Water Corporation

Carnarvon Irrigation Area GFI Expansion Engineering Review

March 2015

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1. Introduction

1.1 Purpose of this report

The purpose of this report is to analyse the current issues with the Carnarvon Irrigation Scheme and investigate options that achieve equitable supply to all customers across the scheme. Additionally, the Gascoyne Food Bowl Initiative, which is managed by the Western Australian Department of Agriculture and Food, is expected to increase source capacity by 4 GL/yr. This report is to analyse options in expanding the scheme to cater for this increase in irrigation demand.

The report is to be used by CMAC to develop an economic and pricing model.

1.2 Scope and limitations

This report: has been prepared by GHD for Water Corporation and may only be used and relied on by Water Corporation for the purpose agreed between GHD and the Water Corporation as set out in this report.

GHD otherwise disclaims responsibility to any person other than Water Corporation arising in connection with this report. GHD also excludes implied warranties and conditions, to the extent legally permissible.

The services undertaken by GHD in connection with preparing this report were limited to those specifically detailed in the report and are subject to the scope limitations set out in the report.

The opinions, conclusions and any recommendations in this report are based on conditions encountered and information reviewed at the date of preparation of the report. GHD has no responsibility or obligation to update this report to account for events or changes occurring subsequent to the date that the report was prepared.

The opinions, conclusions and any recommendations in this report are based on assumptions made by GHD described in this report. GHD disclaims liability arising from any of the assumptions being incorrect.

GHD has prepared this report on the basis of information provided by Water Corporation and others who provided information to GHD (including Government authorities), which GHD has not independently verified or checked beyond the agreed scope of work. GHD does not accept liability in connection with such unverified information, including errors and omissions in the report which were caused by errors or omissions in that information.

GHD has prepared preliminary cost estimates set out in sections 7.3 and 8 of this report using information reasonably available to the GHD employee(s) who prepared this report; and based on assumptions and judgments made by GHD. The Cost Estimate has been prepared to facilitate preliminary pricing and economic modelling for the proposed scheme upgrades and to support preferred option selection and must not be used for any other purpose.

The Cost Estimates are preliminary estimates only. Actual prices, costs and other variables may be different to those used to prepare the Cost Estimates and may change. Unless as otherwise specified in this report, no detailed quotation has been obtained for actions identified in this report. GHD does not represent, warrant or guarantee that the works can or will be undertaken at a cost which is the same or less than the Cost Estimates.

Where estimates of potential costs are provided with an indicated level of confidence, notwithstanding the conservatism of the level of confidence selected as the planning level, there remains a chance that the cost will be greater than the planning estimate, and any funding would not be adequate. The confidence level considered to be most appropriate for planning purposes will vary depending on the conservatism of the user and the nature of the project. The user should therefore select appropriate confidence levels to suit their particular risk profile.

1.3 Acronyms and Abbreviations

Annual Average	Total demand for the year/365 days of the year
CMAC	Carnarvon Ministerial Advisory Committee
DAFWA	Department of Agriculture and Food of Western Australia
dia	diameter (tank)
DN	Nominal diameter (pipelines)
DOW	Department of Water (Western Australia)
FCV	Flow Control Valve
GFI	Gascoyne Food Bowl Initiative
GL	giga Litres (10^9 Litres)
GL/yr	giga Litres (10^9 Litres) per year
GWC	Gascoyne Water Co-operative Limited
GWAMCO	Gascoyne Water Asset Mutual Cooperative Limited
Ha	Hectare
HGL	Hydraulic Grade Line
HV	High Voltage
kL	kilo Litres (10^3 Litres)
kL/d	kilo Litres (10^3 Litres) per day
kW	kilo Watts
LAS	Low Aquifer Storage Level within Sub-Basin Area A which when declared by the DoW allows additional water to be extracted from the SBF
L/s	Litres per second
mAHD	elevation in metres in respect to the Australian Height Datum
MAOP	Maximum allowable operating pressure
ML	mega Litres (10^6 Litres)
ML/d	mega Litres (10^6 Litres) per day
mm	Millimetres
NBF	The borefield located on the north side of the Gascoyne River.
pa.	per annum
PD	Peak Day (demand) = highest daily demand in the year (expressed in kL/d or ML/d)
Peak Factor	Ratio of a borefield peak flow rate divided by the annual average flow rate
PS	Pump Station
SBF	The borefield located on the southern side of the Gascoyne River (It is currently owned and operated by the Water Corporation)
SCADA	Supervisory Control and Data Acquisition
TDS	Total Dissolved Solids
TWL	Top Water Level

2. Carnarvon Irrigation Background

2.1 Background

Carnarvon is located 900 km north of Perth, Western Australia, alongside the mouth of the Gascoyne River. Carnarvon sits at the heart of the Gascoyne Region and as such, serves as both a centre of tourism and a focal point for key regional services. The main economic activities in the Gascoyne Region include salt mining, agriculture, fishing and tourism. According to the 2011 census, the population of Carnarvon was 5,787 people which contribute to about 60 per cent of the population of the entire Gascoyne Region. The population in the region has been relatively stable since 2006; however there was a decline in the population by 690 people from June 2001 to June 2011.

The plantations within the Carnarvon Irrigation Area mostly grow bananas, tomatoes, grapes, melons but also a variety of other fruits and vegetables. The annual production is estimated to be worth approximately $80 million (Nationals, 2012). The Carnarvon horticultural area is approximately 2,000 hectares in total area, of which, only 1,530 hectares is cultivated land. The actual area of growing produce is lower again due to crop rotations and preparing land for future seasons. This actual area of growing produce changes over the different crop growing seasons. There are currently 181 active plantations within the irrigation scheme.

The Carnarvon Irrigation Area represents approximately 10% of the State's total horticultural production, and supplies approximately 60% of Perth's vegetables in winter. The irrigation mains were upgraded in 2012, replacing the aging asbestos cement mains utilising Royalties for Regions funding. Prior to this, in 2010, under the Gascoyne Food Bowl initiative, development of a new borefield on the northern side of the Gascoyne River commenced. This borefield currently consists of 9 bores with an allocation of 2.78GL/yr complementing the 5GL/yr available for irrigation from the Water Corporation's Southern Borefield (SBF).

Due to a number of factors the irrigation scheme has encountered problems meeting growers' water requirements, and achieving an equitable supply of water to Growers. These issues have been investigated by the Water Corporation and options identified to achieve a more equitable supply. Further work has been requested by the Gascoyne Water Co-operative (GWC) and CMAC to resolve issues associated with equitable supply of water to Growers.

Further development of the Northern Borefield (NBF) is planned under the Gascoyne Food Bowl initiative to increase the allocation for irrigation by 4GL/yr allowing a further 400Ha of land to be developed for horticulture. Water supply planning is required to develop options to supply the expanded scheme, determine staged capital and operating costs of the options and operating strategy. This study is to inform CMAC and feed into their Economics and Pricing Model project.

2.2 Climate

Carnarvon has a warm, semi-arid climate. Tables 1 and 2 provide the average monthly temperatures and monthly rainfall in Carnarvon (BOM, 2014). Most of the rainfall is between the typical winter months but over the summer period large scale but sporadic rainfall events occur due to cyclones moving down the coast of Western Australia. The Gascoyne River generally only flows after one of these large scale rainfall events occur. These river flows are the primary recharge mechanism for the aquifers that supply the town site with drinking water and irrigation water for the local agriculture.

Table 1. Mean Max Temperature and Mean Minimum Temperature by Month

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Mean maximum temperature (°C)	31.3	32.5	31.6	29.1	26.2	23.4	22.3	23.0	24.4	26.0	27.6	29.3	27.2
Mean minimum temperature (°C)	22.5	23.4	22.1	19.1	14.9	12.3	10.9	11.6	13.9	16.4	18.6	20.7	17.2

Table 2. Mean Rainfall and number of rain days the rainfall >=1 mm.

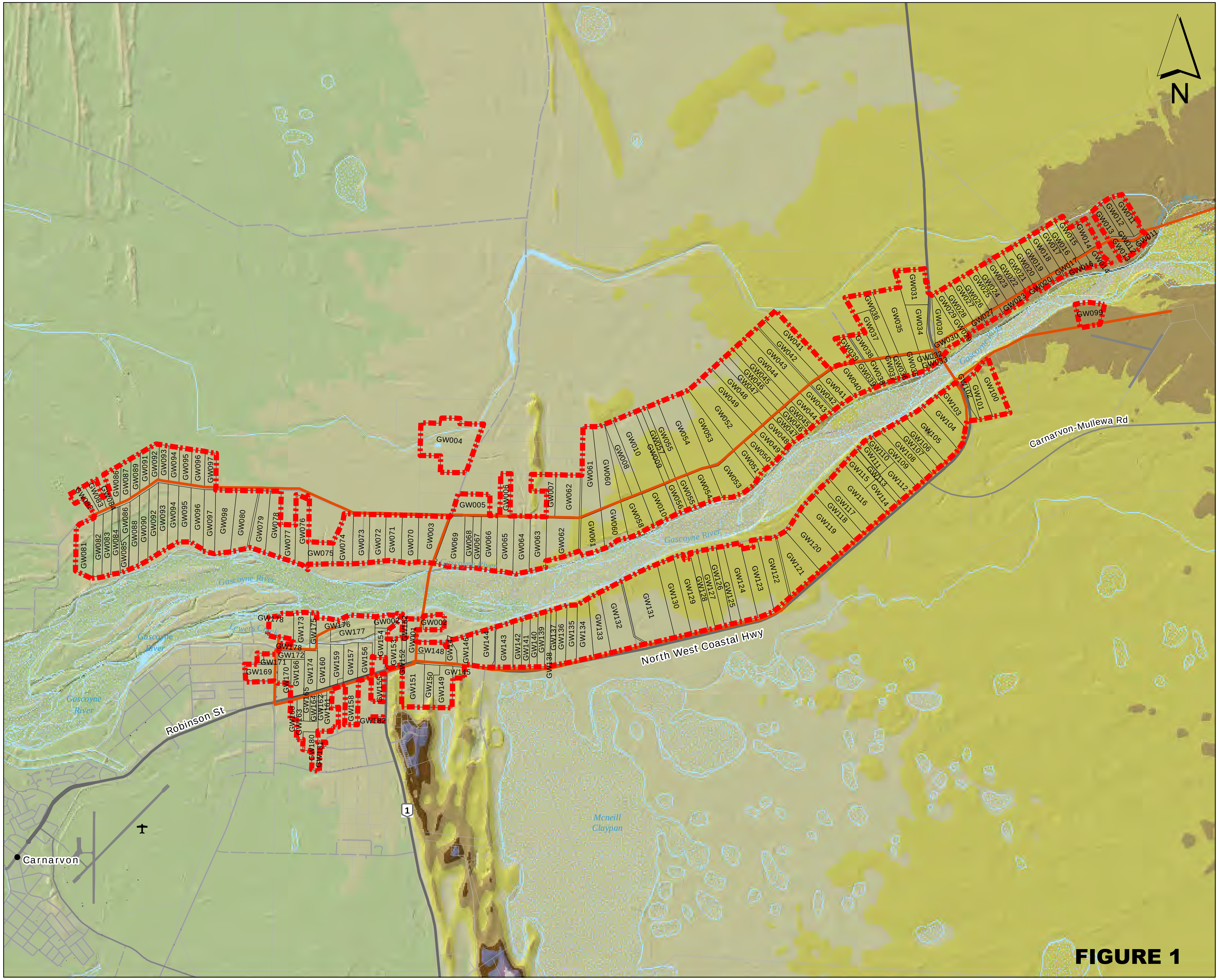
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Mean rain (mm)	12.2	20.3	16.0	13.8	34.7	46.8	44.1	17.5	6.0	5.2	4.1	5.6	226.9
Mean number of rain days of rain >=1 mm	1.3	1.8	1.3	1.4	3.1	5.1	4.8	2.9	1.6	1.1	0.5	0.3	25.2

2.3 Topography

The topography of the land for the existing irrigation scheme and the borefields is shown in Figure 1 and Figure 2 respectively.

The elevation across the existing irrigation scheme varies from as low as 4m AHD in the west of the irrigation area up to 17 mAHD in the east of the irrigation area. This represents an average grade of 1m/km.

The Northern Borefield and Southern Borefield flank the Gascoyne River heading east. Ground levels generally increase in elevation to the east. At the western end of both borefields ground levels are approximately 17 mAHD and at the eastern extremity of the southern borefield (not shown on Figure 2) it is 45 mAHD. This represents an average grade of 0.8m/km.



LEGEND

Existing Irrigation Area

Elevation

- 0 - 5
- 5 - 10
- 10 - 15
- 15 - 20
- 20 - 25
- 25 - 30
- 30 - 35
- 35 - 40

Coordinate System: GDA 1994 MGA Zone 49 Vertical Datum: AHD

1:45,000 at A3

0 500 1000 1500 2000

Metres

AUTHOR: SELLENM0

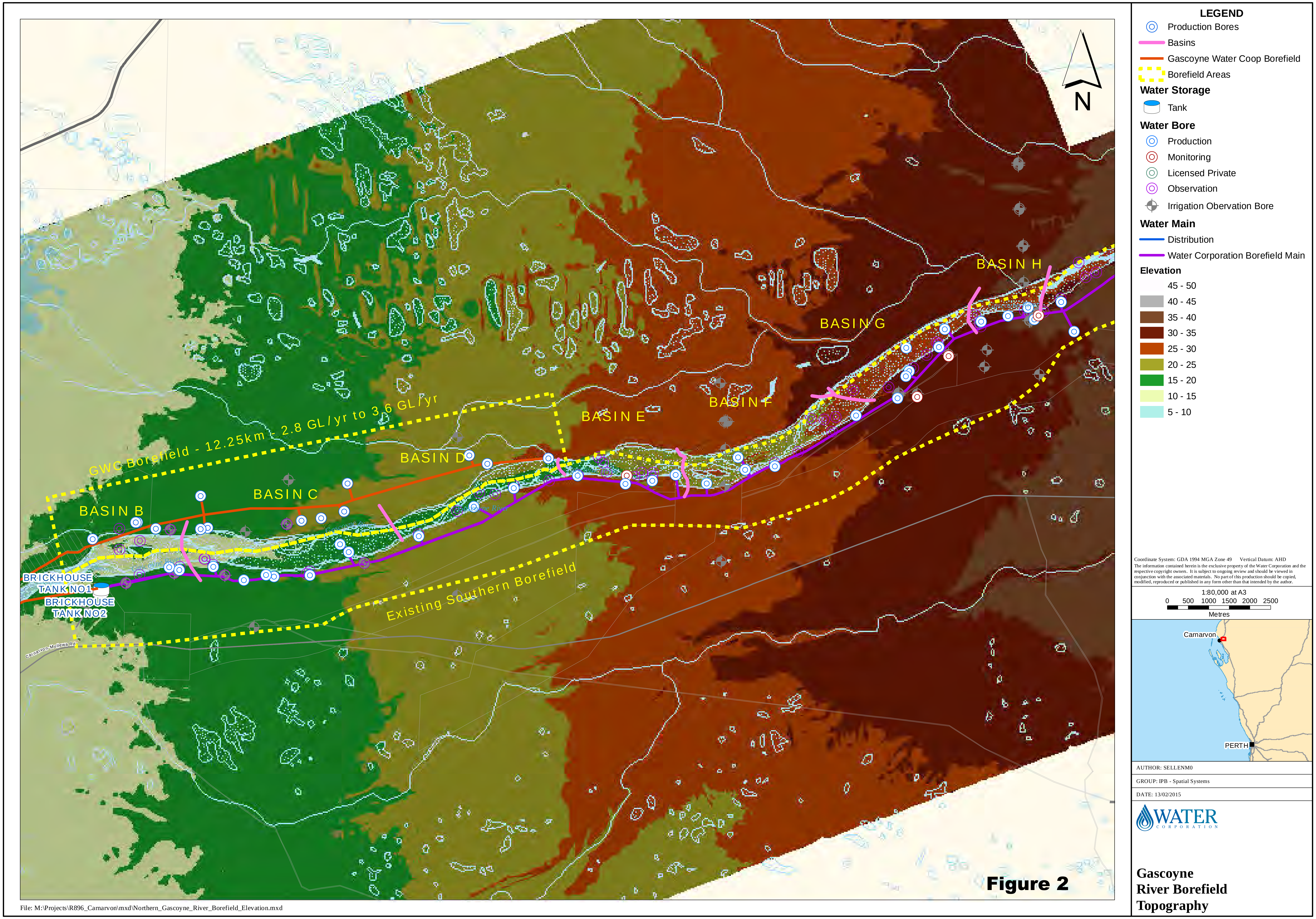
GROUP: IPB - Spatial Systems

DATE: 16/02/2015

WATER CORPORATION

Gascoyne Water Co-op Existing Irrigation Area Topography

File: M:\Projects\R896_Carnarvon\mxd\Gascoyne_Expansion_Borefield.mxd



LEGEND
Production Bores
Basins
Gascoyne Water Coop Borefield
Borefield Areas
Water Storage
Tank
Water Bore
Production
Monitoring
Licensed Private
Observation
Irrigation Obervation Bore
Water Main
Distribution
Water Corporation Borefield Main
Elevation
45 - 50
40 - 45
35 - 40
30 - 35
25 - 30
20 - 25
15 - 20
10 - 15
5 - 10
N
BASIN B
BASIN C
BASIN D
BASIN E
BASIN F
BASIN G
BASIN H
GWC Borefield - 12.25km - 2.8 GL/yr to 3.6 GL/yr
Existing Southern Borefield
BRICKHOUSE TANK NO1
BRICKHOUSE TANK NO2
Figure 2
Coordinate System: GDA 1994 MGA Zone 49 Vertical Datum: AHD
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1:80,000 at A3
0 500 1000 1500 2000 2500
Metres
Carnarvon
PERTH
AUTHOR: SELLENM0
GROUP: IPB - Spatial Systems
DATE: 13/02/2015
Gascoyne River Borefield Topography
File: M:\Projects\R896_Carnarvon\mxd\Northern_Gascoyne_River_Borefield_Elevation.mxd

3. Groundwater

3.1 Groundwater

The water supply for both town potable use and irrigation water on the plantations is sourced from the Lower Gascoyne aquifer system. This system is a regional unconfined to semi-confined system contained within floodplain sediments of the Gascoyne River. The sediments host two distinct aquifers in hydraulic connection: the riverbed sand aquifer and the underlying older alluvium aquifer. For management purposes the aquifer system is divided into eleven subareas (A to L). The sub-areas are divided further as Sub-area A and Sub-areas B-L as shown in Figure 3 (Source – Lower Gascoyne Water Allocation Plan, DoW, October 2011).

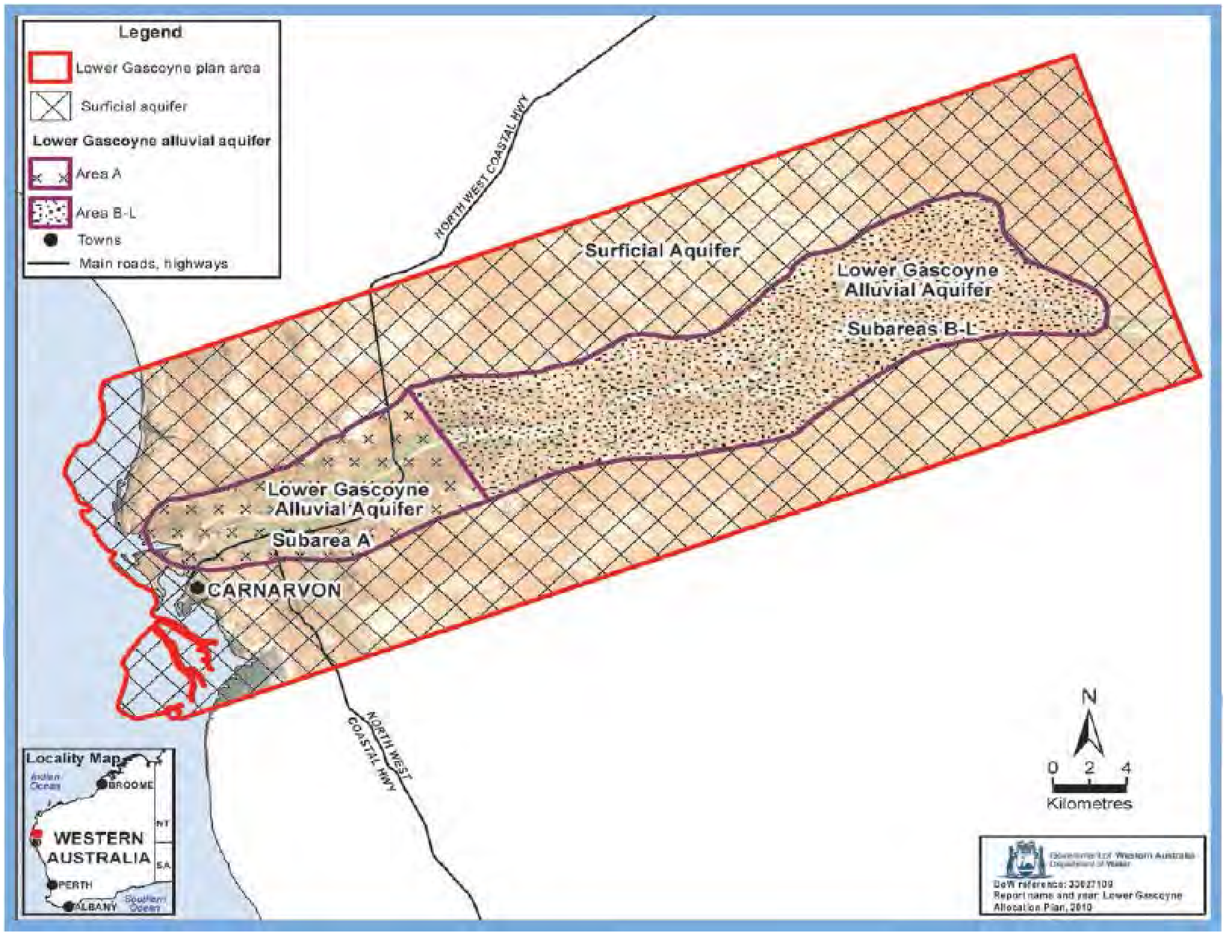


Figure 3. Aquifer Areas for the Lower Gascoyne Aquifer System

3.2 Lower Gascoyne River Aquifer System Allocation Plan

The DoW released the Lower Gascoyne River aquifer system Allocation Plan in October 2011. The plan aims to maximise the volume of ground and surface water available for licensed use that can be sustainably abstracted. The Plan defines allocation limits for the town water supply and irrigation scheme, allocation and licensing policies, and local licencing rules designed to achieve the following outcomes:

- Continued provision of good quality water from subarea B-L to meet town water supply demand.
- Support growth of the horticultural industry by making additional water available in subarea B-L, through water service providers.

