: Perth, W.A. |
| **16** | ATA Environmental | Turquoise coast development Jurien Bay : wetland survey. Unpublished report 2001/92. 2001, Allan Tingay and Associates Environmental: Peth, W.A. |
| **17** | CALM | Nambung National Park, Wanagarren Nature Reserve, Nilgen Nature Reserve, Southern Beekeepers Nature Reserve, Management Plan 1998-2008 1998, Department of Conservation and Land Management for the National Parks and Nature Conservation Authority: Perth W |
| **18** | CALM | Wedge and Grey Masterplan (amendment to Nambung National Park, Wanagarren Nature Reserve, Nilgen Nature Reserve, Southern Beekeepers Nature Reserve, Management Plan 1998-2008). 2001, Department of Conservation and Land Management for the National Parks |
| **19** | CALM | Lesueur National Park and Coomallo Nature Reserve Management Plan1995-2005 1995, Department of Conservation and Land Management for the National Parks and Nature Conservation Authority: Perth, W.A. |
| **20** | PBP | Northern Extension Project. Draft report on Investigations of Data and Resource Requirements to Extend the Local Biodiversity Planning process North of Perth. 2010, Perth Biodiversity Project (Western Australian Local Government Authority) for the WA Pl |
| **21** | Beard, J.S. | The vegetation of the Moora and Hill River areas, Western Australia. Map and Explanatory Memoir 1:250 000 series. 1979, Perth: Vegmap Publications. |
| **22** | Griffin, E.A. | Flora of the Quindalup Dunes between the Swan and Irwin Rivers, Western Australia. . 1993: Unpublished report to Coastal Planning Branch, Department of Planning and Urban Development, and the Heritage Council of W.A. |
| **23** | Beard, J.S. | The vegetation of the Swan Area, Western Australia,. Map and Explanatory Memoir. 1:1 000 000 Series. 1981, Nedlands, WA: University of Western Australia Press. |
| **24** | Alan Tingay & Associates | Environmental appraisal of properties at Jurien Bay for Ardross Estates Pty. Ltd. 1996, Alan Tingay & Associates Perth. |
| **25** | Dames and Moore | Report: consultative environmental review, Warradarge Coal Project for Warradarge Resources Pty Ltd. 1999. |
| **27** | Martenick,. | Gairdner Range Coal Project Vegetation types, Vegetation Mapping and Rare Plants 1988, CRA Exploration Pty. Ltd. : Perth. |

| refid | Author | Title |
|---|---|---|
| **28** | Martenick,. | Hill River Project Biological Studies, Vegetation of the Project area in A Regional Context. 1989, CRA Exploration Pty. Ltd. : Perth. |
| **29** | Martenick,. | Hill River Project Biological Studies, Fauna Surveys. 1989, Canning Resources. Perth. |
| **30** | ECOS Consutling (Aust) Pty Ltd | Flora and Vegetation Prepared for Warradange Recourses. 1998. |
| **31** | Griffin, E.A. and B.J. Keighery | Moore River to Jurien Sandplain survey. 1989, Western Australian Wildflower Society Inc: Perth, WA. |
| **32** | MGA Town Planners | Amendment 20 to Shire of Dandaragan Local Planning Scheme No.7 2012. |
| **33** | Coffey Environments | Spring Flora and Vegetation Assessment Marine Fields and North Cervantes Study area. 2011, Prepared for Ardross Group of Companies: Perth. p. page 48 in Ref 32. |
| **36** | Jackson, E. | Northern Agricultural Catchments Council Regional Environmental Account Trial, Proof of Concept Account 2013. 2012, Northern Agricultural Catchments Council: Geraldton, WA. |
| **37** | DOW | Environmental Considerations for Groundwater Management in the Northern Perth Basin Environmental Water Report No.8 in Environmental Water Report. 2009, Government of Western Australia Department of Water: Perth. |
| **38** | WAPC | Indian Ocean Drive Planning Guideline Draft for public comment. 2013, Western Australian Planning Commission. |
| **39** | Resource Allocation Branch of the Resource Management Division and Midwest Gascoyne Region | Managing the Water resources of the Jurien Groundwater Area, WA. Interim Sub-Regional Allocation Strategy. 2002, Water and Rivers Commission: Perth, W.A. |
| **41** | Trudgen, M.E.T. | A Flora and Vegetation Survey of the Coastal Stip between Jurien Bay and Hill River. Prepared for Alan Tingay & Associates. 1996. |
| **42** | Griffin, E.A. | Floristic Survey of Northern Sandplains between Perth and Geraldton. Resource Management Technical Report 144, in Resource Management Technical Report 1994, Department of Agriculture: South Perth. |

