Gascoyne Food Bowl Initiative
Identification of Potential Horticulture Land — Carnarvon
Disclaimer

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Background

The identification and development of potential horticulture land to support the expansion of the Carnarvon horticulture precinct is a key deliverable of the Gascoyne Food Bowl initiative which was implemented in 2008 under the Royalties for Regions scheme.

The selection of land for development is under the premise that the land is suitable for sustainable horticulture development such that horticulture production will be economically viable, development will not incur significant on-site or off-site degradation and maximize production from limited water resources.

Factors pertaining to the soil or land that need to be assessed to determine land capability for horticulture include:

- Flooding and soil erosion risk
- Soil drainage
- Soil texture
- Soil constraints (salinity, sodicity, boron toxicity)

Initial soil/land assessment commenced in August 2009 and a draft map indicating potential horticulture areas was produced in February 2010. Further work on land development was disrupted by the 2010/2011 floods.

The 2010 flood was the highest on record and it caused significant soil degradation to the Carnarvon horticulture area and town services. This flood provided the impetus to secure government funding under the Royalties for Regions scheme so that Stage II flood mitigation works could commence. Construction of flood mitigation works began in late 2012 with final completion in June 2014.

The construction and design of the levees along South River Road, North West Highway, McGlades Road and Lawson Street were modified after the initial modelling and proposed works plans produced by SKM.
in 2002. These levee modifications made it necessary to reassess the flood risk on potential horticulture land once the position of the levees were re-established.

Assessment of flood risk by DAFWA made use of historical data compiled by Parr (2003) and soil loss data from the 2000 and 2010/2011 floods, which identified soil loss within individual horticulture blocks (CGFRF unpublished 2010). This quantified data could be referenced to recent digital elevation model (DEM, 2012) to determine areas of high flood risk. Also, as part of the flood mitigation works, flood modelling by SKM (2002) and GHD (2013) provided predicted flood depth and velocity for 1:10 and 1:100 annual exceedance probability interval (AEP) events before and after the construction of the flood levees.

After the review of the 2010 draft soil/land map by stakeholders the LCC committee recommended that land expansion should progress in 3 phases:

1. Make use of current resources on horticulture properties
2. Annexure/amalgamation to extend current land holding boundaries
3. Open unimproved land and water allocations to the market. (GFB, LCC 2010)

The LCC committee also stated that increasing the viable size of existing properties by developing annex blocks was a pressing need and took precedence over the land’s capability for horticulture. It was also the opinion of the LCC that with current technology, land of low horticulture potential such as saline soils could be improved through amelioration and leaching. This view was supported by several growers who have put forward anecdotal evidence suggesting DAFWA’s existing soil mapping and capability ratings did not reflect the lands capability once it was developed. In order to verify these claims and ensure potential horticulture land is productive and sustainable an electromagnetic (EM) survey was undertaken over existing horticulture areas and adjacent un-improved land.

A ground EM survey, which measures soil electrical conductivity, is a cost effective and rapid method of mapping land where soil distribution is difficult to delineate by conventional soil survey methods and where soil constraints such as salinity are limitations to horticulture production. The complex and stratified alluvial soils of the Carnarvon flood plain fit these criteria as most un-improved alluvial soils contain salts within the soil profile (Tille and Smolinski 2003). Low salt levels are associated with the Gascoyne loams while moderate to high salt levels that can limit crop production are associated with medium and heavy textured Gascoyne soils and saline or sodic duplex that belong to the Coburn association (Wells and Bessell-Browne 1990).

Ground EM mapping commenced over potential un-improved land in August 2012 and was completed together with mapping of the existing irrigation area by March 2013. Subsequently, the ground EM data was utilised to verify the aerial EM survey, which was commissioned to aid the location of potential groundwater reserves within the surrounds of the Carnarvon irrigation area and along the Gascoyne River upstream to Rocky Pool. The ground and aerial EM data was compiled to provide an indication of subsoil salt storage in the Carnarvon irrigation area and surrounds (see Appendix 1).