- Avoid permanent salinity damage to the water resource by addressing the over-allocation in subarea A and redistribute water abstraction from areas of poor water quality to areas of high water quality (DoW, 2011).

The Lower Gascoyne Water Allocation Plan (2011) set aside an allocation of 3.3 gigalitres a year of groundwater to be developed from an expansion of the Northern Borefield.

The plan specifies rules that restrict the rate of abstraction in Subarea A in response to increasing salinity. The plan allows for the temporary increase to the allocation limit of subarea B-L (Southern Borefield) by 2 GL/annum (or proportion of 2 GL/annum for proportion of water year remaining) to offset any restricted availability in Sub-basin A due to Low Aquifer Storage (LAS) or elevated salinity levels. Typically, a LAS is declared 18 months after the previous river flow.

3.3 Growers Bores (located in Sub-basin A)

A vast majority (approximately 160 growers) of the horticultural properties within the irrigation scheme have their own private bores to abstract from Sub-basin A. These growers hold individual groundwater licences for their bores in Sub-basin A.

Allocation amounts for each license are determined according to the hydrogeological characteristics of the river bed in that particular location. Department of Water actively manage the allocations to the license conditions to avoid salinity thresholds being breached.

There has been a trend of increased reliance on the GWC irrigation supply and declining usage of private bores in recent years. However, the LAS situation in 2013/14 appears to have prompted a renewed interest in maintaining private bores.

4. Existing Irrigation Scheme

4.1 Scheme Description

The supply to the scheme is via two borefields, the Southern Borefield and the Northern Borefield. Figure 4 below shows a schematic of the scheme (both irrigation and water supply).

The Southern Borefield is owned and operated by the Water Corporation and bulk supplies the irrigation scheme under agreement. The Southern Borefield also supplies the Carnarvon Town demands.

The Northern Borefield is owned by GWAMCO and operated and maintained by GWC and solely supplies the irrigation scheme. The Northern Borefield is currently being expanded by the Department of Agriculture and Food of Western Australia as part of the Gascoyne Food Bowl Initiative which is funded by the Royalties for Regions Program.

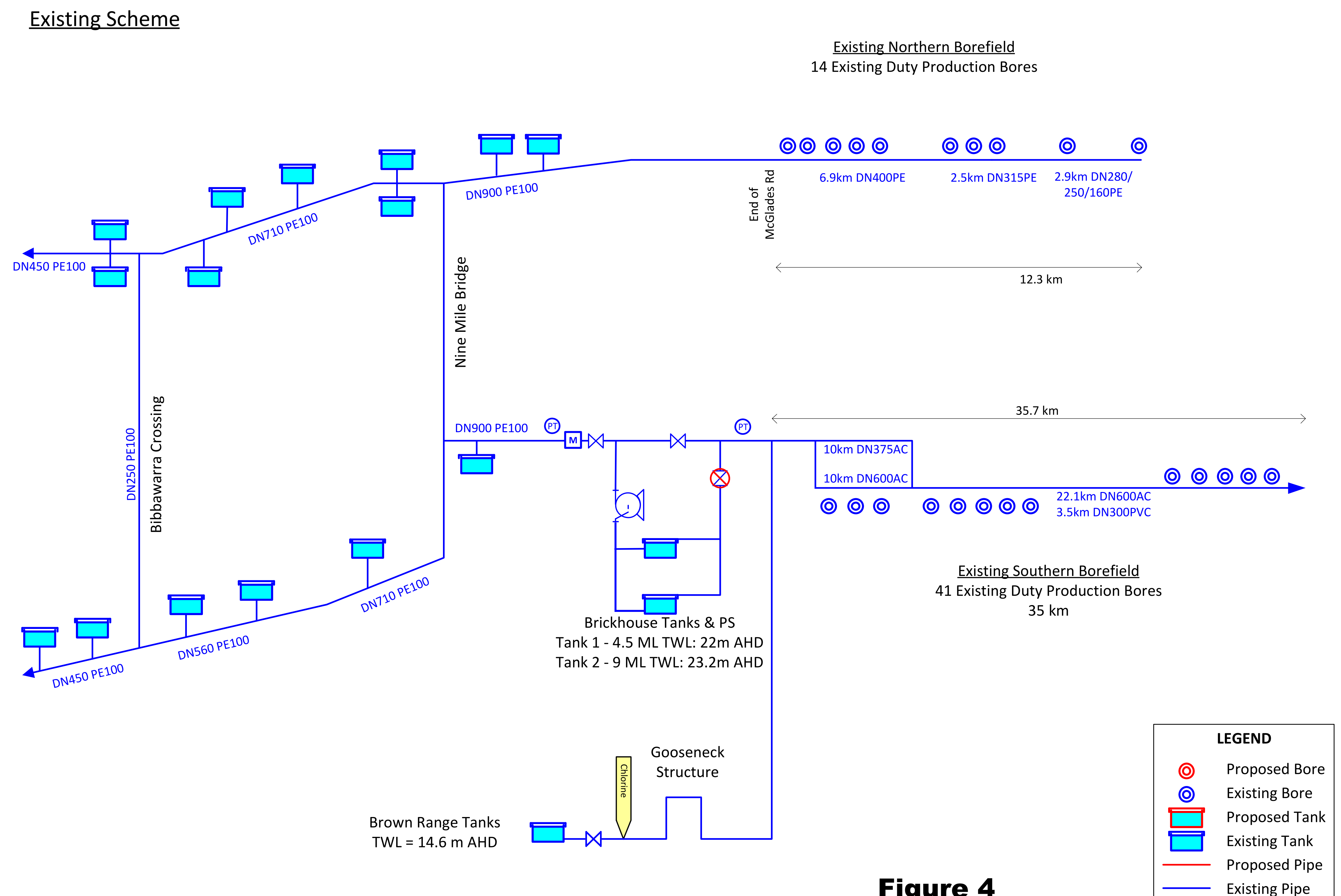


Figure 4

S:\active\SpatialSystems\Projects\R1029_Carnarvon\Visio\CarnarvonNorthernBorefieldExpansionSchematic.vsd 14/01/2014

4.2 Southern Borefield

The Southern Borefield consists of 41 production bores on the southern side of the Gascoyne River connected by a 35km collector main. Eight bores are manually operated. The remaining bores are controlled via SCADA. The details of these production bores are provided in Appendix D.

The bores pump to the Brickhouse Complex where flow splits to directly supply the irrigation scheme and the town supply. Normally, the Brickhouse Tanks are bypassed and the irrigation component of the supply from the Southern Borefield pumps directly to the irrigation scheme. When irrigation demands warrant, irrigation flow is directed to the Brickhouse Tanks from where it is boosted via the Brickhouse Booster Pump Station. Flow into the Brickhouse Tanks is throttled so that the hydraulic level upstream remains sufficiently high to supply onto Town. The Brickhouse Tanks and Brickhouse Pump Station are rarely used due to the high power cost of the Brickhouse Pump Station which is wholly charged to GWC.

Over the previous 4 years there has been a rising trend in bore salinity. A number of bores in Sub-basins B-E and Sub-basins K to L have salinity above the aesthetic guideline value (Criteria for Drinking Water Supply, July 2010) of 700mg/L. Salinity is generally higher in Sub-basins K to L than in Sub-basins B-E due to higher abstraction from these bores in recent times (Water Corporation, 2009b). Salinity of water supplied from the Southern Borefield since 2011 has ranged from 400mg/L to 600mg/L and more recently has varied in the range of 470mg/L to 530mg/L.

Bores in the Southern Borefield are turned off and on to maintain pressure at the Brickhouse Tank within a band of 14m to 16m. A pressure of 15m at Brickhouse Tanks is sufficient to maintain levels of service in the irrigation scheme. However, as the originally installed flow control functionality at each Growers customer assembly is not currently in use, the Southern Borefield cannot always keep up with the uncontrolled instantaneous demands and pressures drop well below 14m.

The town supply component is pumped to the Brown Range Low Level Tank. Supply to the Brown Range Low Level Tank is controlled by an inlet control valve.

The supply to Carnarvon Town passes through a gooseneck structure at the Brickhouse Tank complex and is then chlorinated. The gooseneck, being higher than any point in the irrigation scheme, was originally built to address the risk of contamination of the town supply with water back flowing from the irrigation scheme (where the water is considered non-potable) and entering into the town water supply. However, the backflow prevention role of the gooseneck has been lost due to the construction of the Northern Borefield which can provide pressures that exceed the level of the gooseneck structure.

When pressure at the Brickhouse Complex drops to 9m the chlorinator shuts off which then triggers the inlet control valve at Brown Range Tank to close to prevent the supply of un-chlorinated water to the town.

There are asset condition issues with the southern borefield bore main whereby the rubber ring joints fail when the pressure in the main exceeds 25 m at the Brickhouse Complex. This limits the amount of water that can be supplied by the Southern Borefield as well as the pressure within the irrigation scheme. A renewal strategy for the borefield collector main has been developed by the Water Corporation which is summarised below.

- Replace 14km. Project proposed to be activated in April 2015 at which point the design process commences followed by tendering and then construction.

- Replace 10km to be activated in November 2016.
- Replace 9km to be activated in June 2044.

The capacity of the Southern Borefield was recently investigated as part of the Carnarvon Water Supply System Capacity Review (Water Corporation, 2012). The borefield capacity versus upstream pressure at the Brickhouse Complex is shown in Figure 5.

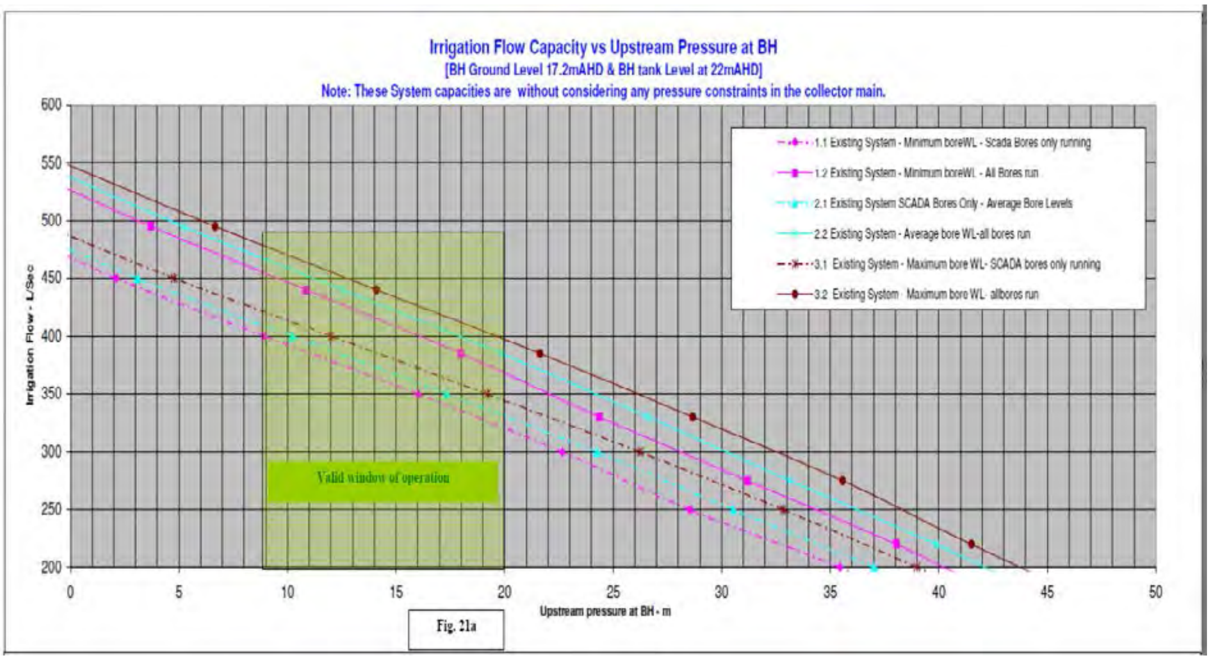


Figure 5. Southern Borefield Flow Capacity versus the upstream pressure measured at Brickhouse.

From the above chart, capacity of the SBF typically varies between 30.2 ML/d (350 L/s) and 37.2 ML/s (430 L/s) at a pressure of 15m head at the Brickhouse Complex.

4.3 Northern Borefield

A total of 9 production bores on the Northern side of the Gascoyne River are owned by GWAMCO and operated and maintained by the GWC. The Northern Borefield Operating Strategy document mentions that the maximum abstraction license for this Borefield is 2.78 GL per annum (7.62 ML/d) although this is to increase to 3.6 GL/yr if GWC adds additional bores to their borefield. These bores pump water into the collector main, which feeds directly into the northern irrigation supply pipeline.

Electrification of the Northern Borefield was completed in late 2014. Prior to this the bores were powered by individual diesel generator sets. The bores are manually operated.

DAFWA has begun drilling exploration bores for both production and monitoring for the Northern Borefield Expansion in both the areas east of the existing borefield and in the existing borefield. Bore 11/13 has been connected to the Northern Borefield collector main and is currently supplying into the irrigation system. A project by GWC to connect a further five bores is currently underway with completion expected by mid-2015 bringing the total number of bores to 14 and an estimated capacity of peak 135L/s.

The details of these production bores are provided in Appendix E.

4.4 Brickhouse Pump Station/Tanks

The Brickhouse Complex belongs to the Water Corporation. The assets on the site are owned and operated by the Water Corporation.

4.4.1 Brickhouse Tanks 1 and 2

Both Brickhouse Tanks 1 and 2 (4500 kL and 9000 kL respectively) were last inspected by the Water Corporation on the 30/06/2014. The tank walls for both tanks were assessed to be in good condition however Tank 2 (9000 m3) was noted to have minor leakage at the base. Both tank roofs were inspected, with Tank 1 roof assessed to be in poor condition and would likely need replacing in the near future.

4.4.2 Pump Station

The asset condition of the pumps was inspected on the 21/02/2013 by the Water Corporation. Pumps 1, 2 and 3 were installed in 1976. Pumps 4, 5 and 6 were installed in 1978. The expected lifespan of all these pumps was 24 years.

It was noted during the inspection that:

- Electrical cubicles, main switch panel, control panels all considerably exceed the Water Corporation's typical asset life for these components. Many of the electrical components in the main switchboards are obsolete and unobtainable to replace if ever was required.
- Some live electrical components were exposed.
- Some cabinet doors did not have the designated electrical lock.
- Pump 1 had a variable speed drive installed. When the pump was operated the electrical motor seized.
- Pump 6 bearings were noisy when tested.
- The pump base frames on pumps 1, 2 and 3 were starting to corrode and grout is breaking away.

The Brickhouse Pump Station is considered past its useful asset life.

4.5 Irrigation Distribution System

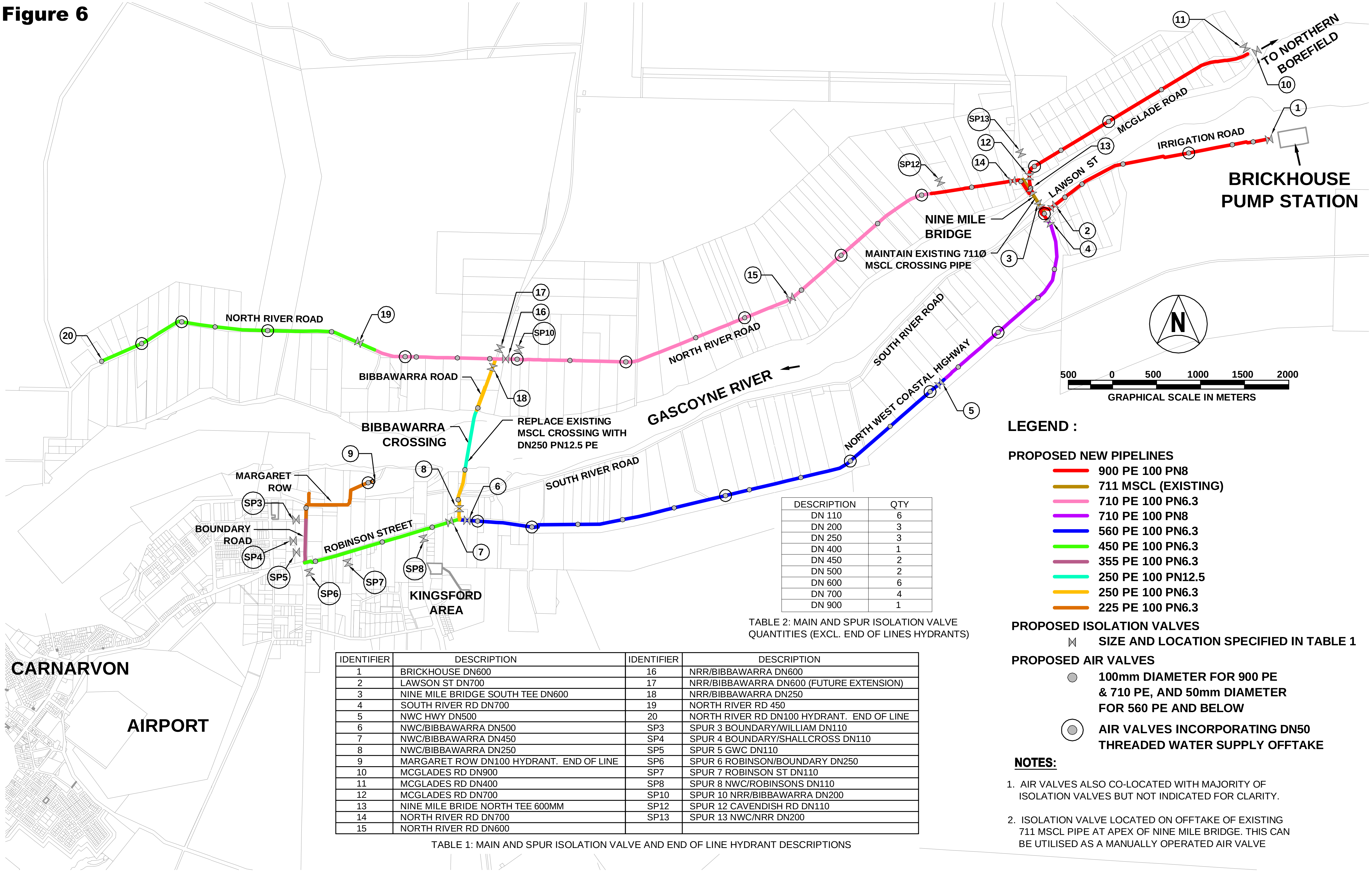
The existing irrigation distribution asbestos cement mains were nearly all replaced in 2012 with polyethylene main (refer to Figure 6). The mains were sized to meet an ultimate design flow of 1400L/s. Accordingly, the pipe sizes of the newly installed irrigation mains are large (up to 900 mm in diameter).

The distribution system has two main legs, with one on each side of the Gascoyne River, which supplies irrigators on both sides. The two legs are connected via pipelines at the Nine Mile Bridge and closer to town at the Bibbawarra Rd Crossing. These cross connections assist in transferring borefield production across the river.

A lack of isolation valves in the distribution system results in significant lengths of main being shutdown to carry out maintenance activities. The distribution system was designed with more isolation valves however these were not installed to reduce costs.

One hundred and eighty one (181) Growers are directly supplied from the scheme. To qualify for an irrigation supply Growers must become a shareholding member of the GWC and GWAMCO. Each Grower has a customer assembly which originally consisted of a flow meter and a flow control valve. At each customer assembly is a SCADA installation which transmits hourly flow data to the GWC office. Reliability of the system has on occasion been impacted by damage by birdlife.

