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About the Gascoyne Food Bowl Initiative

The Gascoyne Food Bowl Initiative (GFBI) was established in 2012 to increase horticultural production in the Carnarvon horticulture district by developing an additional 400 hectares (ha) of new land, sourcing 4GL of new water and installing the necessary infrastructure to efficiently deliver the water into the Gascoyne Water Cooperative (GWC) system.

The Department of Agriculture and Food, Western Australia (DAFWA) was chosen as the lead agency of the 4-year, $25 million state government’s Royalties for Regions program.

The Carnarvon horticulture district supplies about 70% of Perth’s winter fruit and vegetables, with a current average gross value of $85 million in annual production.

The GFBI will add more than $34 million per year to the economy by providing access to land, availability of water and infrastructure to boost horticultural production.
The GFBI had four major outcomes:

1. **Source an additional 4 gigalitres (GL) of water for horticulture**
   - Conduct airborne electromagnetic (AEM) surveying and drilling to identify the location, quantity and quality of aquifers to enable delivery of the expansion.
   - Install a new borefield able to extract at least 400L/s and deliver an annual demand of at least 4GL (see Figure 1, page 6).

2. **Infrastructure**
   - Borefield electrification
     - Select a power system capable of delivering 22000 volts while minimising resistance loss.
     - Design and construct a high voltage powerline to the existing northern (0–11.5 kilometres [km]) borefield to replace the existing GWC diesel powered generator pumping system.
     - Extend the new high voltage powerline from the GWC borefield to the new GFBI borefield (11.5–25km) (see Figure 1, page 6).
   - Water Delivery System
     - Design and install a collector main pipeline to deliver water into the existing GWC distribution system from the new borefield.

3. **Develop additional horticultural land**
   - Identify at least 400ha of additional land suitable for horticulture; Taking into account suitability of soil, potential impact of flooding and the proximity of existing infrastructure to the land selected.
   - In conjunction with the Shire of Carnarvon develop an Irrigated Agriculture Structure Plan (IASP) and makes necessary amendments to the Carnarvon Town Planning Scheme.
   - Undertake all necessary studies over the proposed new land areas.
   - Submit adopted IASP to the Western Australian Planning Commission for endorsement.

4. **Natural Resource Management**
   - Investigate the impact of practices within the catchment area on river flow quality and quantity.
   - Gain a better understanding of the Gascoyne River occasional brackish flows and their impact on the borefields.
   - Improve understanding of climatic conditions further east of the horticultural district and of watering frequency and duration to promote best practice in water use efficiency.
   - Undertake economic analysis and research to establish the impact on existing market values if any and identify potential export markets.
Figure 1. Borefields area in Carnarvon horticulture district
Did you know?

- The Gascoyne River is the longest in Western Australia and its water supports 1550ha of irrigation at Carnarvon that produces $85m in annual production.

- Irrigation from private bores in alluvial aquifers has been undertaken in Carnarvon since 1928.

- Expansion of the borefield to 50km upstream began in the 1960s, at first on the south side of the river. This system supplies town water and contributes to irrigation.

- Development of the first phase of the Northern borefield was completed by Department of Agriculture and Food in 2010, and is now managed by a Gascoyne Water Cooperative (GWC). In 2012, DAFWA commenced the Gascoyne Food Bowl Initiative (GFBI) to establish the second phase of the Northern Gascoyne River borefield to source 4GL/a of water, add relevant infrastructure and grow agriculture by at least 400ha.

- The $25m GFBI includes installation of new bores, infrastructure and natural resource management to enable land and/or production expansion.

LEFT: 3D printed block model of the Old Alluvium (two blue layers), underlying geology (orange is low permeability clays) and overlaying green are dry soils above watertable.
GFBI achievements

- Initiated the project with an emergency drilling program to install four production bores to support growers through the 2013 drought.

- Used airborne electromagnetics (AEM) to install 35 production bores, with a higher success rate and yield than previous programs of drilling.

- Proved sustainable water resources to enable an additional 4GL per year (GL/y) to be allocated to 400ha expansion of the Carnarvon horticulture district.

- Drilled two additional bores to increase the capacity of growers in the existing Northern borefield.