The amalgamated EM map of the Carnarvon irrigation area and surrounds provided a base to identify areas that could be developed for horticulture. The EM map was overlain with existing soil mapping, land contours and SKM and GHD hydraulic modelling so that clearly defined water courses (Class A and B floodways, Parr 2003) were excluded. The resultant areas were reassessed using a decision matrix approach where physical social and environmental attributes were included in the land assessment.
Assessment of flooding and soil erosion

Minor flooding on part of the Carnarvon irrigation area is a common event and is generally accepted by the growers as it ensures recharge of the surficial groundwater aquifer, which the horticulture industry depends on for its existence.

The Carnarvon irrigation area is situated within a flood plain and most horticulture land has a Class C flood classification (Parr 2003) where most of the horticulture land is inundated by floods with 12% AEP (1:8 years or 6.5m + flood depth).

Major flood events that result in significant soil erosion, crop damage and loss of capital infrastructure occurs 1 in 10 years. The last significant flood event of 2010/11 was the highest on record and it was in the order of a 1:100 year event as flood levels had exceeded the 1:100 AEP flood model levels (GHD 2010) on some irrigation properties.

Soil loss from the 2010/11 floods was estimated to be in excess of 160,000m³ from the 160 grower properties within the Carnarvon irrigation area. Approximately 50% of the soil loss was eroded from 11 properties that contained a recognized gully or flow line. Overall, approximately 80% of the soil was lost from annual horticulture blocks. These results are in line with historical trends that were discussed by Parr (2003) who identified areas more susceptible to flooding and the land use practices that increase the risk of soil erosion.

Flooding and soil erosion risk was initially determined by overlaying recent contour information derived from a DEM (DOLA 2012) over potential horticulture blocks. Areas of land that contained flowlines with a cross-sectional fall of more than 1.0m were excluded from the proposed horticulture blocks if the land was not protected by a flood mitigation levee.

Each potential horticulture block was visually assessed for evidence of floodways and water erosion by a senior soil conservation officer (Keen, unpub. 2013) and also traversed by soil survey officers during soil assessment and EM survey (Smolinski et al in progress. 2015). Flood risk was finally cross checked against the 1:10 AEP an 1:100 AEP flood depth and water velocity model (GHD, 2010) to ensure Class A and B floodways were excluded and predicted flood levels were not higher compared with adjoining horticulture land.

The flood risk for the proposed expansion areas is likely to be similar to the adjacent developed land, provided that flow lines and flood channels are not cleared for horticultural development.
Soil/land assessment

The Carnarvon horticulture precinct is located on the Gascoyne River delta. Most horticulture soils are developed from alluvial sediments which have been deposited on terraces that extend approximately 1km on either side of the river. The alluvial soils or Gascoyne soils can be broadly categorized as light, medium and heavy textured soils (Wells and Bessell-Browne 1990). Gascoyne light soils (Gl) have a sand to sandy loam soil texture throughout the soil profile; Gascoyne medium (Gm) have loam to clay loam and Gascoyne heavy (Gh) soils have silty clay to light-medium clay soil textures.

The Gascoyne river channel has changed its course many times in the past so that today the soils are highly variable and stratified (i.e. various sediments ranging from coarse river sands to dark brown saline clays that were originally formed in salt lakes can be found buried in the soil profile).

The Gascoyne soils have developed within an arid environment where mean annual rainfall is <300mm and evapotranspiration is excess of 2500mm/yr. Because there is reduced leaching under native vegetation, salts including sodium chloride, carbonates and calcium sulphates (gypsum) accumulate within the soil profile. After clearing, light textured Gascoyne soils contain negligible soluble salts in the root zone, as it is usually leached under the current rainfall regime to a depth of at least 150cm while in heavy textured soils, salts as well as high levels of boron can occur within 60cm.

Bordering the alluvial terraces on older alluvial benches are Gascoyne and Coburn soil associations (GC1, GC2 and GC3). These are transitional soils that occur on the edge of the main alluvial terraces where minor river channels have deposited alluvial sediments over the back-plains. Soils are commonly shallow to moderately deep loamy sands, loams and clay loams overlying buried Coburn soils. Gascoyne/ Coburn soil associations have a moderate to low capability for horticulture depending on the depth and drainage of the soil profile.