Figure 6



DESCRIPTION	QTY
DN 110	6
DN 200	3
DN 250	3
DN 400	1
DN 450	2
DN 500	2
DN 600	6
DN 700	4
DN 900	1

TABLE 2: MAIN AND SPUR ISOLATION VALVE QUANTITIES (EXCL. END OF LINES HYDRANTS)

LEGEND :

PROPOSED NEW PIPELINES

- 900 PE 100 PN8
- 711 MSCL (EXISTING)
- 710 PE 100 PN6.3
- 710 PE 100 PN8
- 560 PE 100 PN6.3
- 450 PE 100 PN6.3
- 355 PE 100 PN6.3
- 250 PE 100 PN12.5
- 250 PE 100 PN6.3
- 225 PE 100 PN6.3

PROPOSED ISOLATION VALVES

- SIZE AND LOCATION SPECIFIED IN TABLE 1

PROPOSED AIR VALVES

- 100mm DIAMETER FOR 900 PE & 710 PE, AND 50mm DIAMETER FOR 560 PE AND BELOW
- AIR VALVES INCORPORATING DN50 THREADED WATER SUPPLY OFFTAKE

IDENTIFIER	DESCRIPTION	IDENTIFIER	DESCRIPTION
1	BRICKHOUSE DN600	16	NRR/BIBBAWARRA DN600
2	LAWSON ST DN700	17	NRR/BIBBAWARRA DN600 (FUTURE EXTENSION)
3	NINE MILE BRIDGE SOUTH TEE DN600	18	NRR/BIBBAWARRA DN250
4	SOUTH RIVER RD DN700	19	NORTH RIVER RD 450
5	NWC HWY DN500	20	NORTH RIVER RD DN100 HYDRANT. END OF LINE
6	NWC/BIBBAWARRA DN500	SP3	SPUR 3 BOUNDARY/WILLIAM DN110
7	NWC/BIBBAWARRA DN450	SP4	SPUR 4 BOUNDARY/SHALLCROSS DN110
8	NWC/BIBBAWARRA DN250	SP5	SPUR 5 GWC DN110
9	MARGARET ROW DN100 HYDRANT. END OF LINE	SP6	SPUR 6 ROBINSON/BOUNDARY DN250
10	MCGLADES RD DN900	SP7	SPUR 7 ROBINSON ST DN110
11	MCGLADES RD DN400	SP8	SPUR 8 NWC/ROBINSONS DN110
12	MCGLADES RD DN700	SP10	SPUR 10 NRR/BIBBAWARRA DN200
13	NINE MILE BRIDE NORTH TEE 600MM	SP12	SPUR 12 CAVENDISH RD DN110
14	NORTH RIVER RD DN700	SP13	SPUR 13 NWC/NRR DN200
15	NORTH RIVER RD DN600		

TABLE 1: MAIN AND SPUR ISOLATION VALVE AND END OF LINE HYDRANT DESCRIPTIONS

NOTES:

1. AIR VALVES ALSO CO-LOCATED WITH MAJORITY OF ISOLATION VALVES BUT NOT INDICATED FOR CLARITY.
2. ISOLATION VALVE LOCATED ON OFFTAKE OF EXISTING 711 MSCL PIPE AT APEX OF NINE MILE BRIDGE. THIS CAN BE UTILISED AS A MANUALLY OPERATED AIR VALVE

REV	DESCRIPTION	DATE	DRAWN	CHECKED	APPROVED
5	MAIN AND SPUR ISOLATION VALVES NUMBERED AND DESCRIBED	15/02/2012	T.A.	S.S.	B.R.
4	DN50 WATER SUPPLY POINTS ADDED	20/09/2011	T.A.	S.S.	B.R.
3	AIR VALVES AND NOTES ADDED	26/08/2011	T.A.	S.S.	B.R.
2	ISOLATION VALVE LOCATIONS AMENDED	21/07/2011	T.A.	S.S.	B.R.
1	ISOLATION VALVES VARIED	08/07/2011	T.A.	S.S.	B.R.
0	ISSUED FOR CLIENT REVIEW	27/05/2011	T.A.	S.S.	B.R.

Pipe Fusions Australia

		Date
Drawn	TA	27/05/2011
Designed	BR	27/05/2011
Drawing Check	SS	27/05/2011
Design Check	BR	27/05/2011
Project Approval		

Project Details:

GASCOYNE WATER IRRIGATING THE FUTURE

ROYALTIES FOR REGIONS

Australian Government Department of Sustainability, Environment, Water, Population and Communities

GASCOYNE WATER I.P.P.

Job No 210044

TITLE

PROPOSED NEW PIPELINES LAYOUT

Drawing No 210044_001

Rev 5

4.6 Installed Flow Control Valves

Bermad Irrigation valves (type IR-300 and IR-700) were installed on each Grower's customer assembly at the same time as the irrigation main upgrades in 2012. Although labelled a Flow Control Valve, these valves are in fact not a true flow control valve, but rather a manually adjusted flow regulating valve, as the valve position once set does not adjust to changing pressures in the system. Accordingly, the flow control valves will not be able to provide a constant flow rate. The flow rate through the customer assembly will vary depending on the pressure in the distribution system.

For operational reasons the flow regulation functionality was removed by either setting the flow control valve at 100% open or in the case of the 50mm diameter customer assemblies, removing the flow control valves.

Removing the flow regulation functionality has resulted in growers in the eastern areas of the distribution system and in particular in McGlades Road receiving inadequate supply.

4.7 Water Corporation Agreement with GWC

The 2003 water supply agreement (which expired in July 2013 but remains as the current agreement) outlines the terms in which the Water Corporation supples bulk irrigation water to the GWC from the Southern Borefield. The agreement entitles the GWC to receive a maximum flow of 22 ML/d (for a total allocation of 5 GL/yr) during non-LAS periods and 28 ML/d (for a total allocation of 8.6 GL/yr) during LAS periods. Under the agreement, supply to the town has priority over the irrigation supply to the GWC.

5. Demands of Irrigation System

Recent production data was obtained for the Southern Borefield and Northern Borefield to understand the peak demand usage and how demand varies within a year. Only monthly data was available for the Northern Borefield and hence the assessment was limited to monthly averages.

5.1 Groundwater Use from GWC Supply (Southern and Northern Borefields)

The Total Irrigation Consumption from the GWC supply (which is from both Northern and Southern Borefields) based on monthly bore production data (Source: DoW) for the calendar years of 2011 to 2013 is seen in Figure 7. The peak month has consistently been October ranging from 30-31ML/d. This is consistent with the normal peak capacity available being 22ML/d from the Southern Borefield and 7.62ML/d from the Northern Borefield. This suggests that the infrastructure may be a limiting factor on peak demand usage. The data shows a smaller secondary peak in April.

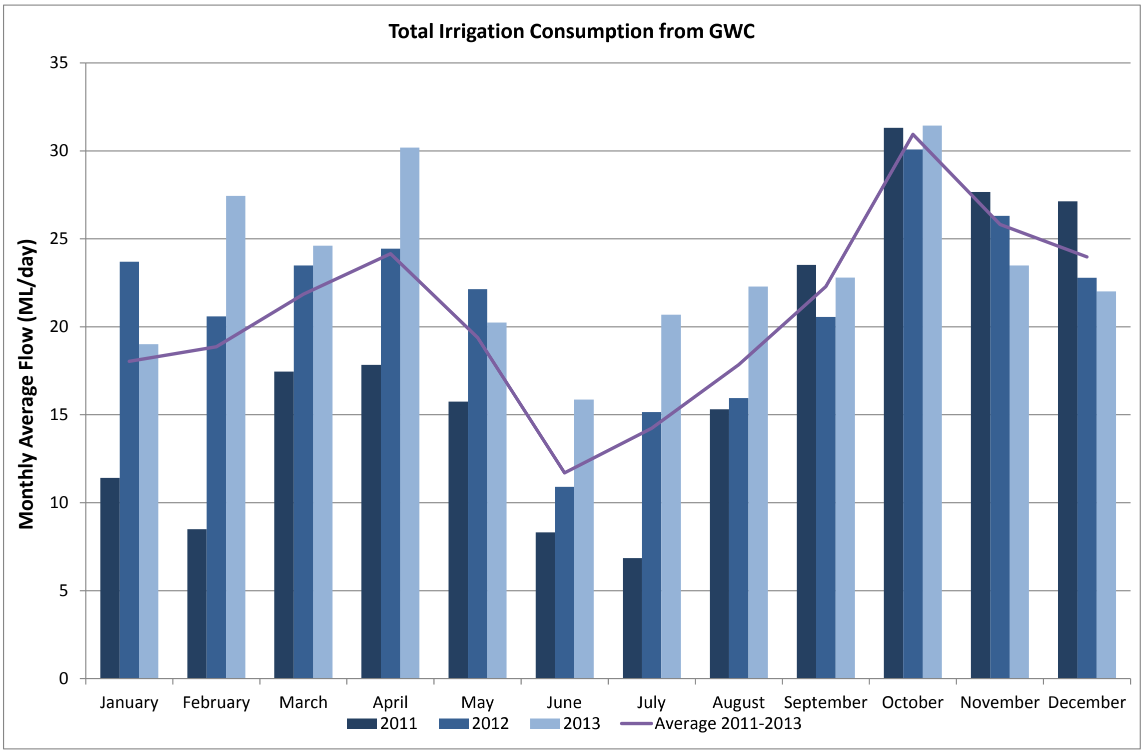


Figure 7. Total Irrigation Consumption from the GWC.

The above data was used to determine the ratio of average monthly GWC supply to annual average GWC supply and this is shown in Figure 8. The chart shows that the peak month factor varies from 1.4 to 1.8. However the value of 1.8 for 2011 is likely to be skewed due to annual usage being low (refer to Table 3) and evidenced by much lower consumption in the first half of 2011 in comparison to 2012 and 2013. This lower consumption is likely a result of high Gascoyne River flows in early 2011.

Table 3. The amount extracted by GWC versus Licence Quantity.

Year	Licence (GL)	Used (GL)	Annual Average (ML/d)
2011	7.78	6.4	17.6
2012	7.78	7.8	21.4
2013	9.275	8.5	23.3

The peak factor available from the Southern Borefield in a non-LAS year is 1.6 (22ML/d peak capacity and 5GL/yr annual allocation which is equivalent to an annual average of 13.7ML/d). The peak factor available from the Northern Borefield is 1.0 (7.62ML/d peak capacity and 2.785GL/yr annual allocation which is equivalent to an annual average of 7.62ML/d). The peak factor when considering both borefields together is 1.4. Again, as the historical peak month factor matches the available peak factor it suggests the installed infrastructure is a limiting factor on peak usage.

However, as most Growers have access to groundwater from Sub-basin A, it is not valid to draw conclusions on the peak irrigation requirements without also considering Sub-basin A usage.

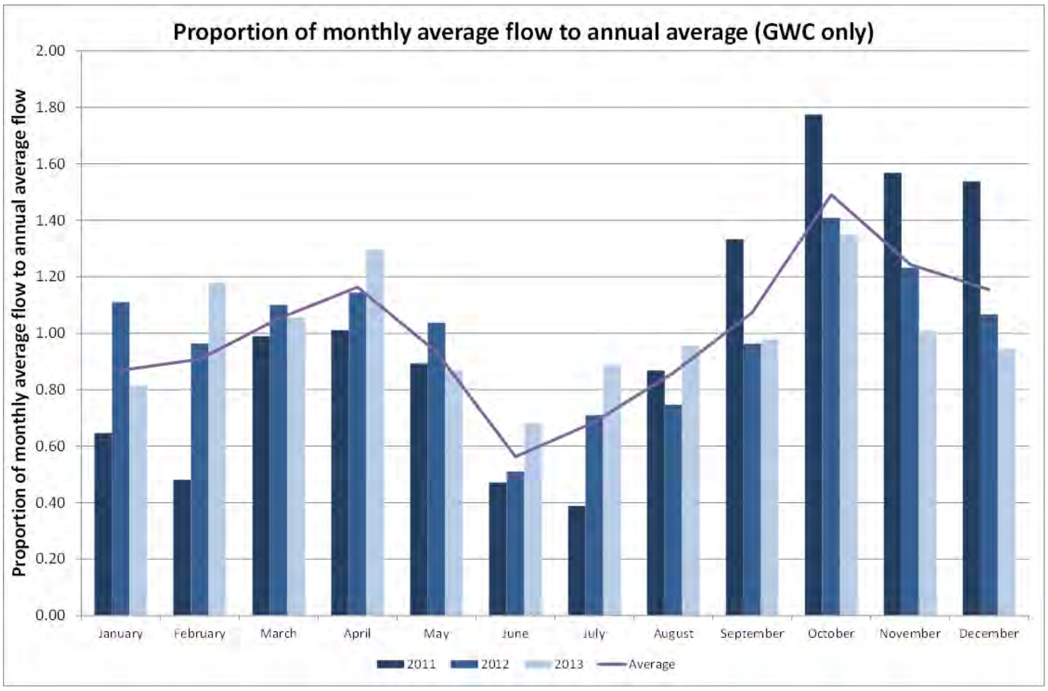


Figure 8. Proportion of monthly average flow to annual average (GWC only).

5.2 Groundwater Use Sub-Basin A

The Sub-Basin A monthly bore production data (Source: DoW) for the calendar years of 2011-2013 is seen in Figure 9. Annual production is shown in Table 4.

The usage pattern is seen to be similar to the GWC water usage with greater usage between September to April and low usage over winter (May – August).

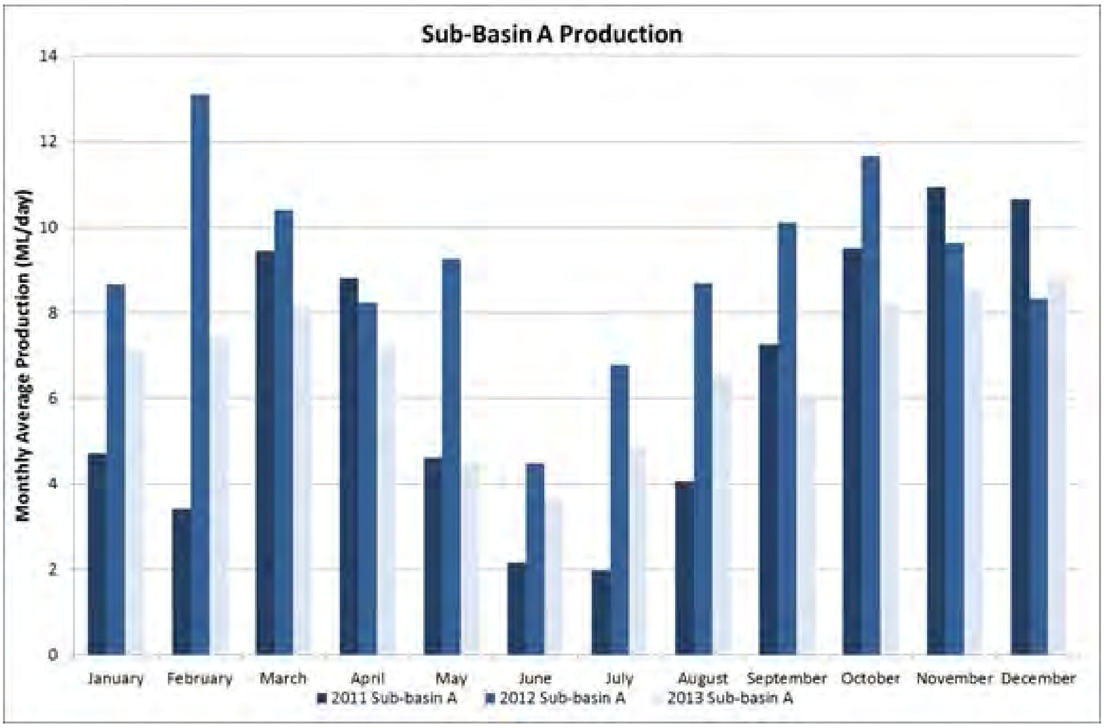


Figure 9. Sub-Basin A Production.

Table 4. Sub-Basin A extraction versus allocation.

Year	Allocation (GL)	Used* (GL)	Annual Average (ML/d)	Comment
2011	6.1	2.4	6.6	Impacted by 2011 floods
2012	6.1	3.4	9.3	LAS declared
2013	6.1	2.5	6.9	LAS declared

* Includes unrestricted pumping

The usage values are low relative to the licence. This is due to a number of factors as detailed below:

- the 2011 river flood destroying sub-basin A infrastructure.
- low aquifer storage level declared in 2012 and 2013.

The monthly usage data was used to determine the ratio of average monthly Sub-basin A supply to annual average Sub-basin A supply and this is shown in Figure 10. This chart shows that during the peak usage period of the GWC of October, Sub-basin A was providing a lower peak factor of 1.3. Recent Sub-basin A usage has provided a lower share of the total irrigation demand during the peak irrigation period of October to December.

It is not clear what the drivers are for the lower contribution of Sub-basin A during the peak demand period or the barriers to Sub-basin A providing a greater contribution and reducing the peak contribution from the GWC scheme. Detailed investigation of this is outside the scope of this study however a better understanding of this is required to be able to draw conclusions on the peak capacity of the GWC scheme.

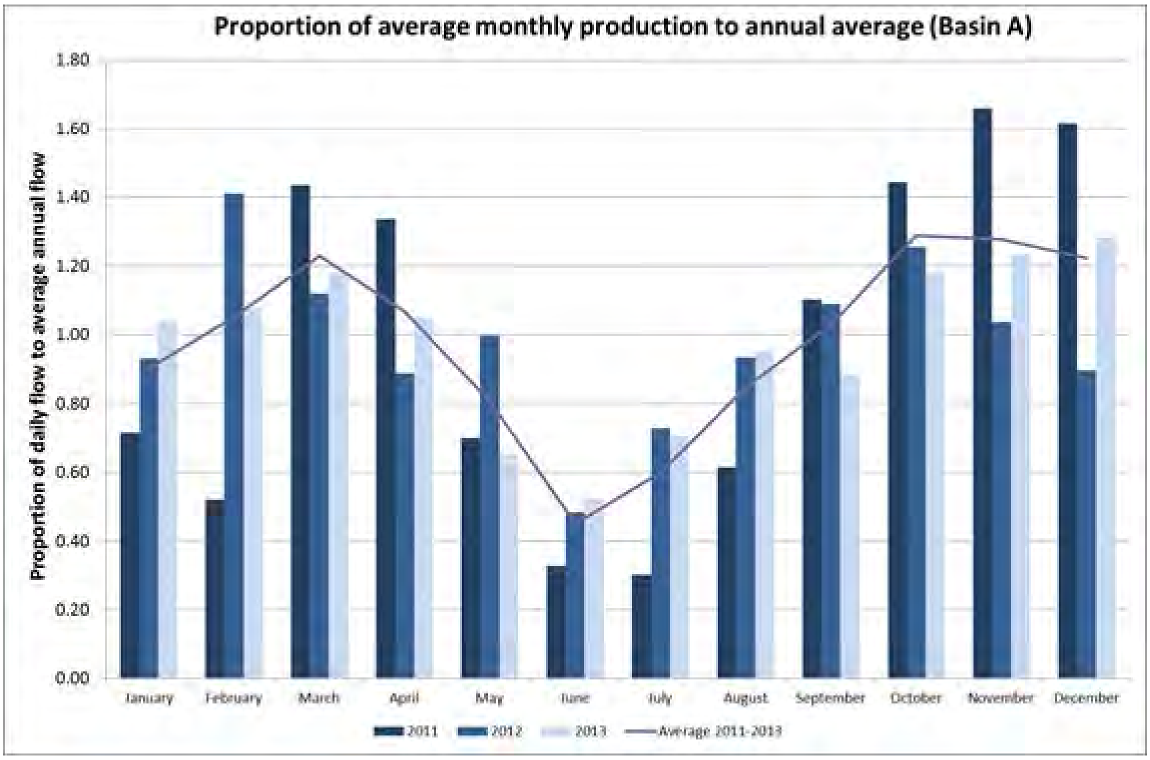


Figure 10. Proportion of average monthly production to annual average for Sub-Basin A.

6. Existing Irrigation Scheme Review

6.1 Background

In 2012 the ageing asbestos cement irrigation pipelines were replaced with polyethylene pipelines jointly funded by the State Government's Royalties for Regions program, the Federal Government's Water for the Future initiative and GWC.

As part of the works, the Grower's connections to the new irrigation pipelines were installed with flow control valves to regulate flow to growers to a determined rate. The flow control valves installed are not a true flow control valve as the valve has no ability to adjust position when system hydraulic conditions change. The valve can be considered as a manually set flow regulation valve.

For operational reasons the flow regulation functionality was removed by either setting the flow control valve at 100% open or in the case of the 50mm diameter customer assemblies (growers connections) removing the flow control valves.

Removing the flow regulation functionality has resulted in growers in the eastern areas of the distribution system and in particular in McGlades Road receiving inadequate supply.

6.2 Hydraulic Analysis of the Current Scheme

A simplified hydraulic model of the irrigation scheme was created to investigate the current issues associated with inadequate supply to growers in the eastern part of the distribution system. The hydraulic model was established with the following characteristics:

- The Northern and Southern Borefields were modelled as flows being injected into the distribution system at flow rates of 7.62 ML/d (88.19 L/s) and 22 ML/d (255 L/s) respectively representing their current peak supply rate to the irrigation scheme.
- The flow control valves at the customer assemblies were excluded from the model.
- The Growers' tanks were modelled with over the top inlets set to 2.5 m above the ground level at the tank site.

The model was used to determine the instantaneous flow rate to each Grower when all Growers want to take water from the scheme. This instantaneous flow rate was then compared to an adopted definition of the Grower's share of the peak production as outlined below

$$Flow\ Ratio = \frac{Grower's\ modelled\ flow\ rate}{Grower's\ Peak\ Share}$$

$$Growers\ Peak\ Share = \frac{Grower's Annual\ Entitlement}{Sum\ of\ all\ Growers\ Entitlements} x\ Peak\ Production\ Rate$$

A flow ratio greater than one indicates that Growers receive an instantaneous flow rate greater than their share. A flow ratio less than one indicates that Growers receive an instantaneous flow rate less than their share.

The outcome of this analysis is shown graphically in Figure 11. Approximately a third of Growers receive an instantaneous flow rate in excess of their share and in some cases many times their share. The chart shows numerous Growers receive no flow however this is only likely when all Growers are taking water. In reality, when Growers' tanks fill up and they stop taking water, pressures in the distribution system will rise and the disadvantaged Growers will receive flow albeit at a daily average basis less than their share.