- Drilled a further six production bores and tested expansion options to allow planning for a third and final phase of Northern borefield to enable up to 2GL to be added.

- Installed horizontal water bores called ‘Sand Spears’ in the Gascoyne River bed capable of monitoring and accessing water during periods of flow and post flow for either irrigation use or artificial aquifer recharge.

- Installed a 24km, large diameter collector main pipeline, and a powerline, to connect all of the GFBI bores and allow diesel generators operated by GWC to be replaced with a more cost efficient and reliable electrical supply; Making it possible to be ‘looped’ to the southern borefield allowing for segmented maintenance shut downs without having to shut down the entire system.

- Undertook prefeasibility for Managed Aquifer Recharge to augment the aquifer supplies using the Sand Spears by an additional 2–3 GL/a.

- Built a new groundwater model based on improved knowledge to allow approval for the allocation of 4GL/y for expansion.
Surveyed and made available in excess of 400ha of land for release with high quality soils with low flood risk to market with water from the GFBI infrastructure (see Figure 2 below).

Figure 2. Proposed horticulture area for release
Background

The Carnarvon horticulture district is 900km north of Perth. It grows a wide range of crops with a gross value of $85 million per year, mainly for the Perth domestic winter market, specialising in horticultural crops including tomatoes, capsicums, beans, bananas and grapes.

The Carnarvon horticulture district consists of about 1550ha of irrigated land and uses groundwater sourced from recharge of the ephemeral Gascoyne River.
Water sources

Generally growers preferentially use private bores located adjacent to Carnarvon with an allocated yield of 6.1GL/y. However in periods of peak demand, or dry periods, or when the Gascoyne River occasionally carries brackish flows, growers transition to use of the Scheme water supply.

The piped scheme is supplied from two borefields, one on the South and the other to the North of the River, and excluding Town Water, can source up to 12.6GL/y of groundwater. Five GL/y is sourced for irrigation from over 40 bores on the southern borefield and presently operated by Water Corporation and 3.6GL/y is allocated from the Phase I Northern Gascoyne River (NGR) borefield established by DAFWA in 2010 and now managed by GWC. Accessing another 4GL/y of irrigation water on the Northern side of the River was a key deliverable of the GFBI project.

Water and infrastructure development

The GFBI Phase 2 area lies east of the Phase 1 GWC borefield from 11.5 to 24.5km from the nearest irrigated land (see Figure 1, page 6). To achieve the required 4GL/y of water for expansion, DAFWA was required to substantiate the availability of 3.3GL/y which had been allocated for irrigation through the Lower Gascoyne Water Allocation Plan, and prove that an additional 0.7GL/y could be sustainably extracted.

As part of the project DAFWA also investigated water resources further to the east referred to as Phase 3 NGR borefield, to underpin any potential future phase of expansion. It also undertook investigations and drilling to support GWC to locate and install greater production capacity in the existing Phase 1 Northern borefield to enable them to access their full allocation.
Finding the water?

In 2013, DAFWA commissioned an airborne electromagnetic survey (AEM) to guide groundwater investigations, borefield design, aquifer modelling, and better understand the two primary alluvial aquifers and find any others at depth.

In collaboration with CSIRO, a helicopter-based SkyTEM AEM, was flown to locate target bore sites. The AEM was interpreted and areas of lowest conductivity identified as targets. The resulting maps were compared to areas with known aquifer conditions assessed during previous drilling programs.

The AEM maps identified likely targets areas on both sides of the river, with most in the new GFBI Phase 2 area. The best AEM targets (71) were prioritised according to likely success. Figure 3 below shows the basis of target selection. Another 43 lower priority sites were selected along the pipeline route to allow additional water to be accessed, to better understand the aquifer, or enable improved monitoring locations (see Figure 4, page 13).

In addition to drilling for water in the Older Alluvium, three deeper bores were drilled to define the thickness and salinity of the deeper aquifer (Cardabia Formation; marine sands in Phase 3 — see yellow layer in the 3D printed model, page 6) and one went to 130m into the Toolonga Formation (marine shales and sands in Phase 1 area).

All exploration holes and production bores were geologically logged and sampled. Exploration bores were drilled at every AEM target and most equipped as monitoring bores. Production bores consisted of 200mm stainless steel screened casing installed close to the monitoring bore for later testing.