| refid | Author | Title |
|---|---|---|
| **43** | Jurien Chamber of Commerce | A look at Jurien 1658 - 1989. 1989: Jurien Chamber of Commerce. |
| **44** | Water Resources Division | Jurien Groundwater Management Plan. 1995, Water Resources Planning and Allocation Branch, Water Authority of WA: Perth. |
| **45** | Chalmers, C.E. and S.M. | Davies Coastal Management Plan Jurien Bay area Department of Conservation and Environment Bulletin No.176 1985, Department of Conservation and Environment and the Coastal Management Coordinating committee in Co-operation with the Shire of Dandaragan: |
| **46** | Ecologia | Environmental Management Plan for Mining Lease for Haggarty Nominees. 1999: Perth. |
| **47** | Bennett Environmental Consulting Pty Ltd | Effects of Water Drawdown on Vegetation near Jurien Bay prepared for Kellogg Brown & Root. 2004: Perth, WA. |
| **48** | Kellogg Brown & Root | Notice of intent/inferal Document Jurien Gypsum mining Operation (application for mining Lease M70/1161) prepared for CSR Gyprock Fibre Cement. 2004: Perth. |
| **49** | Bennett Environmental Consulting Pty Ltd | Comparison of Vegetation at Lakes in the Jurien Bay prepared for Kellogg Brown & Root. 2006: Perth, WA. |
| **50** | Kellogg Brown & Root | Public Environmental Review Jurien Gypsum Mine Phase 2 M70/1161 prepared for CSR Gyprock Fibre Cement. 2004: Perth. |
| **51** | WAPC | Wheatbelt Regional Profile Background and context report to Support the Wheatbelt Land Use Planning Strategy Draft for Public Comment. 2011, Western Australian Planning Commission. |
| **52** | Bamford Consulting Ecologists | The Regional Significance of Gypsum Lake for Water Birds Prepared for Public Environmental Review Jurien Gypsum Mine Phase 2 M70/1161. 2006. |
| **53** | Bamford Consulting Ecologists | Jurien Gypsum Mine: Existing Fauna and Impacts Of Proposed development prepared for Kellogg Brown & Root 2004. |
| **54** | Helleren, S.K.R. | Baseline Study of Aquatic Flora and Fauna Gypsum Lake Beekeepers Reserve WA November 2003 Prepared for Kellogg Brown & Root Pty Ltd. 2004, Dalcon Environmental. |
| **55** | Helleren, S.K.R. and S. Arklie | Baseline Study of Auqatic Flora and Fausn Gypsum Lake Beekeepers Reserve WA Spring 2005 Prepared for Kellogg Brown & Root Pty Ltd. 2005, Dalcon Environmental. |
| **56** | WAPC | Wheatbelt Land Use Planning Strategy Draft for Public Comment. 2011, Western Australian Planning Commission. |

| refid | Author | Title |
|---|---|---|
| **57** | Shire of Dandaragan | Jurien bay Growth Plan Volume 1 Feasible Implementation Plan. 2012. |
| **58** | Shire of Dandaragan | Jurien bay Growth Plan Volume 2 Analysis, Integrated Strategy and Spatial Plans. 2012. |
| **59** | Shire of Gingin | Local Planning Strategy. 2010, Shire of Gingin. |
| **61** | V & C Semenuik Research group 1994 | Ecological assessment and evaluation of wetlands in the System 5 region : report to the Australian Heritage Commission |
| **62** | ATA Environmental and A Tingay | Turquoise Coast Development, Jurien Bay, Environmental Report. Final Report no: 99/07, August 2000. Report prepared for Ardross Estates Pty Ltd. 2000. |
| **63** | WALGA | East Jurien Development lots 1, 501,10600, 10601, Mathews Danielle. |
| **64** | Government of WA | 2012 Statewide Vegetation Statistics incorporating the CAR Reserve Analysis |
| **65** | Gardner C.A. | The Botany of the Hill River District. The Western Australian Naturalist 1: 1-4. |
| **66** | Shire of Dandaragan | 2013 Coastal Settlement and Coastal Hinterland Strategy Plan |
| **77** | Beard, J.S. | 1979. *The vegetation of the Perth area, Western Australia. Map and Explanatory Memoir 1:250 000 series.* Vegmap Publications, Perth. |
| **78** | Beard, J.S., Beeston, G.R., Harvey, J.M., Hopkins, A.J.M. & Shepherd, D.P. | 2013. The vegetation of Western Australia at the 1:3,000,000 scale. Explanatory memoir. Second edition. *Conservation Science Western Australia* 9: 1-152. |
| **79** | Bishop, C.L., Bayliss, B., van Leeuwen, S., Ennis, A., S., F. & Gioia, P. | 2013 Great Western Woodlands Map Project: Consolidation of existing fine-scale vegetation maps using the National Vegetation Information System (NVIS), Department of Environment and Conservation (Science Division), Perth.AU. |
| **70** | Burbidge, A.A. & Fuller, P.J. | 1990. Fauna. In: Burbidge, A.A., Hopper, S.D. & Van Leeuwen, S. (eds.) *Nature Conservation, Landscape and Recreation Values of the Lesueur Area*, pp. 71 - 82. Environmental Protection Authority, Perth. vol. 424. |