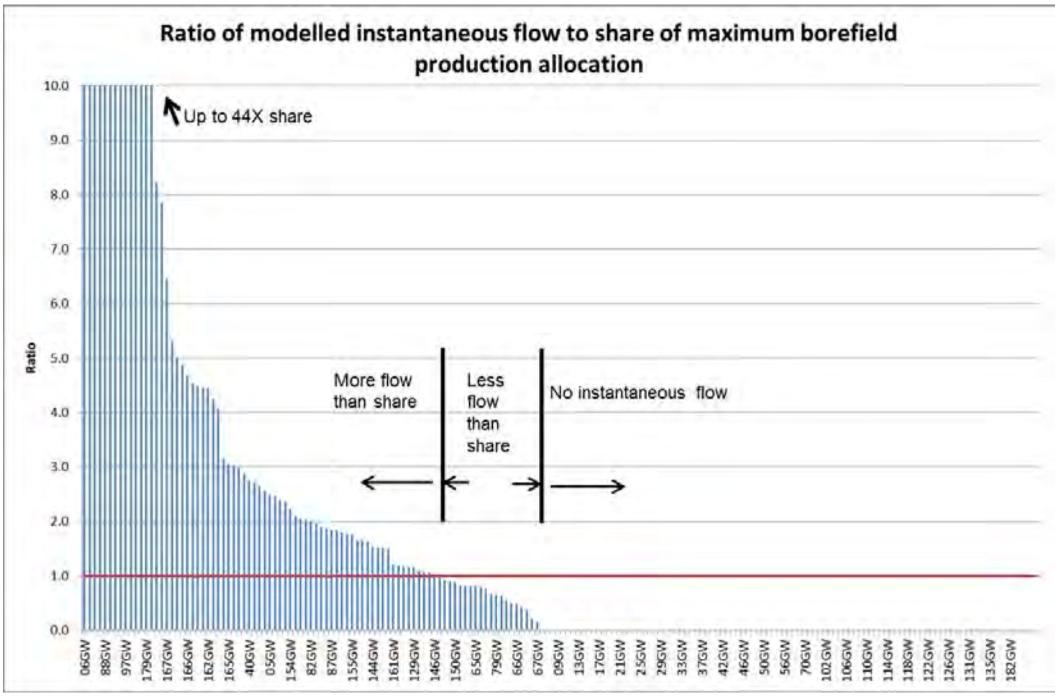


Figure 11. Graphical Representation of Growers Share – No Flow Control Valves

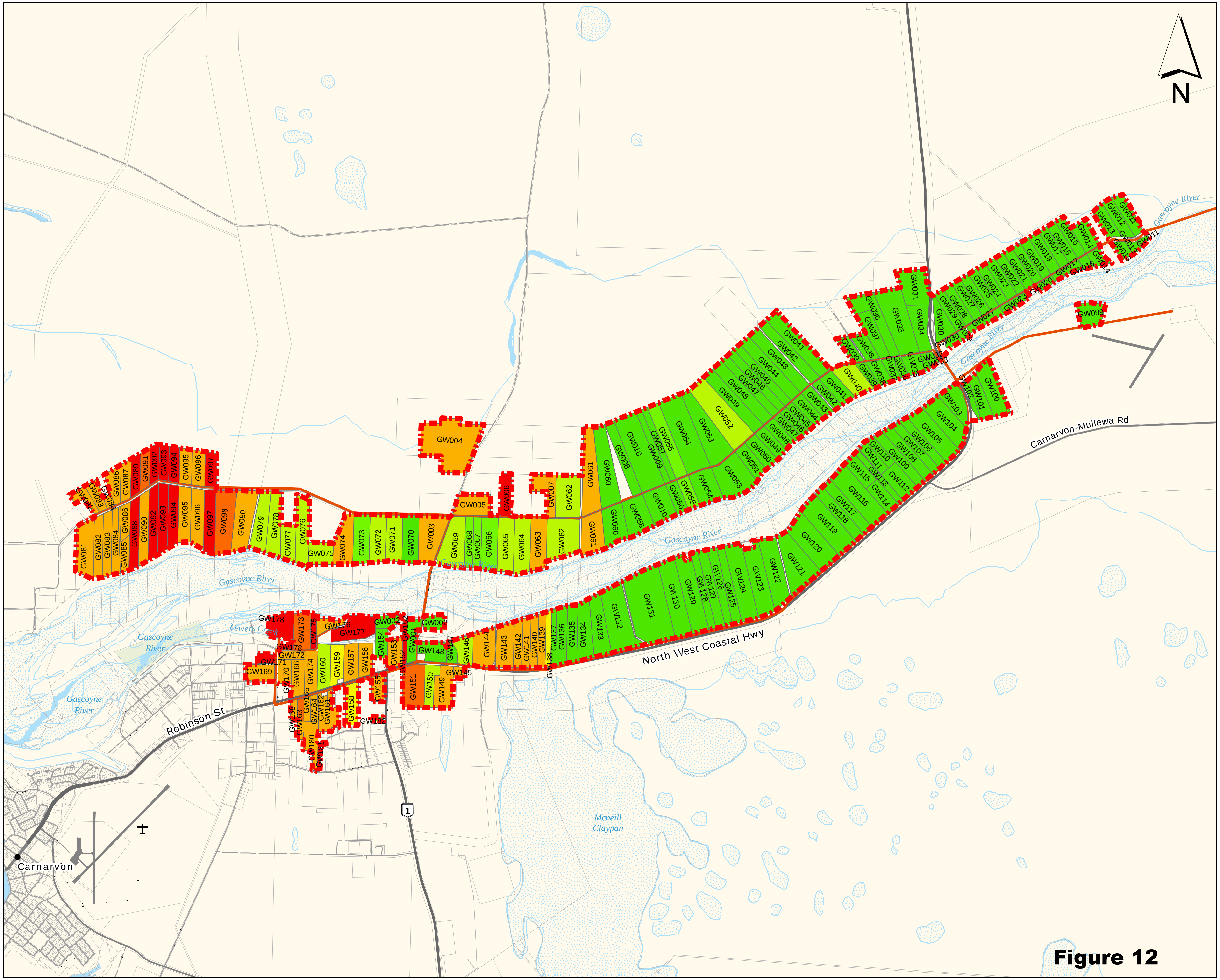
Figure 12 presents the growers share spatially. Growers in the west of the scheme typically receive an instantaneous flow rate greater than their share whilst growers in the east of the scheme receive an instantaneous flow rate less than their share. This is consistent with anecdotal reports of Growers in McGlades Road receiving inadequate supply.

The above analysis shows that an absence of flow regulation at the Grower's customer assembly results in inequitable distribution of the peak production to Growers. This is not surprising as the purchase of annual entitlements is based on an annual volume and not the peak capacity of the system or the resultant instantaneous flow rate available to each Grower. Further, the facility available for Grower's to trade annual entitlements creates a further mismatch. In addition, there are no restrictions on Growers altering their pipes and tanks downstream of the customer assembly which can impact the instantaneous flow rate they receive if there is no control on flow.

Installation of flow regulation at the Grower's customer assembly is required to ensure an equitable (or near to) distribution of the peak production. Flow regulation could be by either of the following methods.

Self Regulation – Growers would be responsible to ensure their daily usage during peak demand periods does not exceed their equitable share. GWC would need to monitor daily usage of each grower, using the existing SCADA system, to ensure growers comply. In the event there is repeated usage by a Grower above their share then GWC could consider installing a flow control device to ensure compliance. Monitoring would only need to be carried out during peak demand periods or when demands approach the capacity of the borefields. The advantage of this method is that outside of peak demand periods Growers could be allowed to receive daily volumes greater than their equitable share. It is recommended that Growers that receive many multiples more than their equitable share should be flow restricted to receive a multiple in the order of 3 times their equitable share or as determined by GWC.

Flow Control Valves – Re-installation of flow control at the Growers customer assembly by the use of a flow control valve. This method is discussed in more detail in the following sections.



LEGEND

Existing Irrigation

Proportion of modelled flow to allocation flow

- 0.0
- > 0.0 - < 0.5
- 0.5 - < 1.0
- 1.0
- > 1.0 - < 5.0
- 5.0 - < 10.0
- 10.0+

Coordinate System: GDA 1994 MGA Zone 49 Vertical Datum: AHD

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1:45,000 at A3

0 500 1000 1500 2000

Metres

AUTHOR: SELLENM0

GROUP: IPB - Spatial Systems

DATE: 25/11/2014

WATER CORPORATION

Gascoyne Water Co-op Existing Irrigation Area Scenario - 0 FCVs installed

File: M:\Projects\R896_Carnarvon\mxd\Gascoyne_Expansion_Borefield_Heat_Map1.mxd

6.3 Progressive Installation of Flow Control Valves

Further analysis was undertaken to understand the impact of progressively installing flow control valves (FCVs) on the customer assemblies. The flow control valves were set at a flow rate equal to the Grower's peak share following the method outlined in Section 6.2.

Analysis was undertaken for the following scenarios:

- 60 FCVs installed on the customer assembly of the 60 Growers with the highest flow ratio
- 120 FCVs installed. Additional 60 FCVs installed on the customer assembly of the Growers with the highest flow ratio.
- FCVs on all Growers' customer assemblies

The same hydraulic model developed for the analysis described in Section 6.2 was used and modified to include the FCVs and the settings described above.

6.3.1 60 FCVs Installed

The outcome of the analysis for 60 FCVs installed is shown graphically in Figure 13. Despite adding in 60 FCVs a number of growers still receive less than their share and a number of growers receive flow far in excess of their share.

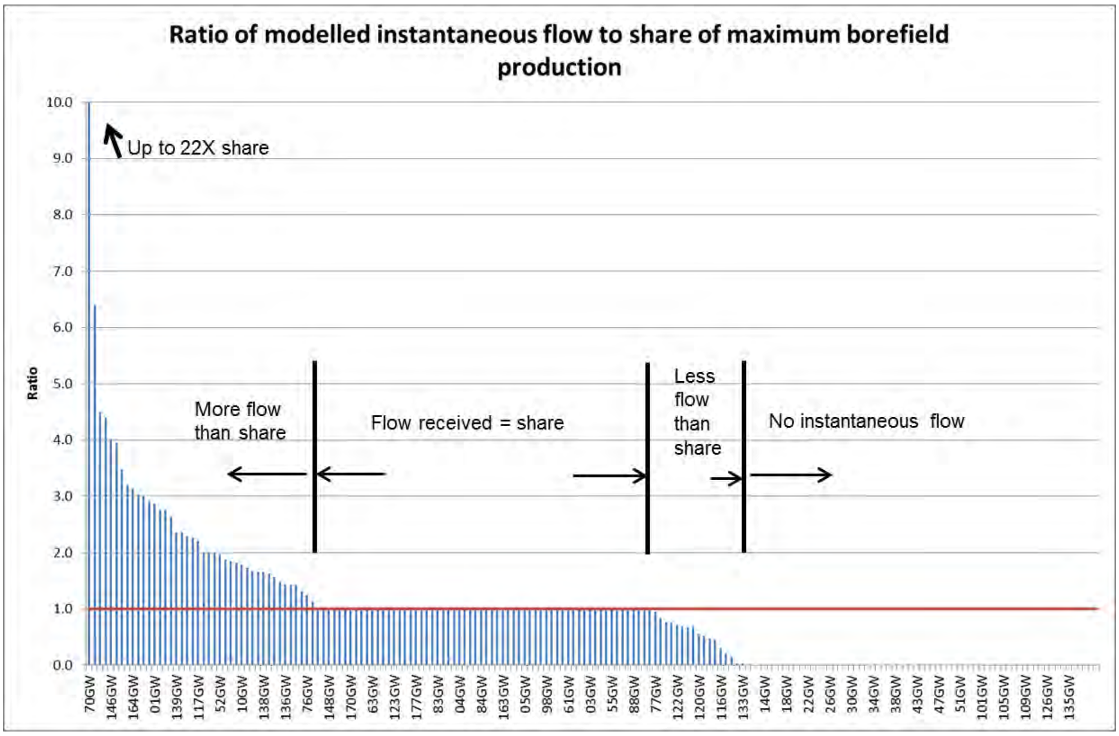
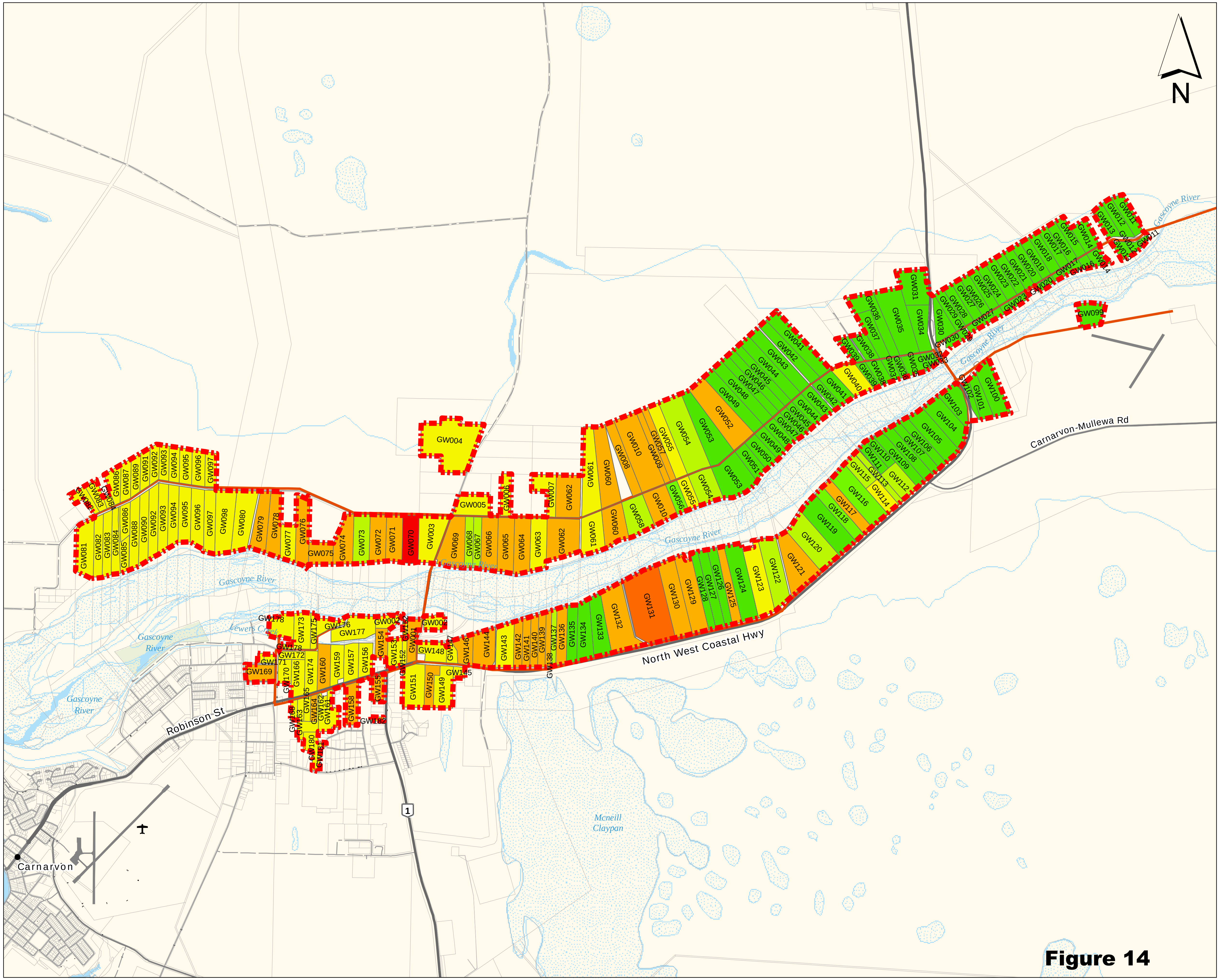


Figure 13. Graphical Representation of Growers Share – 60 Flow Control Valves



LEGEND

Existing Irrigation

Proportion of modelled flow to allocation flow

- 0.0
- > 0.0 - < 0.5
- 0.5 - < 1.0
- 1.0
- > 1.0 - < 5.0
- 5.0 - < 10.0
- 10.0+

Coordinate System: GDA 1994 MGA Zone 49 Vertical Datum: AHD

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1:45,000 at A3

0 500 1000 1500 2000

Metres

AUTHOR: SELLENM0

GROUP: IPB - Spatial Systems

DATE: 25/11/2014

WATER CORPORATION

Gascoyne Water Co-op Existing Irrigation Area Scenario - 60 FCVs installed

File: M:\Projects\R896_Carnarvon\mxd\Gascoyne_Expansion_Borefield_Heat_Map2.mxd

Figure 14 presents the growers share spatially. Growers in the east of the scheme receive an instantaneous flow rate less than their share. Growers in the far west of the scheme mostly have FCVs installed in this scenario and hence they show a flow ratio of 1. Growers that receive more than their share in this scenario are concentrated in the mid part of the scheme.

6.3.2 120 FCVs Installed

The outcome of the analysis for 120 FCVs installed is shown graphically in Figure 15. Whilst installing 120 FCVs gives a marked improvement on distributing an equitable share of the peak flow, a number of growers still receive less than their share and a number of growers receive flow far in excess of their share.

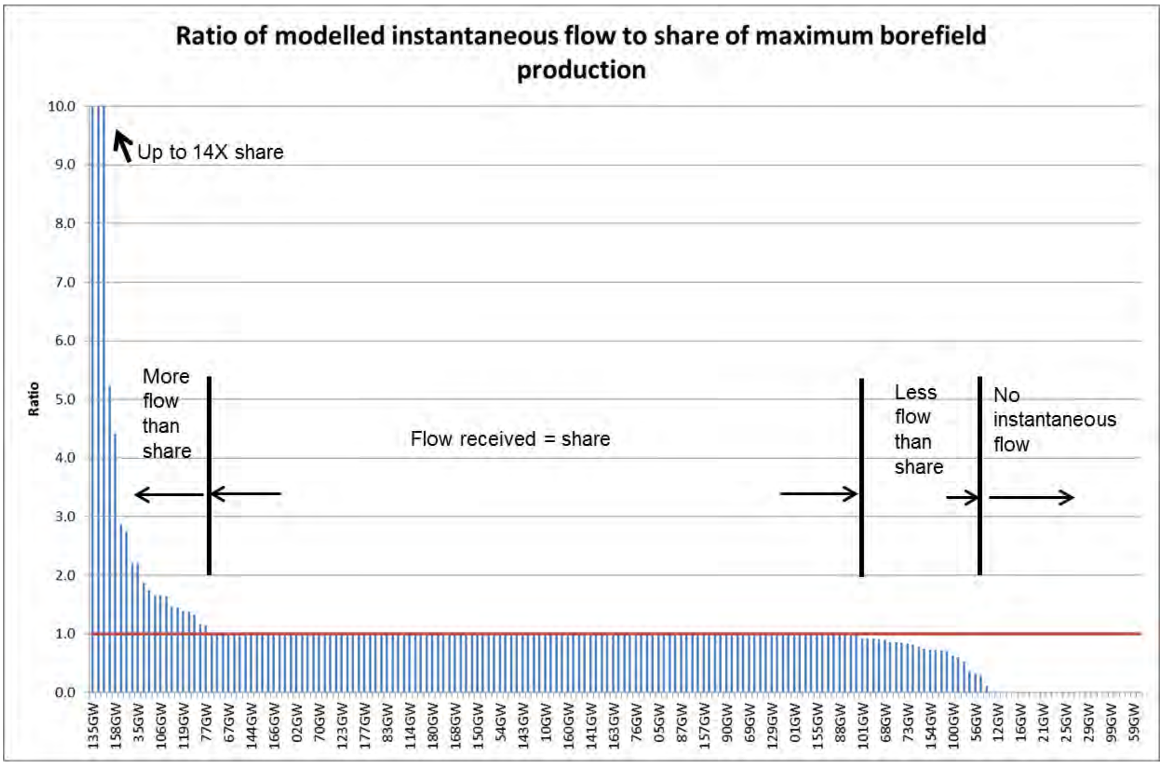
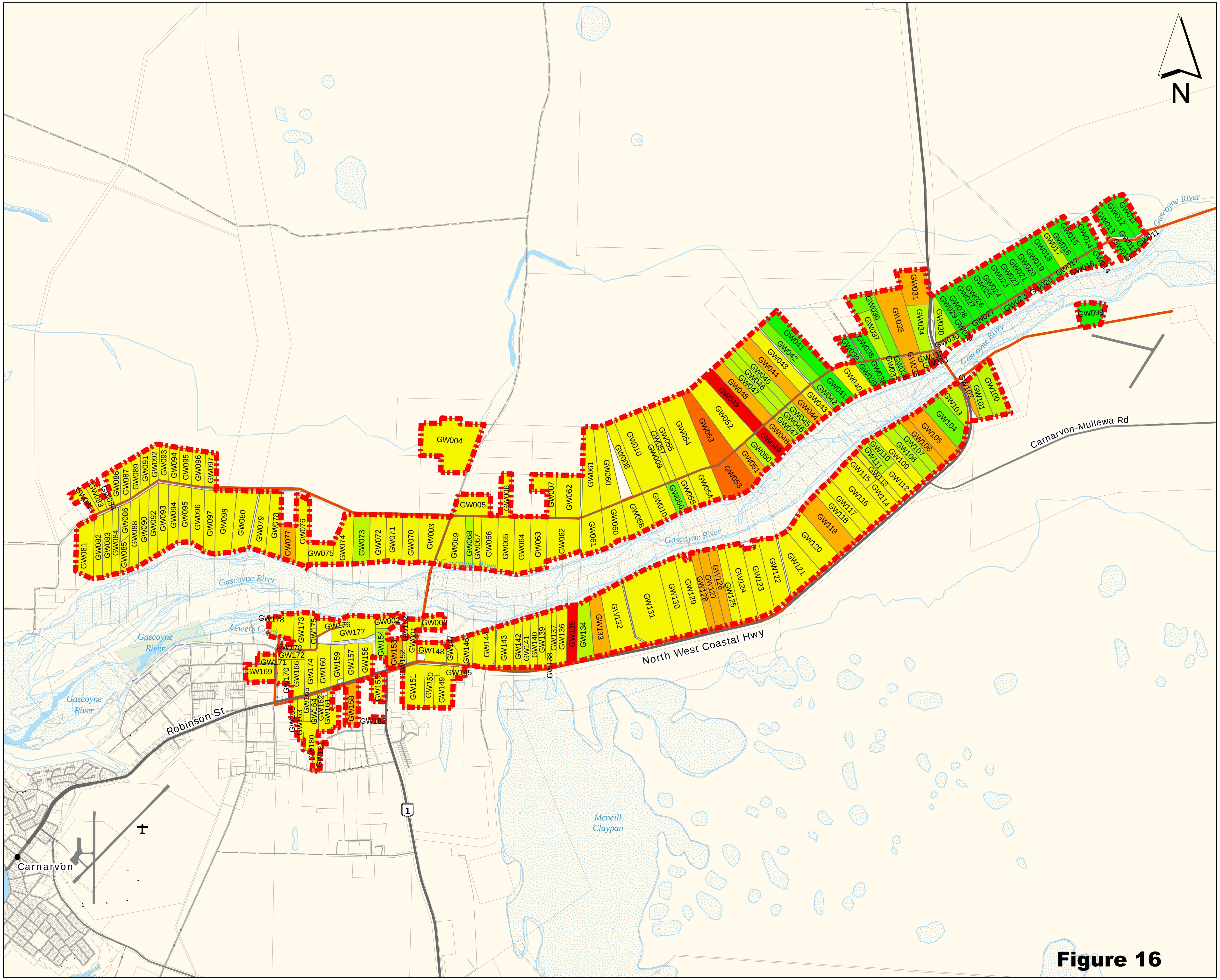


Figure 15. Graphical Representation of Growers Share – 120 Flow Control Valves

Figure 16 presents the growers share spatially. Growers in the east of the scheme receive an instantaneous flow rate less than their share. Growers in the far west of the scheme mostly have FCVs installed in this scenario and hence they show a flow ratio of 1. Growers that receive more than their share in this scenario are concentrated in the mid part of the scheme.