Figure 3. 3D map of AEM conductivity in the Older Alluvium; saline coast (left) and Rocky Pool (right). Blue is fresh and or sandy aquifers
Figure 4. Borefields showing existing bores (black) with new GFBI bores (red) on AEM — best aquifers (blue) to least likely aquifers (white)
What was found

Exploration drilling at 71 of the Northern borefield AEM target sites started in September 2014 with multiple aircore and mud-rotary drilling rigs operating on the borefield. Over 7000m of alluvial sediments were drilled and logged.

Of the 71 exploration sites drilled, 20 of the 25 best targets were defined by the AEM as suitable for production bores and were developed with 200mm stainless steel casing and subsequently aquifer tested. This AEM enabled a 70-80% success rate. For the lower priority sites, the success rate ranged from 40-50%.

Prior to acquiring the AEM, all Gascoyne River drilling programs achieved a success rate of 1 in 5 bores, whereas we delivered one production bore from every 1-2 exploration holes.

The Phase 2 program’s average yield was 17L/s per bore. This yield is higher than previous programs (10 L/sec) and reflects AEM-selected targets were at sites with more sand and gravel and less clay and silt.

In 2016, a second stage of drilling was completed that included drilling and testing bores in the Phase 3 area, increasing supply capacity for GWC (Phase 1) and also exploring the deeper aquifers.
Increased installed capacity

Collectively across the GFBI program (2013–16), 43 production bores were installed from 64 recommended sites, with five beneath the minimum target yield of 5L/sec. Together the installed GFBI bores have a combined maximum instantaneous yield of almost 700L/s. By area the results are:

- **Phase I (GWC) Northern borefield**, twelve targets were assessed and nine recommended for drilling. Of those nine sites, six were converted to production bores with a combined yield of 70 L/s.
- **Phase (GFB) Northern borefield** contained 83 targets, of which 35 were recommended and converted, and are capable of combined production of 580L/s.
- **Phase 3 (potential) Northern borefield**, comprised 28 targets, of which 20 were recommended and six have been converted, comprising production of 50L/s.

The completed capacity of the Phase 2 NGR borefield (580L/s) exceeded the required 400L/s to meet peak demand for the new 400ha area. This was mainly because the bores produced higher yields than forecast. Some additional bores were also drilled to enable optimisation based on impacts of drought, changes in river salinity and operational factors, such as bore maintenance.

Added capacity when the river flows

The GFBI investigated, designed and installed a system to harvest shallow groundwater from within the River Bed Sand aquifer during periods of river flow and also shortly after the flow ceases. Known as topwater optimisation, the spears involve installing horizontal bores at the base of the river bed sands at least 2–3m below the ground to harvest water when the sand is saturated. Use (when approved) of this water is unrestricted until the river flow ceases — similar to arrangements for private bores in Carnarvon.

Sites contain 48m of 200mm diameter stainless steel screen buried into the clay base under the river sands, and flood-resistant concrete liners. Water from the horizontal bores is conveyed up the river bank by a submersible pump located in the liners, from which flows are monitored and delivered to the collector main.

Design flows of up to 200L/s are available from this system, allowing the borefield to be rested and potentially, as part of future investigations, water could be injected into the aquifer as a means to augment recharge and amend water quality.

Installing the screens and collection well in the river bed for water harvesting of the sands.
Testing 4GL/y for delivery

To demonstrate that the aquifer could sustain production of 4GL/y from the Phase 2 NGR borefield, AEM and drilling results were tested in a computer model. The model chosen was developed for the Gascoyne River and updated to with GFBI data.

The model evaluated five pumping scenarios, tested over two climate–river recharge conditions. The first was for the period 1990–99, representing a sequence of close-to-average years, characterised by frequent low-to-medium flows. The second period was 2000–14, a period of infrequent flows (dry period) punctuated by large floods and brackish low-flows events.

These five scenarios focussed on new demands of the GFBI borefield and evaluated the potential for using water from the proposed NGR Phase 3 borefield. The model determined that extracting 4GL/y from the NGR Phase 2 borefield could be conducted without sustained aquifer depletion for the regular flow period, based on existing usage patterns from the Southern borefield and current allocated use from the GWC borefield (up to 20GL/y). For the infrequent flow period, total annual extraction (up to 20GL/y) lowered accessible storage by up to 50GL, at the end of the 15-year period modelled (see Figure 5).