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| **71** | Crook, I.G., Williams, A.E. & Chatfield, G.R. | 1982. Nature reserves of the Shire of Dandaragan, Volume 1, Department of Fisheries and Wildlife, Perth, WA. |
| **75** | Eliot, I., Gozzard, J.R., Eliot, M., Stul, T. & McCormack, G. | 2012. The coast of Shires of Gingin and Dandaragan, Western Australia: Geology, Geomorphology and Vulnerability, Prepared by Damara Pty Ltd and Geological survey of Western Australia for the Department of Planning and Department of Transport. |
| **81** | EPA | 2002. Lancelin to Cervantes Coastal Road, Main Roads Western Australia : Report and recommendations of the Environmental Protection Authority, EPA Bulletin 1053, Environmental Protection Authority, Perth, WA. |
| **73** | Grey, C. | 2005. *Flora and vegetation survey near Fatfields Jurien Bay. ATA Environmental.* |
| **67** | Griffin, E.A. & Hopkins, A.J.M. | 1990. Vegetation In: Burbidge, A.A., Hopper, S.D. & Van Leeuwen, S. (eds.) *Nature Conservation, Landscape and Recreation Values of the Lesueur Area*, pp. 25 - 37. Environmental Protection Authority, Perth. vol. 424. |
| **72** | Griffin, E.A. | 1992. A Brief Assessment of Proposed Access Road from Jurien Road to Sandy Point, Unpublished report to Peter Woods and Associates. |
| **68** | Griffin, E.A., Hopper, S.D. & Hopkins, A.J.M. | 1990. Flora. In: Burbidge, A.A., Hopper, S.D. & Van Leeuwen, S. (eds.) *Nature Conservation, Landscape and Recreation values of the Lesueur area 1990,* , Environmental Protection Authority Bulletin Perth, W.A. vol. 424. |
| **76** | Keighery, B.J., Keighery, G.J. & Longman, V.M | . 2003. *Vegetation and flora of Sappers and Cowalla Road between Nilgen Nature Reserve and the Moore River. Unpublished report for Wildflower Society of Western Australia and WA Landskills Inc.* Wildflower Society of W.A, Perth. |
| **74** | Langley, M.A. | 1999. *West Midlands Survey.* Perth, 1998 - 1999. |
| **69** | McArthur, W.M. & Bettenay, E. | 1960. The development and distribution of soils of the Swan Coastal Plain, Western Australia. *CSIRO Soil Publication* 16. |
| **82** | MRWA 2000. | Lancelin to Cervantes Coastal Road', Main Roads Western Australia, Government of Western Australia, October 2000., Main Roads Western Australia, Government of Western Australia, Perth, WA. |

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|---|---|---|
| **80** | Richardson, J., Gamblin, T., Glossop, B. & Hogben, J. | 2007. The Biodiversity of the Avon NRM Region: Towards Prioritisation for Conservation, DRAFT, Department of Environment and Conservation. |
| **81** | EPA | 2002. Lancelin to Cervantes Coastal Road, Main Roads Western Australia : Report and recommendations of the Environmental Protection Authority, EPA Bulletin 1053, Environmental Protection Authority, Perth, WA. |
| **82** | MRWA | 2000. Lancelin to Cervantes Coastal Road', Main Roads Western Australia, Government of Western Australia, October 2000., Main Roads Western Australia, Government of Western Australia, Perth, WA. |
| **83** | Thomas, J.F., McArthur, W.M. & Bartle, G.A | 1990. Land use and management in the Defence Training Area at Lancelin, Western Australia. Map entitled: Lancelin Defence Training Area (Landforms and soils map in back pocket), CSIRO, Perth. |
| **84** | Halpern Glick Maunsell | 2000. Lancelin to Cervantes Coastal Road Public Environmental Review for Main Roads Western Australia, Perth |
| **85** | Halpern Glick and Maunsell | 2001. Wedge and Grey Biological Survey, Unpublished report for CALM Western Australia, Halpern Glick and Mausell, Leederville , WA |
| **86** | Halpern Glick Maunsell | 2000. Coastal Road Lancelin to Cervantes Biological survey, Unpublished for Main Roads Western Australia, Perth. |
| **97** | Ecologia | 1998. Environmental Profile, Lancelin Defence Training Area (DTA). Unpublished report to the Department of Defence. |

**Appendix B: A summary of NVIS general concepts and description coding**

'App B NVIS_long_summary.pdf'

**Appendix C: Relationships between the National Vegetation Information System (ESCAVI 2003) and Muir (1977) Vegetation Structural Classification Systems**

'App C NVIS_Muir comparison table.pdf'

**Appendix D Conditions of Supply of information pertaining to Rare and threatened species of plant and animals**

- 'App D1 DPaW Flora Data Search Conditions of Supply August 2013.pdf'
- 'App D2 Threatened Fauna Information_ conditions of supply 2013.pdf'
- **Conservation Codes (definitions) for Flora and Fauna**
  http://www.dpaw.wa.gov.au/images/documents/plants-animals/threatened-species/Listings/Conservation_code_definitions_18092013.pdf

**Appendix E: Vegetation statistics for Dandaragan and Gingin Shires**

(See spreadsheet 'App. E Vegetation statistics for Dandaragan and Gingin shire.xls')