LEGEND

Existing Irrigation Area

Proportion of modelled flow to allocation flow

OHTwenty

- 0.0
- > 0.0 - < 0.5
- 0.5 - < 1.0
- 1.0
- > 1.0 - < 5.0
- 5.0 - < 10.0
- 10.0+

Coordinate System: GDA 1994 MGA Zone 49 Vertical Datum: AHD

1:45,000 at A3

0 500 1000 1500 2000

Metres

AUTHOR: SELLENM0

GROUP: IPB - Spatial Systems

DATE: 25/11/2014

WATER CORPORATION

Gascoyne Water Co-op Existing Irrigation Area Scenario - 120 FCVs installed

File: M:\Projects\R896_Carnarvon\mxd\Gascoyne_Expansion_Borefield_Heat_Map3.mxd

6.3.3 FCVs on all Growers' Customer Assemblies

The analysis was repeated with FCVs installed on all Growers' customer assemblies with the FCVs set to each Grower's Peak Share. This results in the sum of the FCVs set points equalling the peak production from the Borefield, in this case 343L/s (88L/s from the NBF and 255L/s from the SBF).

The outcome of the analysis is shown graphically in Figure 17 and spatially in Figure 18 which not surprisingly shows an equitable distribution to Growers.

The above analysis for the progressive installation of FCVs on Grower's customer assemblies shows that a form of flow control is required on each Grower's customer assembly to ensure an equitable distribution of the peak production rate from the borefields. Only installing flow control to a select number of Grower's customer assemblies will not result in an equitable distribution of the peak production.

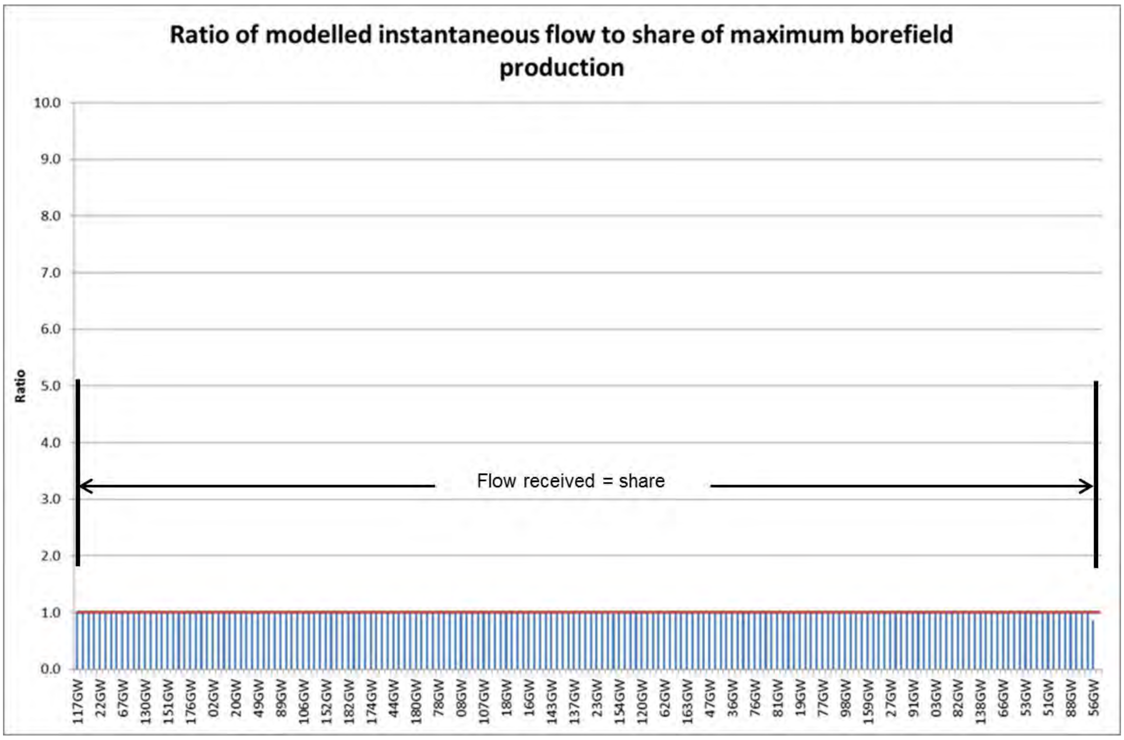
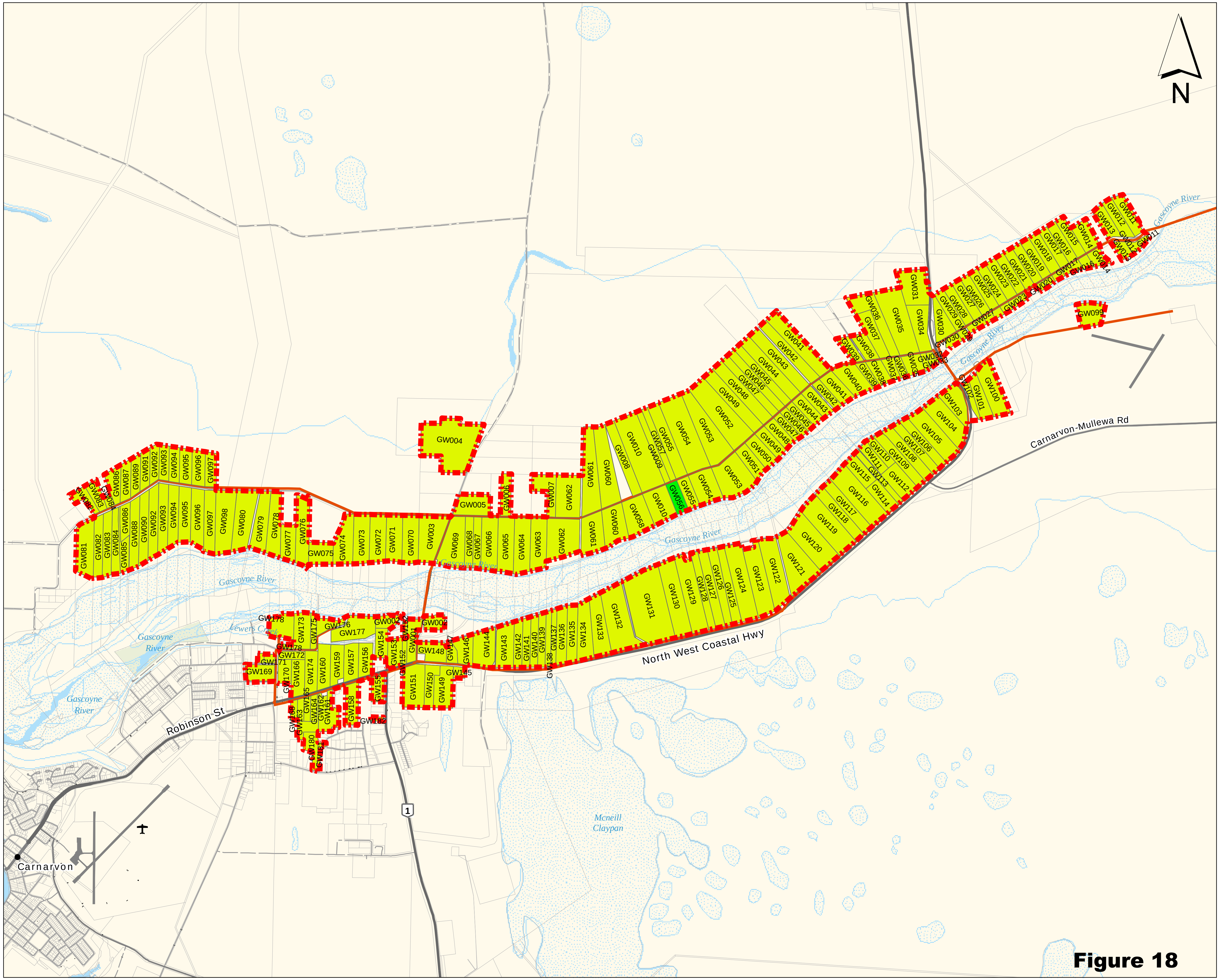


Figure 17. Graphical Representation of Growers Share – FCVs to all Growers



LEGEND

Existing Irrigation

Proportion of modelled flow to allocation flow

- 0.5 - < 1.0
- 1.0+

Coordinate System: GDA 1994 MGA Zone 49 Vertical Datum: AHD

1:45,000 at A3

0 500 1000 1500 2000

Metres

AUTHOR: SELLENM0

GROUP: IPB - Spatial Systems

DATE: 25/11/2014

WATER CORPORATION

Gascoyne Water Co-op Existing Irrigation Area Scenario - All FCVs installed

File: M:\Projects\R896_Carnarvon\mxd\Gascoyne_Expansion_Borefield_Heat_Map4.mxd

6.4 FCV Options

As outlined in Section 4.6 the current Bermad valves are not true flow control valves but instead are a manually adjusted flow regulating valve.

Manually adjusting these valves to achieve an equitable distribution of the peak production to Growers will likely require several attempts with ongoing monitoring. This is because the measure of whether a particular flow control valve is correctly set will be the average flow rate over an extended period rather than the instantaneous flow rate. Accordingly, the process will involve adjusting the valve based on the instantaneous reading available from the flow meter on the customer assembly and then monitoring the average flow rate over an extended period (say a minimum of a day but preferably several days) and re-adjusting the flow control valve accordingly. The existing SCADA system captures hourly meter data and presents this as an average flow rate.

As adjusting valves changes the hydraulic conditions in the upstream system then in theory adjusting a valve one way would require adjusting the remaining valves the other way.

A number of other flow control valve options were investigated. A comparison of these options is included in Table 5.

Options 4 and 5 are a superior flow control valve solution to the other options due to their low pressure loss and adjustability. However upgrading the existing SCADA station from a simple data out facility to a facility that is capable of carrying out local control incurs a significant cost making these options less preferred.

Option 2 is the next least expensive however these valves have a high head loss requirement which will require a higher pressure in the irrigation mains and hence higher power costs. This option also has low adjustability requiring additional orifice plates to be purchased and changed out when flow rates need to be adjusted by more than 10%. This option is less preferred.

Option 3 is also less preferred due to the expense involved and the low adjustability requiring change out of the valves when flow rates need to be adjusted.

Whilst Option 1 will be the least reliable flow control option to achieve equitable flow and will require considerable effort adjusting valves to establish the target flow rates, it is difficult to justify the expenditure required to adopt an alternative flow control method without first disproving the reliability of Option 1.

Option 1 should initially be pursued as the means for achieving equitable flow. However, given that the DN50 flow control valves have been removed (90 in total) and that the DN50 Maric Flow Control valves are cheap ($132 supply), GWC should consider installing the Maric Flow Control valves rather than re-installing the previously removed DN50 flow control valves.

If desired, GWC could consider initially trialling the Maric Flow Control valves so as to prove their suitability for the Carnarvon Irrigation Scheme and to gain customer acceptance for this device.

Table 5. Flow Control Valve Options - Summary.

Option	Description	Pressure Loss Requirements	Adjustability	Robustness	Order of Magnitude Cost per Valve	Comment
1. Use existing "Flow Control Valves"	Re-establish use of existing flow control valves. Re-install previously removed 50 mm flow control valves	Low	Adjustable - adjusted to achieve an average flow rate over an extended period.	Difficult to achieve exact equitable supply. Flow rate will vary as demand varies. Valve setting can be tampered with.	Re-install 50 mm FCV Adjust valve setpoints - likely several iterations	Likely require several attempts to adjust all valves to achieve an equitable supply. Existing SCADA returns an average flow rate - no additional SCADA infrastructure required.
2. Replace existing "flow control valve" to true flow control valve	Replace existing FCV with fit for purpose "true" flow control valve. New valve requires orifice plate to be installed to measure flow.	10 m	Flow rate can only be adjusted by +/-10%. Orifice plate needs to be changed out to achieve greater flow rate adjustment	Capable of achieving near equitable supply. Valve setting can be tampered with.	Supply price DN50 - $1200 DN80 - $1400 DN100 - $1500 DN150 - $2200 Total Supply $243,800 Total incl installation $520,000	Switching between LAS year (SBF 28 ML/d) and non LAS year (SBF 22 ML/d) would require change out of orifice plates.
3. Replace existing "flow control valve" with Maric Flow Control Valve	Install a Maric Flow Control Valve - low pressure version	4 m	Not adjustable - flow rate change would require change of valve	Capable of achieving near equitable supply. Valve setting cannot be tampered with.	Supply price DN50 - $132 DN80 - $318 DN100 - $625 DN150 - $910 Total Supply $51,340 Total incl installation $325,000	Switching between LAS year (SBF 28 ML/d) and non LAS year (SBF 22 ML/d). Would require change out of valve

4. Convert existing valves to a solenoid controlled modulating valve.	Fitting 2 solenoids to each valve enables the existing flow control valve to act as a true flow control valve using a signal from the existing flow meter to adjust the valve position for changing system conditions.	Low	Adjustable	Capable of achieving near equitable supply. Valve setting would only be accessible in locked cabinet.	$1300 per valve $10,000 for additional control and power 182 growers total costs are $2,034,000	No need to purchase any new valves.
5. Convert existing valves to a solenoid on/off valve.	Valve is controlled on daily volume rather than flow rate using a signal from the existing flow meter. Valve is automatically closed when daily usage reaches the growers daily peak share and does not open again until at least the next 24 hour period.	Low	Adjustable	Capable of achieving near equitable supply. Valve setting would only be accessible in locked cabinet.	$500 per valve $10,000 for additional control and power 182 growers total costs are $1,911,000	No need to purchase any new valves. 24 hour reset time would need to be staggered across Growers

6.5 Re-Establishment of Flow Control Valves

6.5.1 Definition of Equitable Flow

GWC/GWAMCO has developed a definition of equity as detailed below.

"Co-operative members are entitled to equitable flow, where equitable means access to the available peak production capacity at a rate of flow proportional to your GWC share allocation, and subject to an agreed minimum flow rate being available to all members.

This definition relates only to GWC shares delivered via the GWAMCO pipeline, and not to water obtained via entitlements through sub-area A."

The peak production capacity is not defined in this statement. It is proposed that the peak production capacity be defined as follows.

- The total flow of the Southern Borefield and the Northern Borefield excluding the capacity of the standby component of the borefields.
- The capacity of the borefields will vary dependent on the hydraulic level (or pressure) that they are required to deliver at the start of the distribution system. The peak production capacity to be the flow rate when the borefields are delivering the target hydraulic level at the start of the distribution system. Currently the target hydraulic level is 32m AHD (15m pressure at the Brickhouse site).

The sum of the average flow rate settings of the flow control valves should always equal (or at least approximate) the peak production capacity. If the sum of the average flow rate settings of the flow control valves is less than the peak production capacity then the peak production capacity will not be realised. If the sum of the average flow rate settings of the flow control valves is greater than the peak production capacity then equitable flow will not be delivered.

When the peak production capacity changes the average flow rate settings of the flow control valves will need to be adjusted to ensure equitable flow. The peak production capacity can change under the following circumstances.

1. Commissioning of additional production bores.
2. Change in flow available from the Southern Borefield as catered for in the current Water Corporation Agreement.
3. Change in target hydraulic level at the start of the distribution system.
4. Bores offline for extended periods due to maintenance.
5. Trading of entitlements.

Adjusting average flow rate settings of the flow control valves when bores are offline for planned or unplanned maintenance is less critical outside of peak demand periods. Whilst equitable flow of the reduced peak production capacity will not be achieved without adjustment of the flow control valves, Growers are still likely to get their daily requirements met.

The provision in the current Water Corporation Agreement for different flow rates from the Southern Borefield dependent on allocation necessitates changes in the setting of the flow control valves. Removal from the agreement of different flow rates for changes in allocation should be considered to avoid the burden of changing settings of the 181 flow control valves. It is noted the new but yet to be endorsed agreement only caters for a single flow rate regardless of allocation.

6.5.2 Minimum Flow Rate Setting

Adopting a minimum flow rate as outlined in the definition of equity will cause a departure from equitable flow, the extent dependent on how high the minimum flow rate is set. A summary of analysis undertaken to investigate the impact of varying minimum flow rate values is shown in Table 6. This analysis shows that as the minimum flow rate setting increases the Growers at the minimum flow rate get a much higher peak factor resulting in the balance of Growers getting a peak factor lower than the scheme peak factor (in this case 1.52). For the case of a minimum flow rate setting of 1.5L/s, the Growers with a small annual entitlement of 5000kL/year receive a peak factor of 9.46 whilst the Growers with a larger entitlement that aren't set at the minimum flow rate get a peak factor 1.28. More detail on the analysis undertaken is included in Appendix F.

GWC need to consider what the minimum flow rate should be, balancing a practical flow rate for Growers with smaller entitlements versus loss of peak factor (or peak share) for the balance of Growers.

Table 6 Minimum Grower Flow Rate Setting

Item	Value		
Peak Production Capacity	390L/s Total 255L/s (22ML/d) from SBF 135L/s from NBF (14 bores)		
Sum of Annual Entitlements	8.063GL/yr – based on entitlements listed in Water Corporation report dated June 2014		
Scheme Peak Factor	1.52		
Minimum Grower Flow Rate	0.5L/s	1.0L/s	1.5L/s
No of growers at Minimum Flow	28	49	86
Peak Factor of Growers at Minimum Flow	1.58 – 3.15	1.58 – 6.31	1.28 – 9.46
Peak Factor for balance of Growers	1.50	1.42	1.28

6.5.3 Establishment of Flow Control

Re-establishing the existing flow control valves so as to achieve equitable distribution of peak production needs to be carried out in a managed way to minimise the effort required to achieve the correct flow control valve settings and the impact to Growers. The following steps should be followed.

1. Agree the minimum flow rate setting.
2. Determine the peak production capacity.
3. Determine the flow rate for each Grower that represents their share of the peak capacity.
4. Adjust the Grower's flow control valve referencing the flow meter on the customer assembly to achieve an instantaneous flow rate that matches the flow rate setting

5. Monitor the average flow rate to each grower regularly and adjust flow control valves as required.

The initial adjustment of the Grower's flow control valves should be carried out under the following conditions.

- Carry out initial adjustment outside of a peak supply period.
- Carry out initial adjustment when the pressures in the scheme match the target pressure. In the initial case this equates to a pressure at the Brickhouse complex of 15m.
- Ensure there is unrestricted flow to the Grower's tank.
- Commence adjustment of flow control in the west of the scheme where a number of Growers currently get much higher than their share.
- Aim to complete adjustment of all flow control valves in the shortest timeframe possible.

7. Gascoyne Food Bowl Initiative (GFI) Future Expansion 4GL/yr

7.1 Planning Assumptions

7.1.1 Overview

A summary of the planning assumptions used for this study is detailed in Table 7.

Table 7. Summary of Planning Assumptions.

Item	Input Used	Comment
Hydrogeological		
NBF yield	0.32GL/annum/km	From Global Groundwater Report – "Northern Gascoyne River Borefield – Hydrogeological Concept Plan", June 2012
Bore Production Rate	10L/s	
GWC Borefield		
Allocation	3.6GL/yr	Current licence.
Peak Production at Planning Horizon	183L/s (15.8ML/d)	Based on an adopted Peak Factor of 1.6.
Existing Capacity	135 L/s	GWC plan to have a total of 14 bores equipped by mid-2015.
Infill Production Bores	5 bores (@10L/s each)	Brings GWC Borefield capacity to 185L/s. Based on 10L/s per production bore
Standby Bores	2 standby bores	Based on Water Corporation criteria of minimum of 10% standby capacity.
GFI Expansion – Northern Borefield		
Allocation	4GL/yr	Only 3.3GL/yr available in allocation plan. Investigations required to prove 4GL/yr available.
Length of GFI NBF expansion	12.5km	Based on 4GL/yr divided by 0.32GL/annum/km.
Peak Production at Planning Horizon	Scenario A - 280L/s (24.2ML/d)	Scenario A - Based on 0.7L/s/Ha. Approximately equivalent to two crops of

Item	Input Used	Comment
	Scenario B - 400L/s (34.6ML/d)	tomatoes in one year. Scenario B – provided by DAFWA.
Production Bores	Scenario A - 28 bores (@10L/s each) Scenario B - 40 bores (@10L/s each)	Based on 10L/s per production bore.
Standby Bores	Scenario A - 3 standby bores (@10L/s each) Scenario B - 4 standby bores (@10L/s each)	Based on Water Corporation criteria of minimum of 10% standby capacity.
GFI Expansion – Irrigation Area		
Levels of Service for Growers in irrigation expansion area	1. Growers' daily supply to be delivered over 24 hours. 2. Growers' customer assembly to be flow restricted to the daily supply. 3. 7m head to be provided to Growers' immediately downstream of the customer assembly. 4. Growers to have on-site storage to enable irrigation at higher rates (but shorter periods) if needed. 5. Growers on-site storage to have an inlet with an air gap for backflow prevention. 6. The irrigation scheme will not provide reserve storage to maintain supply during periods of loss of supply during maintenance.	The levels of service of new land sold for the GFI expansion is to match the existing GWC Customer Charter.
Staging		

Item	Input Used	Comment
Staging	Stage 1 – GWC NBF upgrade to 183L/s (minimum) Stage 2 – GFI Expansion to 50% Stage 3 – GFI Expansion to 100%	

7.1.2 Planning Horizon

The planning horizon adopted for this study is based on the following and shown on Figure 19.