Back plains and depressions contain soils belonging to the Coburn Association (C, Ce1, and Ce2). Coburn soils are commonly red to dark brown alkaline duplex soils or clay loams. Coburn soils are usually excluded from horticulture development as they are imperfectly drained and subsoil horizons are typically saline and strongly sodic.
Existing soil mapping of the Carnarvon irrigation area is semi-detailed and inadequate to delineate the complexity of the alluvial soils. For example, growers have indicated that some soils that were originally mapped as being saline can be improved through amelioration and leaching while other soils still remain saline after decades of gypsum application and irrigation.

To assess the accuracy of the existing soil maps and determine why some soils do not respond to amelioration a ground EM survey, using Geonics EM38, was conducted over potential horticulture land. Approximately 2000ha was surveyed between July-September 2012. The surveyed area was traversed on foot by two surveyors using portable EM 38 and hand held GPS.

Soil apparent electro-conductivity (ECa) was recorded in the horizontal and vertical dipole mode on a 100x50m to 200x100m grid depending on the uniformity of ECa values and the vegetation cover. EC Data and GPS co-ordinates were recorded manually and transcribed to Windows Excel.

Soil conditions were consistently dry during the survey and the Geonics EM 38 instruments were calibrated each day in an area of low conductivity on the Carnarvon Research Station.

During the EM survey, a second team of soil surveyors described and sampled 72 soil profiles within the survey area and adjacent horticulture land. Soil profiles were described and sampled in the upper 150cm using a percussion rod or hand auger. Twenty six sites were also auger drilled to 3-8m to determine the texture and salinity of the subsoil.

A ground EM survey was conducted over 1500ha of the established irrigation area between January and March 2013. This was undertaken to determine the salinity status of the irrigation area in relation to potential horticulture land and how well soil conductivity is related to the existing soil mapping. The information could also be used by growers to identify paddock variability, gypsum responsive soils and aid irrigation design, soil nutrient sampling and crop selection.

Fallowed horticulture blocks and plantation inter-rows were surveyed using a sled mounted EM38 which was dragged behind an all-terrain vehicle with transects spaced between 30-50m. ECa data in the horizontal dipole mode and GPS locations were logged using a Campbell’s Scientific CR850 logger at 2-4m intervals, travelling at <10km/hr. Over 230,000 EC data points were collected.

To correlate EM38 ECa values with actual soil EC, soil samples were field tested at 72 soil observation sites. In addition, soil profile core samples from 51 soil observation sites were collected between 0-60cm for EC 1:5 analyses. This data was use to compare soil EC 1:5 with EM38 ECa in the horizontal dipole mode (equivalent to 0-60cm depth range).
Development of ground EM maps

Data was imported into single ArcGIS feature consisting of approximately 235,000 points (Table 1). All logged EC data was converted to mS/m units. Extreme data values (<0 and >199) and spatial outliers were excluded (i.e. extreme values were associated with dump sites, gravel deposits, road or metallic infrastructure).

An EM38 conductivity surface layer was produced from the point data using ArcGIS kriging interpolation tools. Kriging is a statistical interpolation method that analyses the spatial variation of point data to produce an optimal interpolation surface. This is particularly useful when data points are sparse. This method is described by O’Sullivan and Unwin (2003).

Ordinary kriging, using a spherical model, was used based on 12 nearest neighbours to a maximum search radius of 150m. 79% of interpolated cells were within 50m of a sample point.

A 30m interpolation layer was created and clipped to an area approximating the sampling area (Fig 1). The surface was classified with 8 conductivity classes: 0-20, 20-40, 40-60, 60-80, 80-100, 100-120, 120-140 and 140-190.

Table 1. Range of conductivities from drill and sled EM38 point data

<table>
<thead>
<tr>
<th>EM range (mS/m)</th>
<th>n</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-25</td>
<td>158,521</td>
</tr>
<tr>
<td>25-50</td>
<td>57,343</td>
</tr>
<tr>
<td>50-100</td>
<td>14,841</td>
</tr>
<tr>
<td>100-150</td>
<td>3163</td>
</tr>
<tr>
<td>150-200</td>
<td>1536</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>235,404</strong></td>
</tr>
</tbody>
</table>
Figure 1. EM38 interpolated surface produced from point data
Soil EC analysis

Figure 2 presents the correlation between the EM38 ECa with actual mean soil EC for the 0-60cm depth range. The correlation is highly significant and indicates 76% of the variation in the EM38 survey data can be attributed to soil EC. Other factors that influence ECa are soil density, clay content, soil mineralogy, metallic interference (netting, cables and wire trellising) and soil moisture. Note: under an arid environment soil clay content and soil density are generally strongly correlated with soil conductivity (EC) as these factors often restrict drainage resulting in the accumulation of salts.