**Table E-1 Beard vegetation associations and System association that intersect with the IOD core study are**

| LGA | BVA | SYSTEM_ASS | BSA | Map code | NVIS 6 |
|---|---|---|---|---|---|
| DAN | 4 | GAIRDNER_4 | 4.8 | e3,5Mi | U1+Corymbia calophylla,+Eucalyptus wandoo\tree\7\i;U2 Banksia attenuata\tree\6\i;M1 Acacia pulchella, Macrozamia riedlei, Xanthorrhoea preissii\shrub,cycad,xanthorrhoea\4\i;G1 Astroloma sp., Craspedia uniflora, Conostylis sp., Eryngium pinnatifidum, Hake |
| GIN | 37 | JURIEN_37 | 37 | mSc | U1+Melaleuca sp.\shrub\4\c |
| GIN | 37 | BARRAMBER_37 | 37.4 | mSc | U1 Melaleuca rhaphiophylla\tree\6\c |
| DAN | 125 | CLIFF HEAD_125 | 125 | sl | salt lake |
| DAN | 125 | JURIEN_125 | 125 | sl | salt lake |
| GIN | 125 | GUILDERTON_125 | 125 | sl | salt lake |
| GIN | 129 | GUILDERTON_129 | 129 | ds | sand dune |
| DAN | 129 | JURIEN_129 | 129 | ds | sand dune |
| DAN | 377 | ILLYARRIE_377 | 377.1 | x6SZc/e44Lp | U1 Banksia attenuata, Banksia prionotes, Nuytsia floribunda\tree\6\r;M1 Acacia rostellifera, Calothamnus chrysantherus, Dryandra sessilis, Hakea platysperma, Acacia xanthina\shrub\4\i;G1 Acacia alata, Allocasuarina humilis, Astroloma sp., Banksia sphaerocarpa\ U1 Eucalyptus erythrocorys\tree\6\r |
| DAN | 949 | JURIEN_949 | 949.1 | bLi | U1+Banksia attenuata, Banksia menziesii, Eucalyptus todtiana, Nuytsia floribunda, Allocasuarina fraseriana\tree\6\i;M1 Calothamnus sanguineus, Petrophila brevifolia, Eremaea pauciflora, Hakea costata, Jacksonia hakeoides\shrub\4\i;G1 Hibbertia hypericoid |
| GIN | 949 | JURIEN_949 | 949.1 | bLi | |

| LGA | BVA | SYSTEM_ASS | BSA | Map code | NVIS 6 |
|---|---|---|---|---|---|
| GIN | 949 | BASSENDEAN_949 | 949.2 | bLi | U1+Banksia attenuata, Banksia menziesii, Eucalyptus todtiana, Nuytsia floribunda, Allocasuarina fraseriana\tree\6\i;G1 Conospermum incurvum, Verticordia nitens\shrub\4\c |
| DAN | 949 | BASSENDEAN_949 | 949.2 | bLi | U1+Banksia attenuata, Banksia menziesii, Eucalyptus todtiana, Nuytsia floribunda, Allocasuarina fraseriana\tree\6\i;G1 Conospermum incurvum, Verticordia nitens\shrub\4\c |
| GIN | 998 | JURIEN_998 | 998 | e4Mi | U1+Eucalyptus gomphocephala\tree\7\i |
| DAN | 998 | JURIEN_998 | 998 | e4Mi | U1+Eucalyptus gomphocephala\tree\7\i |
| GIN | 1007 | GUILDERTON_1007 | 1007.1 | a26,m4Sc/a23,32Zc | U1+Melaleuca acerosa, Acacia lasiocarpa, Olearia axillaris\shrub\3\d/U1+Acacia lasiocalyx, Acacia cyclops\shrub\2\d |
| GIN | 1008 | BARRAMBER_1008 | 1008 | e3Mr | U1+Corymbia calophylla\tree\7\i |
| GIN | 1008 | BASSENDEAN_1008 | 1008 | e3Mr | U1+Corymbia calophylla\tree\7\i |
| GIN | 1008 | JURIEN_1008 | 1008 | e3Mr | U1+Corymbia calophylla\tree\7\i |
| GIN | 1009 | BARRAMBER_1009 | 1009.1 | e3,18Mr | U1+Corymbia calophylla,+Eucalyptus rudis\tree\7\i;U2 Melaleuca preissiana, Melaleuca rhaphiophylla, Banksia attenuata, Banksia menziesii\tree\6\r;M1 Jacksonia furcellata, Jacksonia sternbergiana\shrub\4\i |
| GIN | 1011 | JURIEN_1011 | 1011 | e4Mr | U1+Eucalyptus gomphocephala\tree\7\r |
| GIN | 1012 | BASSENDEAN_1012 | 1012 | e4Mr/bLi | U1+Eucalyptus gomphocephala\tree\7\r/U1+Banksia sp\tree\6\i |
| GIN | 1014 | BASSENDEAN_1014 | 1014.1 | bLi/mSc | U1 Melaleuca preissiana\tree\6\d |
| GIN | 1026 | GUILDERTON_1026 | 1026.1 | a23,32m3Sc/a26m4Zc | U1+Acacia rostellifera,+Acacia cyclops\shrub\4\c/U1+Melaleuca acerosa, Acacia lasiocarpa, Olearia axillaris\shrub\3\d |
| DAN | 1028 | JURIEN_1028 | 1028 | e18Mi | U1+Eucalyptus camaldulensis\tree\7\i |
| DAN | 1029 | GUILDERTON_1029 | 1029 | x9SZc | U1 Banksia prionotes\tree\6\bi;M1 Dryandra sp., Calothamnus sp., Acacia sp., Grevillea sp., Hakea sp.\shrub,xanthorrhoea\4\i;G1 Conospermum sp., Hibbertia sp.\shrub\2\c |