- GWC Borefield - Development of the existing NBF to restore the peak factor of the scheme to the historical peak factor provided by the Northern Borefield of 1.6. A peak factor of 1.6 was adopted in the absence of a peak demand forecast from the irrigators for the existing irrigation area.
- GFI Expansion – Expansion of the Northern Borefield to provide an additional 4GL/yr.

The capacity of the Southern Borefield is to remain the same as current.

GWC Borefield

The GWC borefield was originally equipped with 9 bores (88L/s). GWC are currently undertaking a borefield expansion to bring the total number of bores equipped to 14 (135L/s) and increase the allocation to 3.6GL/yr.

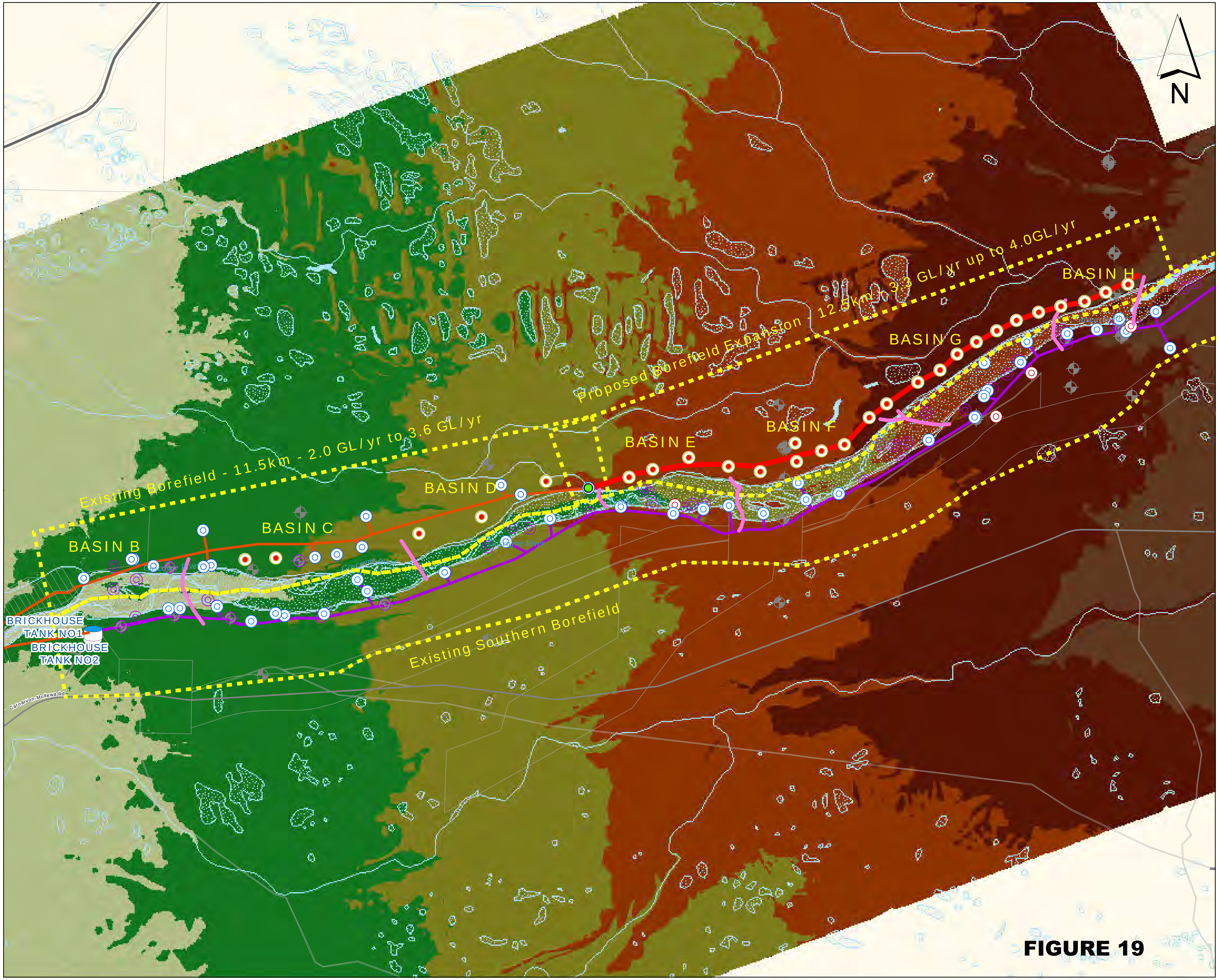
Prior to the construction of the Northern Borefield in 2012, the available peak factor from the Southern Borefield was 1.6 (22ML/d agreement rate in a non LAS year divided by annual average of 13.7ML/d or 5GL/yr). Upon expansion of the Northern Borefield to 14 bores (135L/s) the peak factor will remain below 1.6. The production capacity required from the Northern Borefield to restore the peak factor to 1.6 is 183L/s. This is summarised in Table 8.

Based on 10L/s per production bore, an additional 5 bores are required to achieve a peak production capacity of 183L/s.

Table 8. GWC Northern Borefield Production Capacity.

Item	Peak Capacity	Annual Allocation	Peak Factor
Southern Borefield (Non LAS)	22ML/d	5GL/yr 13.7ML/d	1.6
GWC -Northern Borefield (14 bores)	135L/s 11.7ML/d	3.6GL/yr 9.9ML/d	1.19
Total (SBF + NBF)	**33.7ML/d**	**8.6GL/yr** **23.6ML/d**	**1.43**

Item	Peak Capacity	Annual Allocation	Peak Factor
GWC Northern Borefield Expanded (19 Bores)	183L/s (16.0ML/d)	3.6GL/yr (annual average 9.9ML/d)	1.6



LEGEND

- Planned Bores
- Production Bores
- Northern Borefield Expansion
- Basins
- Gascoyne Water Coop Mains
- Borefield Areas

Water Storage

- Tank
- Elevated tank
- Reservoir

Water Bore

- Production
- Monitoring
- Licensed Private
- Observation
- Irrigation Obervation Bore

Water Main

- Distribution
- Water Corporation Borefield Main

Elevation

- 45 - 50
- 40 - 45
- 35 - 40
- 30 - 35
- 25 - 30
- 20 - 25
- 15 - 20
- 10 - 15
- 5 - 10

Coordinate System: GDA 1994 MGA Zone 49 Vertical Datum: AHD

1:80,000 at A3

0 500 1000 1500 2000 2500

Metres

AUTHOR: SELLENM0

GROUP: IPB - Spatial Systems

DATE: 16/02/2015

WATER CORPORATION

Northern Gascoyne River Borefield Proposed 4GL/Yr Expansion Scenario A - 280L/s

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GFI Expansion

The scope of the Gascoyne Food Bowl Initiative is to provide an additional 4GL/yr water for irrigation.

This study is to consider two scenarios for the peak production capacity of the proposed GFI Expansion as detailed below.

- Scenario A – 280L/s. Based on 2 cropping seasons of 100% tomatoes which equates to a total area of 152 Ha planted. The 152 Ha is equal to 13.2 ML/ha/season or 26.4 ML/ha/year.
- Scenario B – 400L/s. Assessment by DAFWA based on a range of crops and an irrigable area of 400Ha.

Based on a yield of 0.32GL/annum/km for the northern side of the Gascoyne River (Global Groundwater, 2012) the minimum borefield extension required to achieve the target 4GL/yr expansion is 12.5km. A nominal borefield collector main layout is shown on Figure 19 for Scenario A below. This layout is preliminary only and subject to change dependent on the outcomes of DAFWAs drilling investigations currently underway.

However, based on preliminary information from the GFI drilling program it is unlikely that a borefield production of 400L/s will be achievable from a 12.5km expansion of the borefield. It is estimated that an additional 3.3km (15.8km in total) expansion is required.

7.1.3 Borefield Production at the Planning Horizon

Table 9 details the borefield capacity and total capacity at the planning horizon for Scenario A. The peak total flow rate for Scenario A is 787L/s.

Table 9. Borefield Production at the Planning Horizon – Scenario A

Source	No LAS Declared		LAS Declared	
	Peak production	Annual Allocation	Peak production	Annual Allocation
Southern Borefield	22 ML/d 255 L/s	5GL/yr	28 ML/d 324 L/s	7GL/yr
NBF - GWC	15.8 ML/d 183 L/s	3.6GL/yr	15.8 ML/d 183 L/s	3.6GL/yr
NBF – GFI Expansion	24.2 ML/d 280 L/s	4GL/yr	24.2 ML/d 280 L/s	4GL/yr
Total	62 ML/d 718 L/s	12.6GL/yr	68 ML/d 787 L/s	14.6GL/yr

Table 10 details the borefield capacity and total capacity at the planning horizon for Scenario B. The peak total flow rate for Scenario B is 907L/s.

Table 10. Borefield Production at the Planning Horizon – Scenario B

Source	No LAS Declared		LAS Declared	
	Peak production	Annual Allocation	Peak production	Annual Allocation
Southern Borefield	22 ML/d 255 L/s	5GL/yr	28 ML/d 324 L/s	7GL/yr
NBF - GWC	15.8 ML/d 183 L/s	3.6GL/yr	15.8 ML/d 183 L/s	3.6GL/yr
NBF – GFI Expansion	34.6 ML/d 400 L/s	4GL/yr	34.6 ML/d 400 L/s	4GL/yr
Total	72.4 ML/d 838 L/s	12.6GL/yr	78.4 ML/d 907 L/s	14.6GL/yr

7.1.4 Proposed Staging

The staging adopted for this study is detailed below. It is not clear what the timings of the stages are likely to be. Timing scenarios should be considered as part of the economic analysis. Similarly, it is not clear whether Stage A will occur first given this is subject to GWC/GWAMCO securing funding for this work.

It is likely that under the GFI that stages B and C will be combined however for the purposes of investigating economics of the GFI, the engineering analysis has considered the GFI expansion occurring in two stages.

- Stage 1 – GWC NBF upgrade to 183L/s.
- Stage 2 – GFI Expansion to 50%.
- Stage 3 – GFI Expansion to 100%.

7.2 Conceptual Options

Three infrastructure options were identified and agreed with stakeholders at the workshop held on 18 November 2014. The infrastructure options are detailed below.

- Option 1 – Same as Current/Base Case
- Option 2 – New Northern Storage and 2 Booster Pump Stations
- Option 3 – Northern Borefield Pumps to Brickhouse Tanks

Option 1 adopts the same method of operation as current in that both the Southern Borefield and the Northern Borefield pump directly into the irrigation distribution system without breaking pressure (refer to Figure 26).

Option 2 involves both borefields pumping to different ground storages from where new pump stations boost the supply to the irrigation distribution. This option takes advantage of the existing substantial storage available at the Brickhouse complex but requires a new ground storage to be constructed at the Northern Borefield. Use of scheme storage provides a security of supply benefit. In addition, this option has potential operating cost savings as it uses booster pumps to partially lift the water rather than solely rely on much less efficient borehole pumps (refer to Figure 29).

Option 3 is similar in to Option 2 except that rather than build a new storage at the northern borefield a new main is constructed across the Gascoyne River so that the Northern Borefield supply can be pumped to the Brickhouse Tanks (refer to Figure 33).

7.3 Southern Borefield – Potable/Irrigation Separation

A number of options were identified to own and operate the Carnarvon Irrigation Scheme and these are discussed in more detail in the "Mid Term Report – Carnarvon Irrigation District", Carnarvon Ministerial Advisory Committee, May 2014.

Several of these options involved separating the Southern Borefield into two supplies. One supply being a potable supply to continue to supply the potable needs of the town of Carnarvon. The potable supply would continue to be owned and operated by the Water Corporation. The other being an irrigation supply which would be owned and operated by an entity other than the Water Corporation.

Separating the Southern Borefield into a potable supply and an irrigation supply would require construction of a new bore collector main for the potable supply in addition to the future replacement of the aging existing asbestos cement bore collector main.

Requirements for establishment of a separate potable supply borefield were investigated by the Water Corporation. A copy of their high level assessment is included in Appendix G.

Key points from this summary are repeated below.

- A total of 10 bores in the Southern Borefield are required to meet Carnarvon's current annual average and peak day demands.
- The 10 bores to make up the potable source are the 10 closest to the Brickhouse complex excluding bores 20/02 (water quality) and 03/73 (asset condition).
- A 14km DN250 PVC main would be required to connect the 10 bores to the existing town supply main at the Brickhouse complex.

As Carnarvon's demand grows additional production bores will need to be connected to the potable borefield collector main. If feasible, this additional capacity may be met by drilling of new infill bores within the extent of the proposed 14km potable borefield collector main. Should this not be feasible, the increase in capacity would need to be met by extending the potable borefield collector main to connect existing suitable bores. In this instance, an agreement would need to be reached between the Water Corporation and the entity that has ownership of the irrigation component of the Southern Borefield to facilitate transfer of bores to the potable component and restoration of the capacity of the irrigation component of the Southern Borefield.

A more detailed estimate of capital cost for these works was prepared by McGarry Associates as part of this study. This latest estimate put the capital cost for the new 14km DN250 collector main at $6.3M based on the following estimating parameters:

- Contingency 20%.
- Location Factor of 1.3.
- Non direct costs of 18.5%.
- Contractor's preliminaries at 25%.
- Estimate in financial year 2016 dollars.

A summary of the estimate by McGarry Associates is provided in Appendix H. Annual power costs are estimated to be $106,000/yr based on an annual demand of 1.2GL/yr and an N2 Tariff.

Figure 20 shows the cumulative recommended flow of bores in the Southern Borefield starting from the Brickhouse Complex for the bores nominated by the Water Corporation to be part of the potable supply. It is noted that up to chainage 6km the borefield production capacity is approximately 5700kL/d which is approximately 88% of the target current peak day demand of 6500kL/d.

Between chainage 6km and 14km there are only a few low yielding suitable bores. This may mean that Subarea D offers limited potential for groundwater supply. If not, then a preferable solution to establishing a separate potable supply in the Southern Borefield may be to drill production bores in Subarea D and construct a shorter main of approximately 10km length.

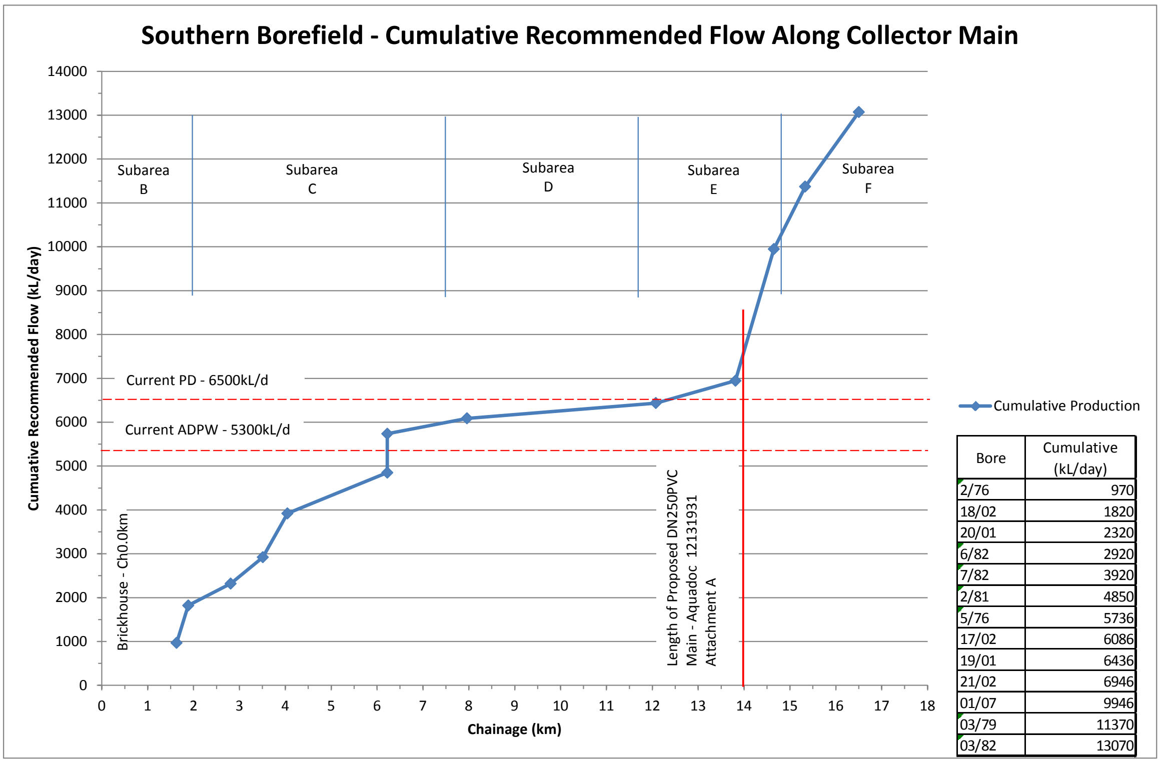


Figure 20 - Southern Borefield - Cumulative Flow

Establishing a separate potable supply changes the control of the bores making up the potable supply. The bores would be controlled on water level in the Brown Range Low Level Tank. The inlet control valve would become redundant and could be at least set manually as always open or preferably bypassed or removed.

Establishing a separate potable supply removes the risk of backflow from the irrigation supply on the basis that all cross connections are removed or at least protected with a double block and bleed arrangement. Accordingly, the “gooseneck” arrangement on the supply main to Brown Range Tank can be removed. Modifications to the emergency shutdown control of the chlorinator would be required.

8. Infrastructure Options – GFI Expansion Scenario A

This section presents the outcomes of the planning assessment of the infrastructure options for Scenario A for the borefield capacities detailed in Table 9.

8.1 Irrigation Distribution System Upgrades

The upgrades required to the irrigation distribution system are the same for the three infrastructure options. Upgrades to the irrigation distribution system are triggered by the GFI Expansion (Stage 2) as the driver of this expansion is the release of more land for irrigation. Upgrades to the irrigation distribution system are not triggered by the GWC Borefield development stage (stage 1) as the additional production is to be distributed to the existing Growers.

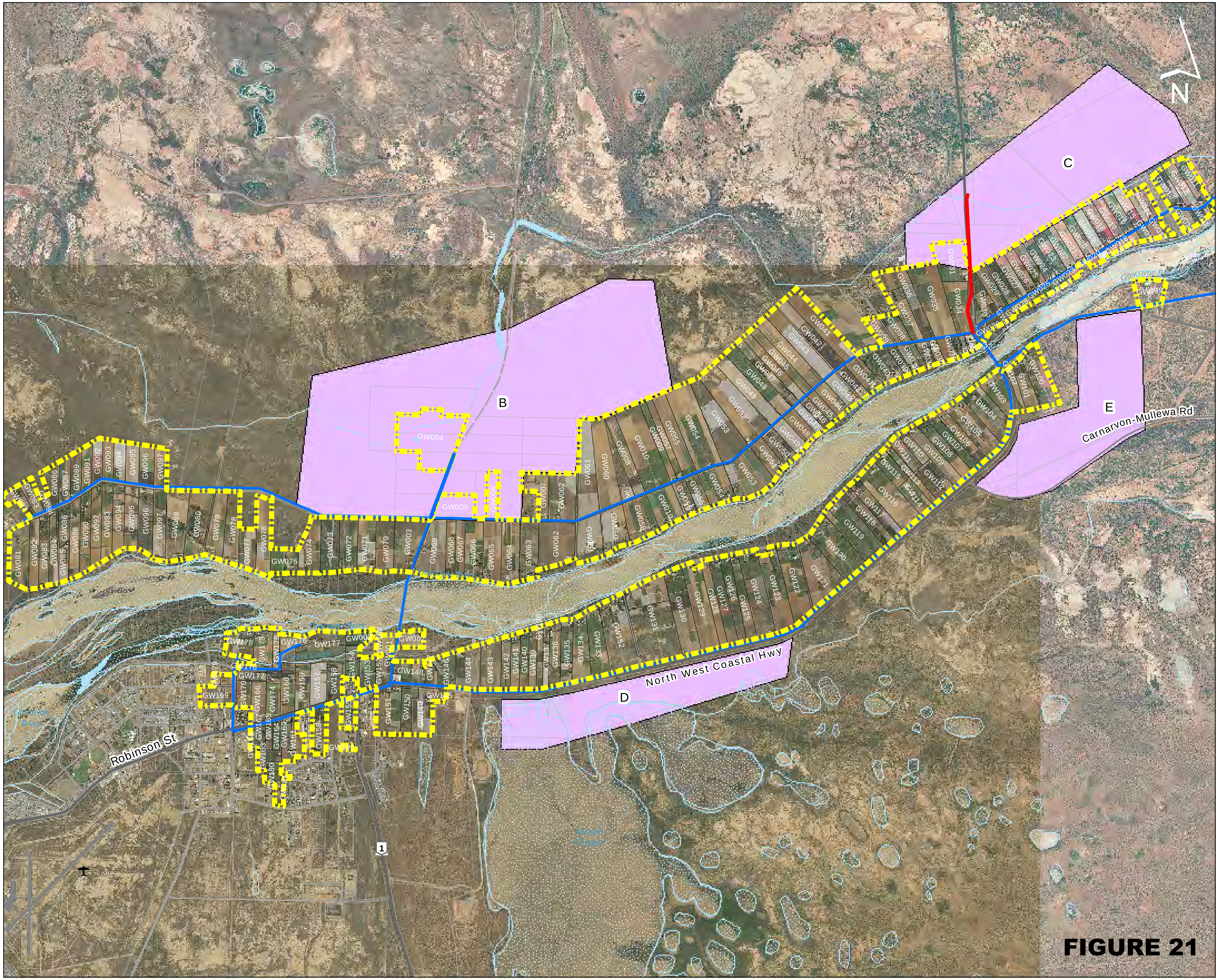
Table 11 details the adopted future irrigation areas and flows for the GFI Expansion under Scenario A. The same irrigation areas are shown in Figure 21. The allocation of the peak flow rate and annual entitlement was based on the land area.