Field observations suggest table grape trellising that has a 3m row spacing increases ECa by 5-10mS/m above background levels while observed ECa differences due to soil moisture variation, in perennial horticulture blocks, is also within this range. These observations suggest EM maps can be used to identify ‘in paddock’ soil EC and soil texture variability provided paddock management was uniform at the time of survey.

Data from Figure 2 also indicates that ECa underestimates soil ECw on highly saline sites. This variation can be mainly attributed to initial calibration of the EM38 on more resistive light textured Gascoyne soils which were more commonly encountered within the survey area. This procedure was necessary to avoid negative ECa readings but resulted in restricting the ECa upper limit to below 200mS/m.

Through discussions with several growers and subsequent field EC tests it is apparent that light to medium textured Gascoyne soils can be leached of excess salts after 1-3 years through irrigation and the application of gypsum. Poorly structured, heavy textured soils can be successfully reclaimed over time particularly if sand or loam lenses occur within the subsoil. However, reclamation was limited or very slow if heavy textured soils are deep (>2m). Deep heavy textured soils are usually saline/ sodic, poorly structured with slow internal drainage. Even after amelioration with gypsum and leaching under irrigation these soils, particularly duplex soils, are comparatively less productive than loams with a 25-50% yield loss being realized for many crops (George and Wren 1985).

To ensure production levels are not limited by soil salinity, areas having soil EC values >100mS/m (as determined from the EM mapping) are not recommended for horticulture development. This assumes that soil EC on these un-improved soils with soil EC of up to 100mS/m can be successfully leached to EC levels below 30mS/m (1:5 H₂O) within the root zone. i.e. <10% yield decline would be expected for most annual horticulture crops growing on loam having an EC of <30mS/m (George and Wren 1985).

Figure 2.  Soil ECw vs EM38 ECa in horizontal dipole mode
Relationship between existing soil maps and EM

Figure 3 illustrates the soil complexity and variability of soil electro-conductivity within alluvial soils. Areas of dark blue indicate very low soil conductivity (very low salinity) while areas coloured yellow have a high soil conductivity (high salinity) e.g. soil site GFB062 has an EC of 30mS/m within 60cm while soil site GFB 025 has an EC of 170mS/m at the same depth.

EC maps provide a method of quantifying soil capability for horticulture. The spatial variation of soil EC can be attributed to a combination of soil texture, buried soil horizons, soil internal and external drainage which influence salt storage in the soil profile.

ECa maps of the Carnarvon irrigation area and potential irrigation blocks are presented in Appendix 1.

Potential horticulture blocks were only selected from areas having capability ratings of I-III. Areas of land with horticulture capability ratings of IV or V were excluded due to major production limitations or risk of degradation. Capability rating tables (see Table 2a and 2b) list the soil/land factors used to derive the capability ratings. The soil/land factors were adapted from Wells and Bessell-Browne (1990) and Tille and Smolinski (2003). The capability ratings assigned to each potential horticulture block have been derived from the most limiting land quality.
Figure 3. Comparison between existing soil mapping and EM
### Table 2a. Land quality/land capability ratings table for annual horticulture

<table>
<thead>
<tr>
<th>Land quality</th>
<th>Capability rating for annual horticulture</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>I</td>
</tr>
<tr>
<td>Soil conductivity ECa mS/m</td>
<td></td>
</tr>
<tr>
<td>0-20</td>
<td>20-40</td>
</tr>
<tr>
<td>Readily available water (mm/m)</td>
<td>&gt;150mm</td>
</tr>
<tr>
<td>(silt loam-silty clay loam)</td>
<td>(sandy loam-clay loam)</td>
</tr>
<tr>
<td>Height above MSL</td>
<td>&gt;6m</td>
</tr>
<tr>
<td>Drainage channels</td>
<td>No drainage channels</td>
</tr>
<tr>
<td>Soil workability</td>
<td>Loamy fine sand-loam</td>
</tr>
<tr>
<td>Waterlogging/inundation risk</td>
<td>Well drained light to medium textured soils</td>
</tr>
</tbody>
</table>
* Surface drainage is a necessary prerequisite of development