| LGA | BVA | SYSTEM_ASS | BSA | Map code | NVIS 6 |
|---|---|---|---|---|---|
| DAN | 1029 | JURIEN_1029 | 1029.1 | x9SZc | U1+Dryandra sessilis,+Calothamnus quadrifidus, Acacia heteroclita, Grevillea thelemanniana, Hakea bipinnatifida\shrub,xanthorrhoea\4\i;G1 Conospermum stoechadis, Lechenaultia linarioides, Hibbertia hypericoides, Dryandra nivea, Hakea prostrata\shrub,forb |
| GIN | 1029 | JURIEN_1029 | 1029.1 | x9SZc | |
| GIN | 1030 | BASSENDEAN_1030 | 1030.2 | b1,2Li | U1 Eucalyptus rudis, Casuarina obesa\tree\7\bi;U2+Melaleuca rhaphiophylla, Banksia littoralis\tree\6\i;M1 Acacia rostellifera, Hypocalymma angustifolium, Melaleuca thyoides\shrub\3\i |
| DAN | 1031 | GAIRDNER_1031 | 1031 | hSZc/dZc | U1+Hakea sp., Allocasuarina sp.\shrub\4\i;M1 Dryandra sp., Allocasuarina sp., Banksia sp., Calothamnus sp., Conospermum sp.\shrub\3\c |
| DAN | 1032 | GAIRDNER_1032 | 1032.1 | e3,5,45Mi/dZc | U1+Corymbia calophylla,+Eucalyptus wandoo, +Eucalyptus accedens\tree\7\ / iU1 Xanthorrhoea reflexa\xanthorrhoea\4\i;M1+Dryandra bipinnatifida, Hakea auriculata,+Dryandra shuttleworthiana, Hakea conchifolia,+Dryandra sp.\shrub\3\c;G1 Banksia sp., Burchardia umbellata, Calectasia cyanea, Conostylis aculeata, Dryandra nana\shrub,forb\c |

**Table E2 Summary small and poorly represented BVAs and SAs in or near the study area (red text < 10% orange 10 – 20 % blue <30%)**

| LGA | System | BVA | BSA | Map code | Pre-European Extent | Current Extent | % Remaining | IN IOD | in DPAW estate | Comments |
|---|---|---|---|---|---|---|---|---|---|---|
| DAN | JURIEN | 949 | 949.1 | bLi | 262.00 | 14.68 | 5.60 | y | 0 | lots in Gingin Shire |
| GIN | JURIEN | 1008 | 1008 | e3Mr | 343.62 | 21.49 | 6.25 | y | 0.00 | More in Barramber system |
| DAN | BASSENDEAN | 1031 | 1031 | hSZc/dZc | 4858.08 | 402.69 | 8.29 | y | 0 | In need of protection |
| DAN | DAN | 1031 | 1031 | hSZc/dZc | 81.94 | 6.82 | 8.32 | y | 0 | In need of protection |
| GIN | BASSENDEAN | 125 | 125 | sl | 355.21 | 39.67 | 11.17 | y | 0.00 | Lake beds considered cleared. |
| GIN | BASSENDEAN | 1008 | 1008 | e3Mr | 1391.08 | 162.34 | 11.67 | y | 0.00 | More in Barramber system |
| DAN | JURIEN | 1028 | 1028 | e18Mi | 421.66 | 82.52 | 19.57 | y | 23.12 | There could be more that what is mapped. |
| GIN | BASSENDEAN | 1012 | 1012 | e4Mr/bLi | 507.81 | 125.14 | 24.64 | y | 0.00 | In need of protection |
| GIN | JURIEN | 1011 | 1011 | e4Mr | 184.37 | 50.18 | 27.22 | y | 0.00 | In need of protection |
| GIN | BARRAMBER | 1009 | 1009.1 | e3,18Mr | 5675.57 | 1575.12 | 27.75 | y | 3.87 | 1009 more common and better conserved |

**Appendix F: Beard Vegetation Associations (BVAs) and System associations (BSA) in the study area**

## Details on poorly represented and reserved unit in and near the core study area

Beard's system associations that intersect with the core study which have less than 30% remaining are discussed in below in context of related associations. This analysis was carried out at the system association (SA) level however most units are not subdivided to this level and appear in the statistics as vegetation associations (BVA). It is important to take into account the actual area remaining and how unique the unit is. Only 1 system association (SA1009.1 e3,18Mr) is in DPaW estate (3.87 ha).