Table 11. Scenario A – GFI Expansion Irrigation Areas

Future Land Identifier	Peak Flow Rate (L/s)	Annual Entitlement (kL/year)
B	47.05	678,500
C	47.05	641,700
D	112.49	1,620,100
E	73.41	1,059,700
Total	280.00	4,000,000

The majority of the future irrigation areas are situated adjacent to the existing irrigation distribution system. An extension to the irrigation distribution system is required to supply area C.

The hydraulic model was developed to include the above future irrigation areas. All growers, including the future irrigation areas were modelled with a FCV on their supply set as described below..



LEGEND

- Existing Irrigation Main
- New Irrigation Main
- Existing Irrigation Area
- Gascoyne Food Bowl - Generic Production Areas

Coordinate System: GDA 1994 MGA Zone 49 Vertical Datum: AHD
The information contained herein is the exclusive property of the Water Corporation and the respective copyright owners. It is subject to ongoing review and should be viewed in conjunction with the associated materials. No part of this production should be copied, modified, reproduced or published in any form other than that intended by the author.

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0 500 1000 1500 2000
Metres

AUTHOR: SELLENM0

GROUP: IPB - Spatial Systems

DATE: 26/02/2015

WATER CORPORATION

Gascoyne Water Co-op Existing & Future Irrigation Areas for NBF Expansion Peak Flow Scenario A - 280L/S

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- The FCVs for the future irrigation areas were set at the peak flow rate shown in Table 11 which sum to 280L/s, the peak flow rate of the GFI Expansion.
- The FCVs for the existing irrigation area were set based on their share of the peak production from the Southern Borefield (324L/s in LAS year) and the GWC component of the Northern Borefield (183L/s) as shown in Appendix B.

Outcomes of the hydraulic analysis are detailed below.

A hydraulic level of 34m AHD is required at the start of the irrigation distribution system which supplies pressures in the distribution system of at least 15m which is sufficient to provide 7m head at the Grower's gate and allows for headlosses through the customer assembly (including flow control valve) and the connecting pipework to the distribution system. The start of the irrigation distribution system is defined as the eastern end of McGlades Road for the Northern Borefield and the Brickhouse complex for the Southern Borefield. The hydraulic level of 34m AHD is equal to a pressure at the Brickhouse complex of 17m.

The extension to the distribution system to supply area C needs to be a DN200 polyethylene main approximately 1500m in length.

Hydraulic grade lines for the southern distribution main and the northern distribution main are shown in Figure 22 and Figure 23 respectively.

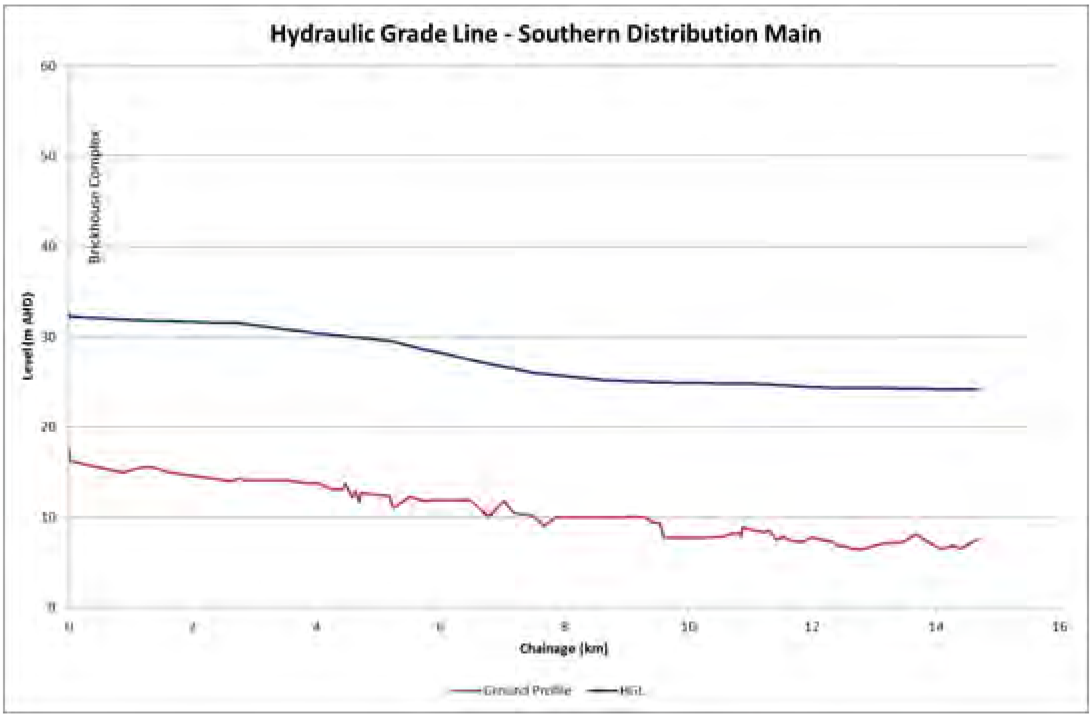


Figure 22 Hydraulic Grade Line - Southern Distribution Main

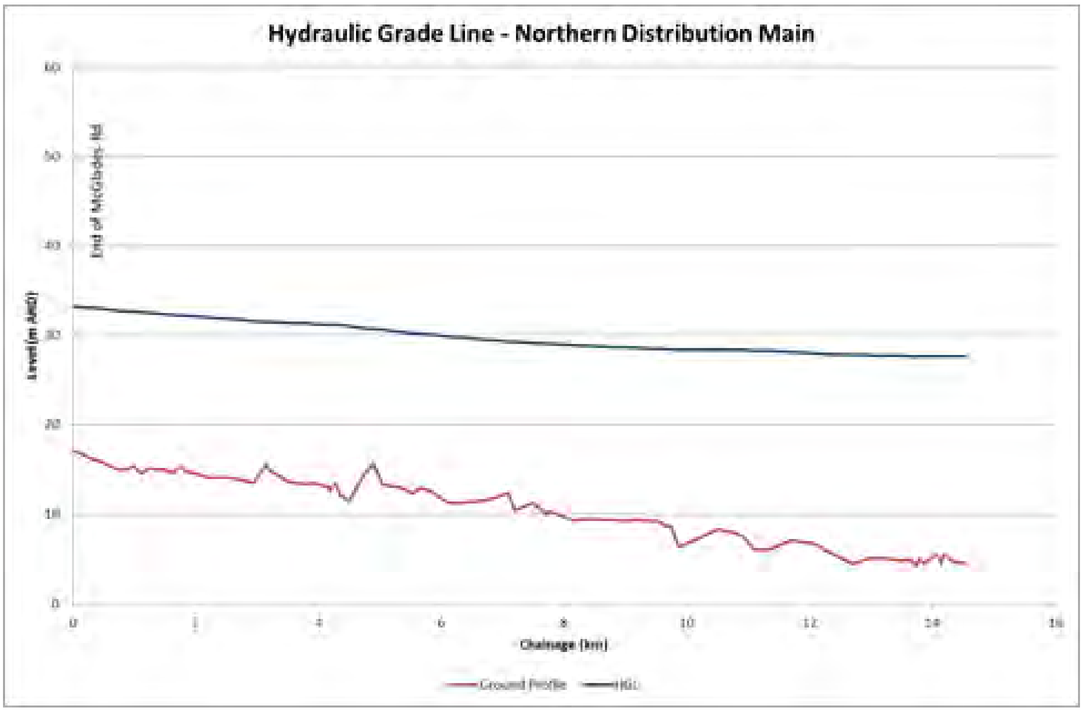


Figure 23 Hydraulic Grade Line - Northern Distribution Main

It should be noted that the system requirements and upgrades detailed above are only relevant to the Scenario A flows (787L/s) and the assumed new irrigation areas and their peak flow rates detailed in Table 11. Should these assumptions change and in particular should DAFWA not take an area based approach to the allocation of peak flows for the GFI Expansion or develop land in areas different to that shown on Figure 21, then hydraulic analysis may need to be repeated to determine the system requirements and upgrades required.

8.2 Northern Borefield Expansion Optimisation

High level analysis was undertaken to understand the optimum combination of borefield collector main and bore pump size. The size of the bore pumps and their operating (energy) cost is dependent on the size of the borefield collector main. A smaller diameter borefield collector main whilst costing less in terms of capital expenditure incurs greater headloss and hence requires more energy input to achieve the same flow. More energy input means larger bore pumps and higher operating costs.

Hydraulic gradients of 1m/km, 2m/km and 3m/km were selected for analysis. Hydraulic gradients represent the energy loss of a pipeline. Borefield collector main diameters, bore pump sizes and operating costs were determined for each of the hydraulic gradient options. The Water Corporation's estimating and financial analysis tool (ACE) was used to develop capital cost estimates and carry out financial analysis

The outcome of the analysis is detailed in Figure 24. A hydraulic gradient of 1m/km has the lowest net present value cost which has been adopted as the basis for sizing the Northern Borefield collector main for Scenario A

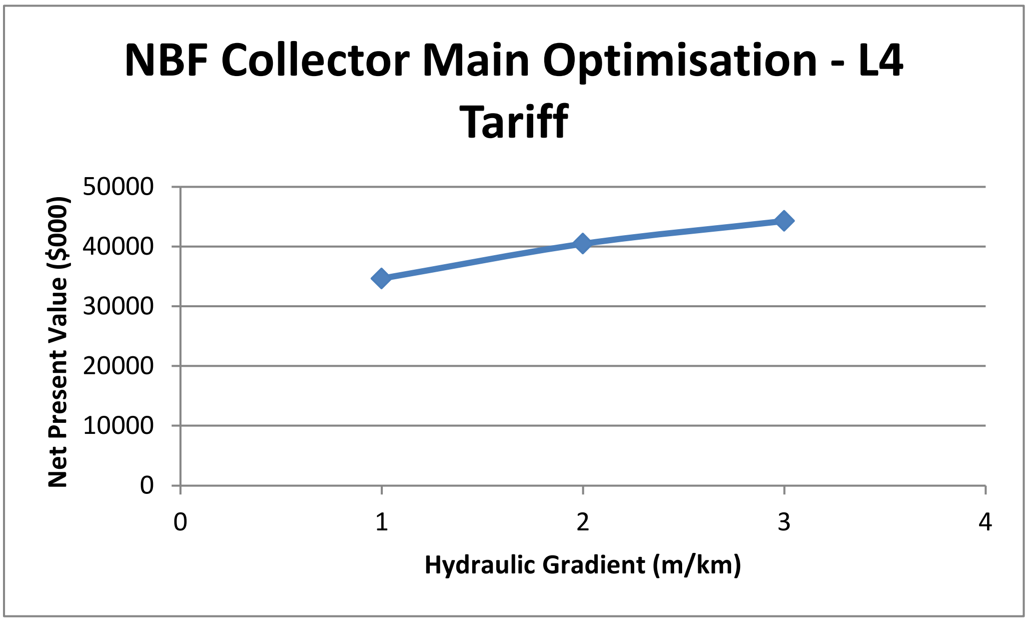


Figure 24 - NBF Collector Main Optimisation

8.3 Option 1 – Same as Current/Base Case

8.3.1 Overview

Option 1 is shown schematically in Figure 26. Option 1 adopts the same method of operation as current in that both the Southern Borefield and the Northern Borefield pump directly into the irrigation distribution system without breaking pressure. The target hydraulic level required at the start of the distribution system is 34m AHD (17m pressure at the Brickhouse complex) which is 2m higher than the adopted target for the current system. The Southern Borefield can meet the LAS agreement irrigation supply rate and the Carnarvon Town demands at this higher hydraulic level.

The existing Northern Borefield collector main is proposed to be retained but will need to be duplicated and extended to accommodate the increased flow from the proposed production bores. Duplicating the main has security of supply advantages as a partial supply from the Northern Borefield will be able to be maintained in the event that one of the duplicate sections should fail.

Hydraulic grade lines for the NBF collector main starting from the end of McGlades Road are shown in Figure 25 for Scenario A. Even at borefield production rates much lower than the annual average rate, pressures in the main will be positive based on the pipe route adopted. Accordingly, during normal operation the collector main will flow full without the hydraulic need for air to enter and exhaust from the main as is the case with the SBF.

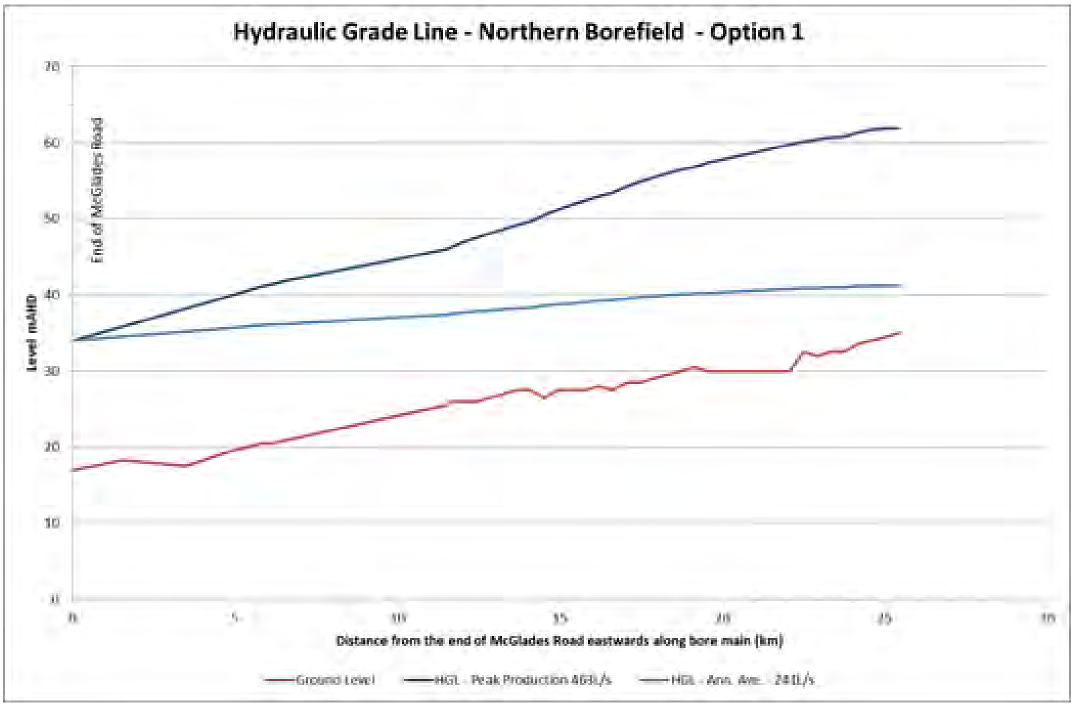


Figure 25. Option 1 - NBF - Hydraulic Grade Lines

The Brickhouse Tanks and Brickhouse Pump Station would continue to be normally bypassed in this option.

The supply to all Growers to be controlled with a flow control valve to deliver their peak daily entitlement at a constant rate over 24 hours.

Key new infrastructure requirements for this option are detailed in Table 12.

Table 12. Option 1 - Scenario A – New Infrastructure Requirements

Item	Detail	Comment
Irrigation Distribution System		
Mains	1.5km DN200PE	Extension to supply new lots of the GFI Expansion
Customer Connections	12 customer assemblies and connections to the distribution mains including SCADA	Connections to supply new lots of the GFI Expansion
Northern Borefield		
GWC Borefield Development	5 duty bores and 2 standby bores. 11kW submersible bores.	Increases peak production capacity to 183L/s to provide a peak factor of 1.6.
GFI Expansion	28 duty bores and 3 standby bores. 11kW submersible bores.	Scenario A peak production capacity of 280L/s
NBF Collector Main upgrade	12.2km DN710 PN6.3 2.5km DN630PE PN6.3 2.5km DN560PE PN6.3 2.5km DN500PE PN6.3 2.5km DN450PE PN6.3 2.5km DN315PE PN6.3	
Monitoring	Magflow meter and pressure transducer	Monitoring of borefield production for regulatory and operational purposes. Monitoring of pressure for borefield control.
Power Supply	12.5km extension of the HV power line	Part of DAFWAs GFI scope.
Southern Borefield		
Potable/Irrigation Separation	14km DN250PVC	Length of main required may be reduced if new production bores can be successfully drilled in Subarea D

8.3.2 Staging

Stage 1 – GWC NBF upgrade to 183L/s

Analysis was undertaken to understand the capacity of the existing Northern Borefield infrastructure to accommodate an increase in capacity to 183L/s. Hydraulic grade lines were prepared for the existing Northern Borefield collector main at borefield peak production rates of 135L/s (14 bores - upgrade underway) and 183 L/s (19 bores - stage 1 upgrade). A chart of these upgrades is included in Appendix I.

The analysis shows the following.

- The hydraulic grade line for a borefield production rate of 183L/s sits comfortably below the maximum allowable operating pressure of the installed main. This is on the basis the 5 new infill production bores and 2 new standby bores aren't concentrated at the eastern end of the existing borefield where pipe diameters are smaller but rather located to give a near even spread of bores along the main. Calculation of the hydraulic grade line should be repeated once the new production bores have been drilled.
- The maximum level the variable speed pumps in the existing 9 bores can pump to at the maximum recommended pumping rate of the bores is shown on the chart. As these values are all at or higher than the curve "Hydraulic Grade Line – 183L/s", the existing bore pumps will be capable of operating to the higher hydraulic grade line once the pump speed has been adjusted.
- The GWC NBF can be upgraded to 183L/s without upgrading the borefield collector main or the pumps in the existing bores.
- The chart also shows the ultimate hydraulic grade line at peak production of 463L/s allowing for the borefield collector main duplication and extension shown in Figure 26. As this hydraulic grade line is lower, selection of pumps for the bores to take the scheme to 135L/s and then take the scheme to 183L/s need to be made in consideration of the ultimate hydraulic grade line. Consideration will need to be made on whether to initially install fixed speed pumps which may need to be changed out when the borefield collector main upgrades are completed or installing a variable speed pump that can handle the varying hydraulic grade lines.

Stage 2 – GFI Expansion to 50% (140L/s).

Extending the NBF to increase capacity by 140L/s nearly doubles the flow through the existing NBF collector mains. This increase in flow would create excessive headloss in the existing mains DN315 and smaller and duplication of these mains with DN710 PE is required at this stage.

This increase in flow increases the velocity and headloss gradient in the existing DN400PE main (the largest diameter existing main) up to 3.1m/s and 16.9m/km. The existing DN400 main is 6.9km long and increasing the flow rate in it by 140L/s will substantially increase the hydraulic grade line whereby the MAOP would be exceeded. The DN400 main also needs to be duplicated with DN710PE at this stage.

The extent of borefield collector main required in stage 2 for connection of 14 production bores and 2 standby bores is detailed below.

- 12.25km of DN710 PE100 PN6.3
- 2.5km of DN630 PE100 PN6.3
- 2.5km of DN560 PE100 PN6.3
- 0.9km of DN500 PE100 PN6.3

The GFI Expansion triggers release of additional irrigation land. It has been assumed that lots that are located adjacent to the main, and hence do not require mains extension to supply, are supplied in Stage 2. The mains extension to supply area C therefore occurs in stage 3.

Separation of the Southern Borefield into a potable supply and an irrigation supply does not have a demand trigger for its timing as it is more driven by governance issues. It has been assumed this separation is to occur as part of a larger project/upgrade to the scheme such as the GFI Expansion. Accordingly, it is assumed this upgrade is to occur in stage 2.

Stage 3 – GFI Expansion to 100%.(+140L/s)

The extent of borefield collector main required in stage 3 for connection of 14 production bores and 2 standby bores is detailed below.

- 1.6km of DN500 PE100 PN6.3
- 2.5km of DN450 PE100 PN6.3
- 2.57km of DN315 PE100 PN6.3

The Stage 3 GFI Expansion triggers release of additional irrigation land. The balance of the lots are connected to the scheme at this stage including the mains extension to supply area C.

8.3.3 Operating Strategy

The proposed operating strategy for both borefields is similar to the current operation of the Southern Borefield. The irrigation component of the Southern Borefield and the Northern Borefield are to operate to maintain pressure at the start of the distribution main within a pressure range, the midpoint of which needs to be the target hydraulic level. The target hydraulic level for stage 1 is to be the same as current, which is 15m head at Brickhouse or 32m AHD. From stage 2 onwards the target hydraulic level should be 34m AHD. It is preferable that the two borefields are controlled from the same pressure transducer and operated as a single borefield however this may only be practical if the borefields are operated by the one entity

As demands increase and the pressure drops to the lower pressure setpoint a bore is called to start. As demands decrease and the pressure rises to the upper pressure setpoint a bore is called to stop.

The pressure range is not able to be defined at this stage as it is dependent on the maximum individual bore production rate which won't be known until the GFI drilling program is complete. Further hydraulic modelling is likely to be required to confirm the pressure setpoints during the design stage.

The bores starting and stopping sequence needs to be adjustable by the operator so that the following drivers can be managed.

- Borefield allocation.
- Balancing of abstraction from subareas.
- Management of water quality.
- Operating cost.
- Power supply constraints for maximum permissible start and stop cycles per hours.

8.3.4 Capital Cost Estimate

Quantity surveyors McGarry Associates were engaged to prepare capital cost estimates. Vendor prices were obtained for key equipment and materials.

The estimated capital costs for Option 1 by stages and expansion is detailed in Table 13 below. Total capital cost is estimated at $21.0M excluding costs to separate the SBF, GFI groundwater investigation costs and NBF overhead power extension.