The 50GL storage decline at the end of the 15-year drier period needs to be seen in the context of the amount of aquifer storage, water levels and the aquifers’ ability to be recharged. Using the AEM, we estimate the main aquifer (Older Alluvium) contains about 1090GL of low salinity water (<1000mg/L) and therefore annual use of 20GL/y and maximum 50GL storage decline represents about 2–5% of the total storage. For water levels, a typical decline of 5–10m is created adjacent to the bores and depends on whether only a few large flow bores or the entire wellfield is pumped.

Water level loggers in bores installed after the large flood in 2010 and a moderate flow at the end of 2014 were matched to model predictions. Levels showed an immediate response to river flows and substantial recovery of storage, and that levels were still rising 3km away from the river up to three years after the flood.

Similarly, DAFWA evaluated the response to brackish low flows monitored after 2011 and in 2014. The salinity of 41 Water Corporation bores recorded between 2000 and 2014 showed that only bores within the river and those close by its banks (< 200m) were affected. While these observations are consistent with the understanding of aquifer behaviour and supported by the model used, further monitoring and testing will be required assess the effect of frequent brackish flows in the longer term.

Figure 5. Model results at the end of the 15-year dry period
**Designing the pipeline**

The GFBI pipeline design was based on several factors, including forecast crop requirements, borefield capacity, optimised pipe size and energy requirements.

**Crop requirements**

Crop water demand scenarios were forecast from existing crops, particularly bananas (a perennial known for its high water use of about 20 megalitres per hectare [ML/ha]), tomatoes (an annual crop with multiple planting dates that uses 9–12ML/ha) and other crops (citrus, mangoes, rockmelons, cucumbers).

Based on this analysis, we concluded the optimum peak flow requirement to be delivered to the farm gate was 1L/s per hectare irrigated. Further we concluded that rather than increase the peak flow (pipe size), growers could adopt on-farm storages (up to 250 kilolitre tanks), to buffer demand in extended hot periods.

**Pipe and energy**

The final design phase involved testing pipeline variables including material type, diameter, pressure, cost and operability with the existing Phase 1 GWC borefield and Carnarvon mainlines.

The design chosen was for high density polyethylene (HDPE PN6.3) pipe, reducing from 900mm diameter in the west to 560mm in the east, at 24.5km. The design adopted a larger pipe diameter to maintain a hydraulic grade line that significantly reduces annual energy use and operating cost.

The pipe design can also support additional water from any potential Phase 3 NGR borefield if required. This would allow either spreading the draw of the GFBI 4 GL/y across a longer length of river or adding another 2 GL/a to the supply system (i.e. 6 GL/y). It will not allow peak flows to be increased above maximum rating (~440 L/s) set by the size and wall thickness of the HDPE pipe chosen.
Engineering to sustain the aquifer

As a consequence of the success of the drilling (580 L/sec installed capacity), DAFWA does not need to plan to equip all 35 Phase 2 production bores to deliver 400L/sec. This left at least 10 production bores available for alternative use, such as Managed Aquifer Recharge. An assessment of the use of the Sand Spears to allow injection (low pressure) of treated river water into these high permeability production bores was carried out. Initial pre-trial results suggest a potential to recharge the aquifer at a rate of up to 2–3GL/y and while still requiring evaluation, represents a relatively low cost way to recover aquifer storage and/or access water and capitalise on the installed GFBI infrastructure.

From here to irrigation

Practical completion of the GFBI borefield, pipeline and power network occurred has been recently achieved. This included commissioning of assets; 43 production bores, the 24.5km collector main and the power grid expansion to 25km.

Equipping bores, connecting to the main line and installation of Supervisory control and data acquisition (SCADA) remains to be completed by the Service provider.

Of the technical tasks that remain, optimising the well field for yield, energy use and salinity is a high priority for the future operator/s. A purpose built groundwater model with real time SCADA could then be used to optimise the borefields to maintain the lowest cost water for growers.

The last part of the project, land sales, will be initiated with the advertising of a Request for Proposals process lead by the Department of Lands.