*In Gingin Shire*

Salt lakes (BVA125) appear to have been excessively cleared (11.17 %, 39.67 ha) remaining in the Gingin shire) but in fact the lake beds are not generally included in the remnant vegetation layer (similarly for freshwater lakes and bare sand dunes). Within the study area the salt lakes are intact apart from a small are of a lake north of Jurien (gypsum mine?) The small area remaining, illustrates a problem with the remnant vegetation layer in that is comprised mainly of shrub and tree dominated vegetation and any vegetation such as comprised of sedges, grasslands and samphire is not recognised as remnant vegetation.

The only unit of BVA1012, (e4Mr/bLi) represented in both shires, is in the core study area flanking the Moore river near Gingin brook. The unit is described as U1+Eucalyptus gomphocephala\tree\7\r/U1+Banksia sp\tree\6\i with the explanatory notes to the Perth Map mentions *Banksia attenuata*, *Banksia menziesii, Jacksonai furcellata* and *J. sternbergiana*. It is not reserved and only 24.64 % or 125.14 ha remain. (This occurrence of unit of BVA1012 is incorrectly labelled as SA1011 in the Pre-European vegetation layer).

Only 27.22 % (50.18 ha) remains of the open tuart woodland (BVA1011, e4Mr) flanking the Moore River downstream of the BVA1012.(Original maps show this is more extensive along the lower reaches of the river than captured in the digital layers). South of the study area (still in the Shire of Gingin) open tuart woodland (e4Mr) in the Spearwood system is 81.51 % (only 70 ha) intact. Of significance is the small patch (0.52 ha) of tuart woodland (BVA998, e4Mi) locate between Lancelin and Wedge Point north of Ocean Farms. This highlights the need to recognised small remaining extents as well as limited extent and poorly reserved units.

Open Marri woodlands are uncommon, heavily cleared and not reserved in the vicinity of the core study area. There are small and poorly conserved areas in Jurien and Bassendean system and a similar unit along Gingin Brook and around Karakin Lake is likely to have different understorey. Within the Gingin Shire only 6.25%, (21.49 ha) of open Marri woodland (BVA1008, e3Mr) (U1+Corymbia calophylla\tree\7\i) remains in the Jurien vegetation system. Only 11.67% (162.34 ha) of this vegetation association occurs in the Bassendean system in and near the IOD. Along the Gingin Brook and around the Karakin Lake (in Karakin Nature Reserve) in the Barramber system the unit is 35% intact but this probably has a different understorey than the Jurien BSA. Further inland, a similar unit Marri woodland (BVA999, e3Mi) has only 29.38 % (213.3 ha) in the northern part of the Pinjarra system that is in the Gingin shire. This polygon should probably be described as for the nearby BSA999.1 in the Gingin veg system in the Gingin shire is described in more detail (U1+Corymbia calophylla\tree\7\i;U2 Banksia attenuata, Banksia grandis, Nuytsia floribunda\tree\6\i;M1 Acacia cyanophylla, Dryandra sessilis, Grevillea vestita, Jacksonia sternbergiana\shrub\4\i;M2 Xanthorrhoea preissii\xanthorrhoea\3\i) and has only 8.17% (920.65ha) remaining.

Another unit which occurs in the study area, within the Gingin shire, is Marri and flooded gum open woodland (BSA1009.1 e3,18Mr) which has only 27.75 % (1575.12 ha) remaining in the Barамber Vegetation system (U1+Corymbia calophylla,+Eucalyptus rudis\tree\7\i;U2 Melaleuca preissiana, Melaleuca rhaphiophylla, Banksia attenuata, Banksia menziesii\tree\6\r;M1 Jacksonia furcellata, Jacksonia sternbergiana\shrub\4\i). It occurs in a corridor between the Moore River and the Karakin Lakes, where 3.87% is in a reserve, and along the River corridor. However the lower reach is originally mapped as open tuart woodland (=BVA1011). BVA 1009 (e3,18Mr) in the Bassendean System, along the Moore river upstream of Karakan Lakes, is well conserved (54 %, 628.31 ha) but not well described (U1+Corymbia calophylla,+Eucalyptus rudis\tree\7\i). This is outside the study area.

Only 94 ha of unusual BSA 1010.1 (e3,4,Mr) is small uncommon and not in any reserves. However is in the Bassendean system and may be more common to the south of the study area.

*In Dandaragan Shire*

Within or near the study area Dandaragan Shire are system associations that have less than 30% remaining but these may be well represented elsewhere or there may be similar units nearby. Some of these units are represented in DPaW estate.

Low Banksia woodland (BSA949.1 bLi) has only 5.6 % (14.68 ha) remaining in the Jurien System, none in reserves. However, this is a large well preserved unit (51.34 % remaining, 26458.53 ha) in the Gingin Shire these units should be amalgamated and considered to have adequate remaining extent.