### Table 2b. Land quality/land capability ratings table for perennial horticulture

<table>
<thead>
<tr>
<th>Land quality</th>
<th>Capability rating for annual horticulture</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>I</td>
</tr>
<tr>
<td>Soil conductivity ECa mS/m</td>
<td></td>
</tr>
<tr>
<td>0-20</td>
<td>20-40</td>
</tr>
<tr>
<td>Readily available water (mm/m)</td>
<td>&gt;150mm</td>
</tr>
<tr>
<td>(silt loam-silty clay loam)</td>
<td>(sandy loam-clay loam)</td>
</tr>
<tr>
<td>Height above MSL</td>
<td>&gt;6m</td>
</tr>
<tr>
<td>Drainage channels</td>
<td>No drainage channels</td>
</tr>
<tr>
<td>Soil workability</td>
<td>Loam-sandy loam</td>
</tr>
<tr>
<td>Waterlogging/inundation risk</td>
<td>Well drained light to medium textured soils</td>
</tr>
</tbody>
</table>
* Surface drainage is a necessary prerequisite of development
Land expansion and potential horticulture areas

1.1 FREEHOLD LAND

Following the recommendations of the LCC to consider “making full use of current resources” an assessment was made of present land use trends within the irrigation area. A visual comparison of annual and perennial horticulture land areas was determined from 2009 and 2012 aerial photography. Areas of land that were under annual and perennial crop or recently cultivated were compared with fallow and un-improved land for each year. Results indicate that within the Carnarvon irrigation area (total of 2000ha), approximately 1500ha is under crop each year. Areas that were not utilised included 175ha of un-improved land that occurs within drainage lines, saline land (determined from EM survey) or has other uses such as infrastructure or storage of plant. Thus, on average, 18% of land area is not utilised each year. This would be expected as some consideration must be made for crop fallow and other management and social issues. It is unlikely that significant areas of undeveloped freehold land will be developed for horticulture in the future.

1.2 ANNEXURE/AMALGAMATION

Land was assessed for potential annexure adjoining existing properties along North River Road and north of McGlades Road. Few potential annex blocks were identified north of North River Road as most existing horticulture blocks abut major drainage lines or highly saline soils (see EM maps, attached). Approximately 200ha of potential horticulture land was identified north of McGlades Road. Part of this area could be subdivided into approximately 15 annex blocks of 3–5ha and either several larger subdivisions.

1.3 EXPANSION AREAS

Potential horticulture areas A-D are identified in Figure 4 and a description of each potential horticulture block and its horticulture capability ratings for annual and perennial horticulture are provided in Table 3.

1.3.1 Area A

This area is relegated to future consideration as existing horticulture blocks adjacent to Area A are of viable size. These blocks were part of an earlier annexure development to maintain productive land units on the proviso that land along Sheridans Gully would be taken out of production and made part of a drainage corridor. Other factors and limitations that were considered in the assessment of Area A are:

- Blocks in area A are predominantly sandy with sand or loamy sand textures that have low water holding capacity
- Drilling identified shallow saline groundwater in this area, which is also verified by the aerial EM.
- Higher flood risk due to low elevation (<5m).
- Reticulated water supply infrastructure to support development within Area A may require upgrading i.e. larger pumping capacity to maintain sufficient head (Ivor Gaylard, August 2013, pers. comm.).

1.3.2 Area B

Areas B is dissected by a major drainage line and associated flow lines. Several potential development areas have a moderate capability for horticulture. Most blocks can be accessed from North River Road or Bibbawarra Bore Road although drainage line crossings would be required to access Blocks B3 and B7.

Blocks B1 and B2 are currently excluded from development for similar limitations as described for Area A.