Another unit which is has limited extent in three systems in a mixed heath–scrub heath unit (1031, hSZc/dZc); Bassendean system (8.29%, 402.69 ha), Dandaragan system (8.32 %, 6.82 ha) and the eastern Warro system (21.81 %). None of this unit is reserves in or near the study area (in the Bassendean and Dandaragan systems). This is described as U1+Hakea sp., Allocasuarina sp.\shrub\4\i;M1 Dryandra sp., Allocasuarina sp., Banksia sp., Calothamnus sp., Conospermum sp.\shrub\3\c. However, with further survey there may be more system specific descriptions. It is described differently for the occurrence (29.01 % remaining) in the Lesueur System (BSA1031.1) (U1 Eucalyptus johnsoniana, Eucalyptus lane-poolei, Eucalyptus pendens, Banksia attenuata, Banksia menziesii\mallee,tree\5\bi;M1^Hakea obliqua, Allocasuarina humilis, Adenanthos cygnorum, Banksia candolleana, Calothamnus sanguineus\shrub,xanthorrhoea\4\i;) This BVA is well represented (66.56 %) in the Gardner System further inland.

Another riverine unit (BVA 1028, e18Mi) is Cockleshell Gully in the study area and along the Hill River, very near the study area, where a total of only 19.57 % (82.52 ha) remains. These corridors may not be picked up the coarse resolution of the regional mapping. For example, this vegetation association is present all along the Hill River to the coast (Orthophotographic interpretation and limited ground observations in the vicinity of the IOD). Only 23.12% of this unit is in a reserve.

Comments on the Source Descriptions for BVAs and NVIS level 6 descriptions for System Associations between Cervantes and Jurien.

*Widespread Vegetation Associations*

BVA1026 Mosaic: Shrublands; Acacia rostellifera & Melaleuca cardiophylla thicket / Shrublands; Acacia lasiocarpa & Melaleuca acerosa (now sestina) heath (a23,32m3Sc/a26m4Zc) in the Guilderton System

BSA 1026.1 in the Jurien System is described as NVIS Level 6 U1+Melaleuca cardiophylla\shrub\4\c / U1 Acacia rostellifera, Allocasuarina baxteriana, Melaleuca cardiophylla, Acacia xanthina, Melaleuca huegelii\shrub\4\r;M1+Acacia lasiocarpa, +Melaleuca acerosa, Adriana quadripartita, Conostylis sp., Cuscuta australis\shrub\3\c,

Adjoining this to the south in the Guilderton System is a mosaic very similar to 1026; BSA 1007.1a (a23,32Z/c26m4Zc) described at NVIS level 6 as U1+Melaleuca acerosa, Acacia lasiocarpa, Olearia axillaris\shrub\3\d/Acacia lasiocalyx, Acacia cyclops\shrub\2\d. This covers 12636.74 ha which is 84.15% remaining Only 8.35 % of pre-European Extent is in IUCN I – IV reserves in the Gingin shire. More than

There is a small patch (279.61 ha) of BVA 1029 in the Guilderton system which is not represented in any reserve. This is described as for the Jurien System as x9SZc Shrublands; scrub-heath dryandra-calothamnus alliance with *Banksia prionotes* on limestone in the northern Swan Region. This patch of BVA 1029 is the only occurrence in the Guilderton System. This description is similar to the Jurien/Illyarrie System description and these species are not mentioned by Trudgen. This unit is also not discernible on orthophotos and may be an error in the mapping which would need careful checking on the ground.

NVIS level 6 has have a 'GENERAL' description for 1029.0 U Banksia prionotes\tree\6\bi;M^^Dryandra sp., Calothamnus sp., Acacia sp.\shrub,xanthorrhoea\4\i;G Conospermum sp., Hibbertia sp.\shrub\2\c, which is from the Jurien System description dryandra-calothamnus association with *B. prionotes* (see Beard, 1979a).

BSA1029.1 inland large area in Jurien System 38,900 ha 38% in reserves, described as NVIS level 6 U^Dryandra sessilis,^Calothamnus quadrifidus, Acacia heteroclita\shrub,xanthorrhoea\4\iG Conospermum stoechadis, Lechenaultia linarioides, Hibbertia hypericoides\shrub,forb\2\c.

There is another patch of general 1029 in Illyarrie System which adjoins x9SZc in Jurien

**Appendix G Guidelines for vegetation assessment in WA wheatbelt reserves; an extract from an unpublished report (Beecham, 2006).**

Beecham, Brett C. 2006. Assessing the Nature Conservation and other Values of Crown Lands within the Wheatbelt Region of CALM. Unpublished report, Department of Conservation and Land Management, Narrogin.

3.2.4 Mapping Vegetation Units

Vegetation units within each reserve will be initially identified and mapped from aerial photography. Some fieldwork will be required to produce more detailed mapping of vegetation associations and refine boundaries.

- Vegetation mapping will follow the method of Muir (1977), characterising vegetation units to the level of Association based upon the growth form, height, cover and floristics of the dominant species for all strata. Vegetation unit boundaries will be interpreted from available colour or black and white aerial photos. In general all vegetation will be mapped at a scale of 1:25 000, meaning that only vegetation units exceeding approximately 75 metres in diameter or in the narrowest dimension will be mapped. However vegetation units of particular interest, such as in narrow zones along drainage lines, lunettes, or fringing granite outcrops should be mapped at finer scales. .

Boundary mapping will not follow Muir's methodology. Boundaries between vegetation units will be mapped using solid lines. Where transitions from one vegetation type to another are indiscernible, then differences will described by using more than one survey location (see 3.2.5 below).

- In following the method of Muir (1977), it is expected that mapping will generally be at a minimum Level 2 detail (Muir 1977:22), depending on the size of the area being mapped, accessibility, and the scale of mapping as described above. There is no requirement for a soil profile (c) to be described. More details on the data to be collected for each association type are provided in Section 3.2.5 below.

- A reliability diagram showing the path of any ground traverse should be provided as per Muir (1977).

- Vegetation units that exist as a mosaic of two or more associations should be mapped as one unit if they cannot be mapped as separate associations, and should be noted as such. See Section 3.2.5.

- Areas composed largely of outcropping rock such as granite should be mapped as a vegetation unit (eg. lithic complex).

- Lakes, salt pans, large dams etc. should be mapped as separate vegetation units.

- Areas of degraded, modified or cleared vegetation should be mapped and characterised in the same way, and should reflect, for example, the loss of strata, loss of dominant species or changes in species composition. Each distinct unit should be characterised by the dominant species present (if any), in combination with the type(s) of degradation or modification likely to have occurred. See Degraded or Modified Vegetation below for a list of the different types of degradation or modifications.

- Sampling strategies must take into consideration the magnitude of floristic turnover across relatively small distances; for example 15 km in mallee communities (Burgman, 1988) and as little as 10 km in kwongan. It is important that all vegetation units mapped be readily identifiable on the ground, based on structure and dominant floristics.

Each vegetation unit may exist as one or more separate polygons within each reserve and between reserves.

For each vegetation polygon mapped above record the following information in the Access database table:

- Reserve Number;
- Unique polygon number (from the ArcView shapefile);
- The area of the polygon in hectares;
- Where appropriate, a location identifier (each polygon is to be attributed with the sampling location number that corresponds to the vegetation type within that polygon, even though the sampling location may be physically located elsewhere. Each sample site's attributes may therefore be associated with many separate vegetation polygons across many reserves.);
- A Muir vegetation description;
- Any brief comments, including notes on degraded vegetation units, such as the obvious loss of strata or species.

### 3.2.5 Detailed Vegetation Description

For each distinct vegetation association mapped within each reserve a series of floristic, structural and canopy cover measures will be taken to enable the vegetation to be characterized. The information will be collected from a "location" (Muir 1977) within each distinct mapped vegetation association.

Vegetation data will be collected in sufficient detail to enable the vegetation at each site to be described to the "Sub-association" level under the National Vegetation Information System NVIS (Executive Steering Committee for Australian Vegetation Information [ESCAVI] 2003). This requires that the growth form, height, and cover be recorded for up to 5 dominant species and/or for each layer/stratum (up to 8 layers/strata).

At each location record the following:

Vegetation Floristics

Identify up to five dominant vascular plant species to the species and subspecies level (where possible) in each stratum at each location. Dominant species can be defined as the species that contribute the greatest biomass/cover abundance, or indicator/diagnostic species (not necessarily with the greatest biomass).

Record the stratum occupied by each of the species identified above using Table 2 NVIS (sub-)stratum codes and descriptions (ESCAVI 2003:9).

Vertical Structure

or each of the dominant/co-dominant species in each stratum, calculate and record the following:

- Growth form (Table 4 NVIS Structural Formation Terminology (ESCAVI 2003:12).
- Average height; and
- Height class and name Table 3 Height classes defined for the NVIS. (ESCAVI 2003:10)

Vegetation Cover

For each stratum, use the field criteria in Table 16 (McDonald et al 1990, 1998:16) to estimate crown cover class and foliage cover percent. Record a cover class and code for each stratum using Table 4 NVIS Structural Formation Terminology (ESCAVI 2003:12).

A Muir and NVIS classification/description is to be derived from the vegetation data.

Degraded or modified vegetation should also be described using the above methodology. In addition the following attributes need to be recorded:

- The type of degradation or modification to each stratum present (or missing) ie. overstorey, understorey and ground layer (decline/stress, death/loss, regenerating, other [state]);

- For each stratum identify the likely predominant cause of degradation (fungal dieback, waterlogging, salinity, clearing for roaded catchment, clearing for gravel/sand extraction, other clearing, grazing, insect damage, weed invasion, fire, other [state]);

- For degradation or modification caused by waterlogging or salinity, also record whether it's likely to be due to rising watertable, discharge from a constructed drain or altered/impeded surface run-off.

4. References:

Executive Steering Committee for Australian Vegetation Information (ESCAVI) (2003). Australian Vegetation Attribute Manual: National Vegetation Information System Version 6.0. Department of Environment and Heritage.

http://www.deh.gov.au/erin/nvis/publications/avam/pubs/vegetation-attribute-manual-6.pdf

McDonald R.C., Isbell R.F., Speight J.G., Walker J. and Hopkins M.S. (1990). **Australian Soil and Land Survey Field Handbook.** Second Edition (Australian Collaborative Land Evaluation Program, CSIRO Land and Water, Canberra).

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Muir, B.G. (1977). **Biological Survey of the Western Australian Wheatbelt. Part 2: Vegetation and habitat of Bendering Reserve.** Records of the Western Australian Museum Supplement No 3.