Block B8 is designated for annexure however parts of this block may not be developed as it contains sandy soils.
1.3.3 Area C
This area contains light to medium textured Gascoyne soils that can be utilised for annexure and expansion blocks. Major drainage lines have been excised from potential development blocks.
Block C5a contains minor flow lines however the McGlades Road levee should limit overland flow and reduce flood height and velocity in most of Area C.
Blocks C2, C3 and C4b are earmarked for annexure while blocks C1, C4a and C5a could be developed as new expansion blocks.

1.3.4 Area D
This area contains Gascoyne Gm and Gh soils that have clay loam or clay topsoils overlying lenses of alluvial loam or sand. These soils are slightly to moderately saline however, salt levels could be reduced through leaching and amelioration with gypsum. Highly saline areas have been excised from potential expansion blocks (D1 and D2).
Both blocks contain burrow pits and flow lines that would require fill and land grading to divert flow west to the drainage channel adjacent to Giles Road. Management of surface water is a necessary development requirement to reduce the risk of inundation.

1.3.5 Area E
Area E contains three potential expansion blocks between Lawson St and the Gascoyne Junction Road. GHD modelling (2013) indicates the levees situated on the east and southern boundaries should reduce flood levels.
Block E1 contains light to medium textured Gascoyne soils. Land grading would be required to fill and level a minor flow line and depression area.
Block E2 and E3 mainly contain medium textured Gascoyne soils that have slight to moderately saline subsoils. These soils can be improved by amelioration with gypsum.
Figure 4. Potential horticulture areas
<table>
<thead>
<tr>
<th>Area id</th>
<th>Area (ha)</th>
<th>Annual capability</th>
<th>Perennial capability</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>72</td>
<td>III</td>
<td>III</td>
<td>Future consideration. Predominantly light textured Gascoyne soils with loamy sand topsoil. Lenses of coarse sand can be encountered in the subsoil. These soils have low water holding capacity. Includes sand dunes and unused abattoir complex, waste pits and dump sites. Approximately 42ha.</td>
</tr>
<tr>
<td>B1</td>
<td>20.3</td>
<td>III</td>
<td>III</td>
<td>Exclusion Medium textured Gascoyne soils and includes GC association duplex soils that have saline subsoils. Surrounded by flow lines. Excluded due limited access.</td>
</tr>
<tr>
<td>B2</td>
<td>35.3</td>
<td>III</td>
<td>III</td>
<td>Exclusion Light to medium textured Gascoyne soils and includes GC duplex soils surrounded by flow lines. Excluded due limited access.</td>
</tr>
<tr>
<td>B3</td>
<td>97.1</td>
<td>II</td>
<td>II</td>
<td>Land expansion block. Medium textured Gascoyne soils. Moderately saline subsoils can be encountered along northern boundary.</td>
</tr>
<tr>
<td>B4</td>
<td>6.9</td>
<td>II</td>
<td>II</td>
<td>Land expansion block. Light to medium textured Gascoyne soils. Loamy sand or clay subsoil maybe encountered within 100cm. Borders minor drainage line.</td>
</tr>
<tr>
<td>B5</td>
<td>14.9</td>
<td>II</td>
<td>II</td>
<td>Land expansion block. Light to medium textured Gascoyne soils. Loamy sand or clay subsoil maybe encountered within 100cm. Contains minor drainage line and borders saline area.</td>
</tr>
<tr>
<td>B6</td>
<td>12.1</td>
<td>II</td>
<td>II</td>
<td>Land expansion block. Light to medium textured Gascoyne soils. Moderately saline subsoils can be encountered along northern boundary.</td>
</tr>
<tr>
<td>B7</td>
<td>46.4</td>
<td>II</td>
<td>II</td>
<td>Land expansion block. Light to medium textured Gascoyne soils. Moderately saline subsoils can be encountered along boundary areas. Surrounded by drainage lines which may limit access.</td>
</tr>
</tbody>
</table>
Table 3. Land quality/land capability ratings table for perennial horticulture

<table>
<thead>
<tr>
<th>Area id</th>
<th>Area (ha)</th>
<th>Annual capability</th>
<th>Perennial capability</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>B8</td>
<td>24.8</td>
<td>II-III</td>
<td>III-IV</td>
<td>Annexure or land expansion blocks. Sand dune and medium textured Gascoyne soils. Sand dune areas have a low water holding capacity that can limit production of perennial crops particularly bananas.</td>
</tr>
<tr>
<td>B9, B10, B11</td>
<td>30+</td>
<td>II</td>
<td>II</td>
<td>Exclusion Light to medium textured Gascoyne soils. Areas have been excluded due to access and dissection by drainage lines.</td>
</tr>
<tr>
<td>B12</td>
<td>8.1</td>
<td>II</td>
<td>II</td>
<td>Land expansion block. Light to medium textured Gascoyne soils. Sand or clay substrate maybe encountered within 100cm.</td>
</tr>
<tr>
<td>B13</td>
<td>6.7</td>
<td>II</td>
<td>II</td>
<td>Annexure or land expansion block. Light to medium textured Gascoyne soils. Sand or clay substrate maybe encountered within 100cm. Contains minor drainage line.</td>
</tr>
<tr>
<td>C1</td>
<td>11.8</td>
<td>II</td>
<td>II</td>
<td>Land expansion block. Medium textured Gascoyne soils. Silt loam topsoil. Clay loam or light clay may be encountered below 100cm. Contains minor areas with moderately saline subsoils.</td>
</tr>
<tr>
<td>C2</td>
<td>6.8</td>
<td>II</td>
<td>II</td>
<td>Annexure Medium textured Gascoyne soils. Silt loam topsoil. Clay loam or light clay may be encountered below 100cm. Contains minor areas with moderately saline subsoils.</td>
</tr>
<tr>
<td>C3</td>
<td>7</td>
<td>II</td>
<td>II</td>
<td>Annexure Medium textured Gascoyne soils. Silt loam topsoil. Clay loam or light clay may be encountered below 100cm. Flood risk is reduced after construction of the McGlades road levee.</td>
</tr>
<tr>
<td>C4a</td>
<td>11.3</td>
<td>II</td>
<td>II</td>
<td>Land expansion block Medium textured Gascoyne soils. Silt loam topsoil. Clay loam or light clay may be encountered below 100cm. Flood risk is reduced after construction of the McGlades road levee.</td>
</tr>
</tbody>
</table>
### Table 3. Land quality/land capability ratings table for perennial horticulture

<table>
<thead>
<tr>
<th>Area id</th>
<th>Area (ha)</th>
<th>Annual capability</th>
<th>Perennial capability</th>
<th>Description</th>
</tr>
</thead>
</table>
| C4b     | 16.4      | II                | II                   | Annexure  
Medium textured Gascoyne soils. Silt loam topsoil. Clay loam or light clay may be encountered below 100cm. Flood risk is reduced after construction of the McGlades road levee. |
| C5a     | 153.1     | II                | II                   | Land expansion blocks.  
Light to medium textured Gascoyne soils. Clayey fine sand to silt loam topsoil. Clay loam or light clay may be encountered below 100cm. Flood risk is reduced after construction of the McGlades road levee. Contains areas of moderately saline subsoils along northern boundary. |
| C5b     | 14        | II                | II                   | Annexure and land expansion block.  
Light to medium textured Gascoyne soils. Clayey fine sand to silt loam topsoil. Clay loam or light clay may be encountered below 100cm. Flood risk is reduced after construction of the McGlades road levee. Contains drainage lines that may require fill. |
| D1      | 45.3      | III               | III                  | Land expansion block.  
Medium and heavy textured Gascoyne soils containing minor areas of saline clay and Coburn soil. Sand lenses occur in the subsoil. Protected by the levee however surface drainage is required. |
| D2      | 42.2      | II-III            | II-III               | Land expansion block.  
Predominantly medium textured Gascoyne with secondary heavy Gascoyne soils containing minor areas of saline clay and Coburn soil. Sand lenses occur in the subsoil. Protected by the levee however surface drainage is required. |
| E1      |           | II                | II                   | Land expansion block.  
Light to medium textured Gascoyne soils. |
| E2      |           | II                | II                   | Land expansion block.  
Medium textured Gascoyne soils. |
| E3      |           | II                | II                   | Land expansion block.  
Medium textured Gascoyne soils. |
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APPENDIX 1 AEM and EM38 compilation map of the Carnarvon horticulture area and surrounds