Table 13 Option 1 Capital Estimate

ITEM	DESCRIPTION	Stage 1	Stage 2	Stage 3
1	**GWC NBF UPGRADE**	**$2,020,000**	**$-**	**$-**
1.1	INFILL BORES DRILLING	$1,451,348	$-	$-
1.2	EQUIP & CONNECT INFILL BORES	$318,128	$-	$-
1.3	BORE COLLECTOR MAIN	$102,877	$-	$-
1.4	SCADA / ELECTRICAL WORKS	$147,361	$-	$-
2	**GFI NBF EXTENSION - BOREFIELD WORKS**	**$-**	**$13,660,000**	**$5,360,000**
2.1	BOREFIELD INVESTIGATIONS	$-	Note 1	Note 1
2.2	EQUIP & CONNECT BORES	$-	$1,045,533	$963,057
2.3	NBF EXTENSION - BORE MAIN	$-	$12,202,230	$3,845,152
2.4	SCADA / ELECTRICAL WORKS	$-	$303,661	$282,470
2.5	DISTRIBUTION SYSTEM/GROWER CONNECTIONS	$-	$103,961	$265,012
2.6	OH POWER EXTENSION	$-	Note 1	Note 1
	Total	**$2,020,000**	**$13,660,000**	**$5,360,000**

NOTES

1 Works being managed or scoped by DAFWA GFI project team. Costs/estimates not repeated here.

2 Estimates subject to outcomes of groundwater investigations

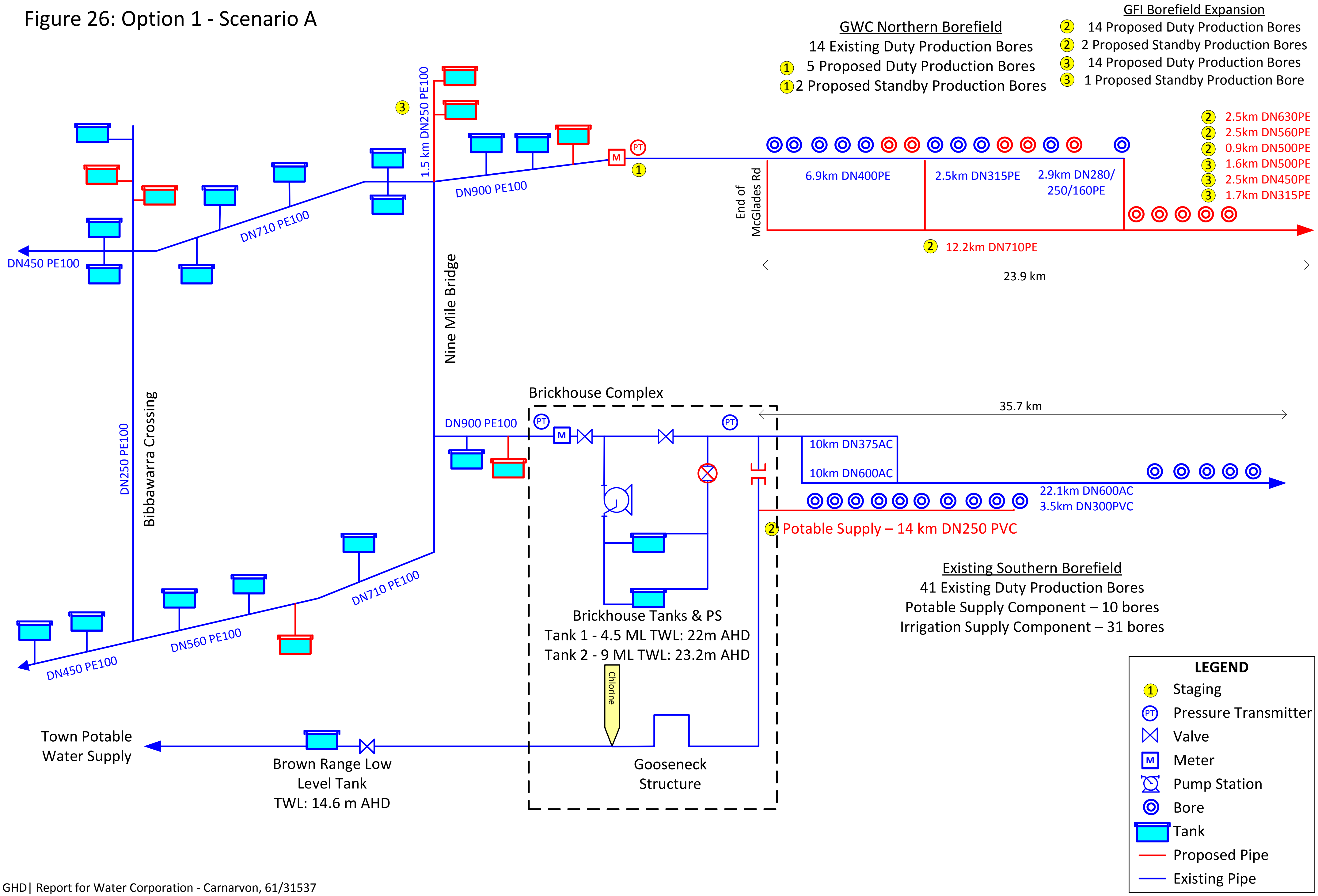
3 Assumed that insitu materials mostly suitable for bedding and backfill of pipes

4 Location factor of 1.3 adopted. Contractor's preliminaries at 25%... Costs for project management, engineering and approvals adopted as 18.5%. Contingency of 20% adopted

5 Estimates are in $FY 2016.

6 Excludes Southern Borefield potable/irrigation separation costs

Figure 26: Option 1 - Scenario A



8.3.5 O&M Estimate

Estimated power costs for Option 1 are summarised in Table 14 by stages.

An L4 Tariff has been adopted for the NBF in the absence of negotiations being finalised with Horizon Energy on the tariff that will apply for the recent electrification.

The SBF power costs have been determined using the N2 power tariff which is the tariff that the Water Corporation is currently charged. The N2 tariff has increased sharply for 2015. If transfer of ownership of the Southern Borefield irrigation assets from the Water Corporation to GWAMCO enables negotiation to a cheaper tariff then power costs for the SBF will reduce.

Table 14. Option 1 - Power Cost Estimate

Item	Power Cost ($/yr)	Comment
Northern Borefield		
Stage 1	$260,000/yr, $0.072/kL	3.6GL/yr, L4 Tariff
Stage 2	$458,000/yr, $0.082/kL	5.6GL/yr, L4Tariff
Stage 3	$622,000/yr, $0.082/kL	7.6GL/yr, L4 Tariff
Southern Borefield		
Stage 1	$944,000/yr, $0.15/kL	5GL/yr Irrigation, 1.2GL/Yr Town, N2 Tariff
Stage 2	Potable Borefield $130,000/yr, $0.108/kL	5GL/yr Irrigation, 1.2GL/Yr Town, N2 Tariff
Stage 3	Irrigation Borefield $622,000/yr, $0.124/kL	5GL/yr Irrigation, 1.2GL/Yr Town, N2 Tariff

Estimated annual maintenance costs for Option 1 are detailed in Table 15. Historical maintenance costs were obtained from GWC and these were used to determine unit maintenance rates to be applied to the expanded scheme. The unit maintenance rates assessment is included in Appendix J. Maintenance costs for the Southern Borefield are not included here. These need to be obtained from the Water Corporation for the economic and pricing modelling.

Table 15. Option 1 – Annual Maintenance Cost Estimate

Item	Stage 1	Stage 2	Stage 3
Northern Borefield	$25,400	$45,700	$63,800
Irrigation Scheme	$15,400	$15,500	$16,200
Scheme Wide – General Maintenance	$19,400	$44,200	$71,000
SBF Potable Water Main	-	$3,500	$3,500
TOTAL	$60,200	$109,000	$154,500
Notes 1. Does not include GST			

8.4 Option 2 – New Northern Storage and 2 Booster Pump Stations

8.4.1 Overview

Option 2 is shown schematically in Figure 29. Option 2 differs from Option 1 in that both borefields pump to ground tanks from which water is supplied to the distribution system from transfer pump stations equipped with typical centrifugal pumps. The NBF pumps to a new ground tank located adjacent to the end of McGlades Street upstream of the distribution system. The SBF irrigation component is to be directed to the Brickhouse Tanks. The advantages of this option are twofold:

- The tanks provide reserve storage, albeit limited, reducing the impact to Growers of a shutdown of either of the borefield collector mains.
- Lower power costs. Submersible borehole pumps are less efficient than normal centrifugal transfer pumps. Having part of the pumping being carried out by the more efficient transfer pumps may reduce power costs.

The supply to all Growers to be controlled with a flow control valve to deliver their peak daily entitlement at a constant rate over 24 hours.

NBF Collector Main

The existing Northern Borefield collector main is proposed to be retained but will need to be duplicated and extended to accommodate the increased flow from the proposed production bores. Duplicating the main has security of supply advantages as a partial supply from the Northern Borefield will be able to be maintained in the event that one of the duplicate sections should fail

Hydraulic grade lines for the NBF collector main starting from the end of McGlades Road are shown in Figure 27 for scenario A. At borefield production rates matching the annual average rate and lower the hydraulic grade line will intersect the level of the borefield collector main based on the pipe route adopted. This will result in the main upstream of this intersection flowing partially full or even empty. Care will need to be taken during design to ensure the following.

- Sufficient air valves are provided in the borefield collector main to enable air to enter and vent from the main.
- The pipeline is designed and installed to minimise reversal of pipeline grade.
- Minimum cover to avoid flotation of the pipe in high groundwater areas.
- Bore headworks design ensures accurate meter reading for bores that are located upstream of where the hydraulic grade line intersects the pipe profile, which may involve installation of pressure sustaining valves to maintain minimum pressure within the bore headworks arrangement.

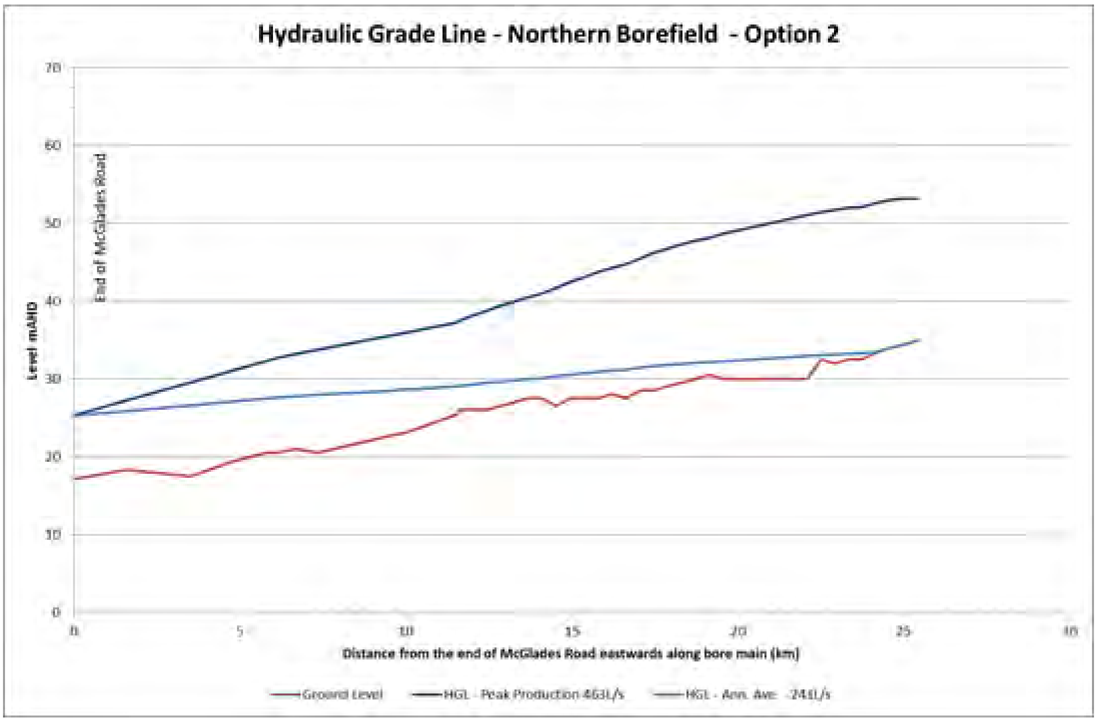


Figure 27. Option 2 - NBF - Hydraulic Grade Lines

<u>NBF Tank and Booster Pump Station</u>

The proposed capacity of the new NBF Tank is 7ML on the basis of the following.

- Control storage – 2.9ML. Volume required to manage starting and stopping of NBF bores
- Reserve storage – 3.3ML – Provides 2 hours reserve storage at the ultimate peak production rate (463L/s) sufficient to make operational changes and advise Growers to reduce demands.
- Unusable Storage – 0.8ML

Ground levels adjacent to the end of McGlades Street upstream of the distribution system are in the order of 17.5m AHD, below the 1:100yr flood level of 18.8m AHD. The estimate allows for fill to be placed to raise ground elevation to 19.3m AHD to avoid flooding of the site and in particular the booster pump station.

The NBF Booster Pump Station pumps from the NBF Tank to the distribution system to achieve the target hydraulic level of 34m AHD. The pump station will need to be variable speed to accommodate the range of flows. A pump station configuration of three duty pumps and one standby pump has been recommended by the vendor based on a minimum flow rate of 10% of peak. Further consideration of the pump station configuration needs to be carried out during design development.

<u>Southern Borefield</u>

Directing flow from the irrigation component of the Southern Borefield to the Brickhouse Tanks rather than pumping over the top of (or bypassing) the tanks as is the current practice changes the hydraulics of the borefield.

Hydraulic grade lines for the SBF collector main starting from the end of McGlades Road are shown in Figure 27 for scenario A

The Brickhouse Tanks are approximately 10m lower than the current target hydraulic level. A lower hydraulic grade line will result, meaning that at low production rates the majority of the main will be operating partially full or empty. The adequacy and frequency of air valves will need to be assessed to ensure that air can enter and vent from the main at appropriate rates.

Pumping to the lower hydraulic level of the Brickhouse tanks will result in the bores operating further to the right on their pump curve. For a number of bores, this will result in them operating outside of their recommended range in which case the pumps will need to be changed out to a smaller pump or alternatively flows throttled to a maximum flow rate. Further assessment of bores likely to be impacted and options to be addressed should be carried out if this option is adopted as the preferred option.

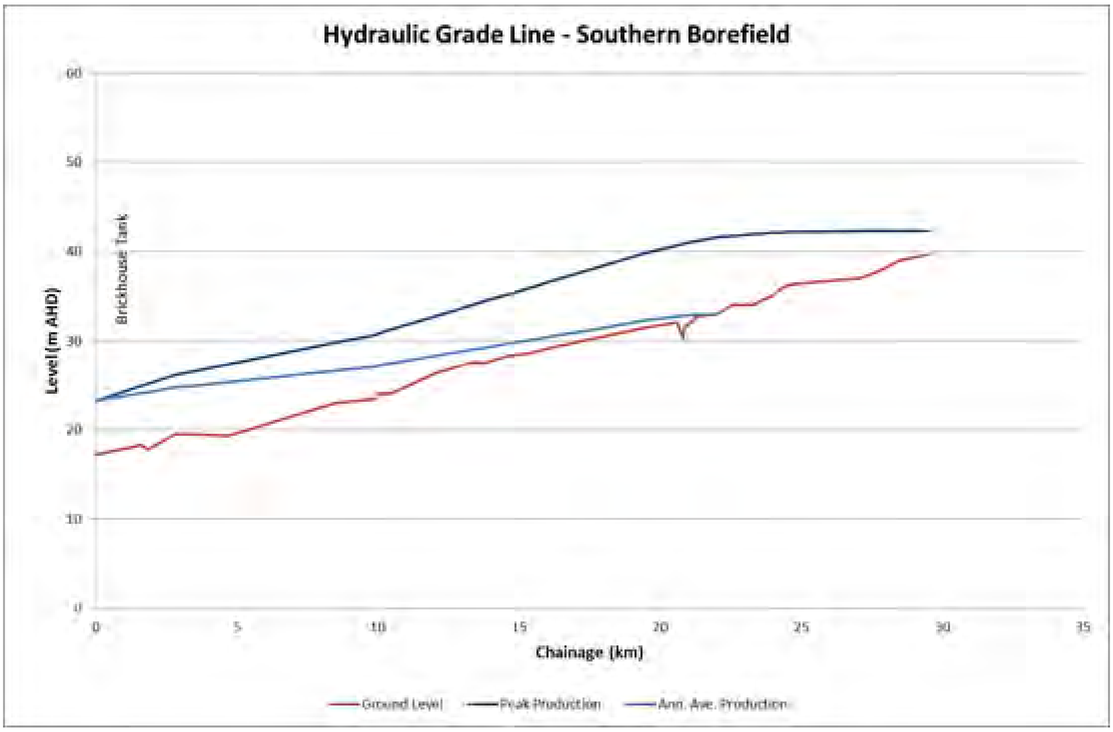


Figure 28. Option 2 - SBF - Hydraulic Grade Lines

Brickhouse Tanks and Booster Pump Station

The smaller Brickhouse Tank complex consists of two tanks as outlined in Section 4.4.1. The roof of the smaller 4.5ML tank is in poor condition and needs replacement. It is proposed that the 4.5ML tank is not brought back into operation due to the cost of replacing the roof and the operational issues of an unroofed tank. An unroofed tank will become an attraction for vermin and wildlife which would create a potential water quality risk given anecdotal reports of use of the irrigation supply for potable purposes.

The 9ML Brickhouse Tank has reserve storage sufficient to maintain supply for 4 hours.

The existing Brickhouse PS has reached the end of its useful asset life. It is proposed, for Option 2, that the Brickhouse PS is abandoned and a new Booster PS with sun shelter is constructed at the Brickhouse Site. The new Brickhouse Booster Pump Station pumps from the 9ML Brickhouse Tank to the distribution system to achieve the target hydraulic level of 34m AHD. The pump station will need to be variable speed to accommodate the range of flows. A pump station configuration of three duty pumps and one standby pump has been recommended by the vendor based on a minimum flow rate of 10% of peak. Further consideration of the pump station configuration needs to be carried out during design development.

Key new infrastructure requirements for this option are detailed in Table 16.

Table 16. Option 2 - Scenario A – New Infrastructure Requirements

Item	Detail	Comment
Irrigation Distribution System		
Mains	1.5km DN200PE	Extension to supply new lots of the GFI Expansion
Customer Connections	12 customer assemblies and connections to the distribution mains including SCADA	Connections to supply new lots of the GFI Expansion
Northern Borefield		
GWC Borefield Development	5 duty bores and 2 standby bores. 5.5kW submersible bores.	Increases peak production capacity to 183L/s to provide a peak factor of 1.6.
GFI Expansion	28 duty bores and 3 standby bores. 5.5kW submersible bores.	Scenario A peak production capacity of 280L/s
NBF Collector Main upgrade	12.25km DN710 PN6.3 2.5km DN630PE PN6.3 2.5km DN560PE PN6.3 2.5km DN500PE PN6.3 2.5km DN450PE PN6.3 2.5km DN315PE PN6.3	
Monitoring	Magflow meter and pressure transducer	Monitoring of borefield production for regulatory and operational purposes. Monitoring of pressure for NBF Booster pump station control.
Power Supply	12.5km extension of the HV power line	Part of DAFWAs GFI scope.
NBF Tank	7ML Ground Tank	
NBF Booster Pump Station	463L/s @ 15m Head	Variable speed. 3 x duty and 1 x standby. 30kW each
Southern Borefield		
New Brickhouse Booster PS	324L/s @ 16.5m	Variable speed. 3 x duty and 1 x standby. 30kW each

Potable/Irrigation Separation	14km DN250PVC	Length of main required may be reduced if new production bores can be successfully drilled in Subarea D

8.4.2 Staging

Stage 1 – GWC NBF upgrade to 183L/s

Analysis was undertaken to understand the capacity of the existing Northern Borefield infrastructure to accommodate an increase in capacity to 183L/s. Hydraulic grade lines were prepared for borefield peak production rates of 135L/s (14 bores - upgrade underway) and 183 L/s (19 bores - stage 1 upgrade). A chart of these upgrades is included in Appendix I.

The analysis shows the following.

- The hydraulic grade line for a borefield production rate of 183L/s sits comfortably below the maximum allowable operating pressure of the installed main. This is on the basis the 5 new infill production bores and 2 new standby bores aren't concentrated at the eastern end of the existing borefield where pipe diameters are smaller but rather located to give a near even spread of bores along the main. Calculation of the hydraulic grade line should be repeated once the new production bores have been drilled.
- The maximum level the variable speed pumps in the existing 9 bores can pump to at the maximum recommended pumping rate of the bores is shown on the chart. As these values are all at or higher than the curve "Hydraulic Grade Line – 183L/s", the existing bore pumps will be capable of operating to the higher hydraulic grade line once the pump speed has been adjusted.
- The GWC NBF can be upgraded to 183L/s without upgrading the borefield collector main or the pumps in the existing bores.
- The chart also shows the ultimate hydraulic grade line at peak production of 463L/s allowing for the borefield collector main duplication and extension shown in Figure 26. As this hydraulic grade line is lower, selection of pumps for the bores to take the scheme to 135L/s and then take the scheme to 183L/s need to be made in consideration of the ultimate hydraulic grade line. Consideration will need to be made on whether to initially install fixed speed pumps which may need to be changed out when the borefield collector main upgrades are completed or installing a variable speed pump that can handle the varying hydraulic grade lines.

Stage 2 – GFI Expansion to 50% (140L/s).

Extending the NBF to increase capacity by 140L/s nearly doubles the flow through the existing NBF collector mains. This increase in flow would create excessive headloss in the existing mains DN315 and smaller and duplication of these mains with DN710 PE is required at this stage.

This increase in flow increases the velocity and headloss gradient in the existing DN400PE main (the largest diameter existing main) up to 3.1m/s and 16.9m/km. The existing DN400 main is 6.9km long and increasing the flow rate in it by 140L/s will substantially increase the hydraulic grade line whereby the MAOP would be approached. Further, the resultant hydraulic grade line would be much higher than the ultimate hydraulic grade line requiring oversized bore pumps for stage 2. The DN400 main also needs to be duplicated with DN710PE at this stage

The extent of borefield collector main required in stage 2 for connection of 14 production bores and 2 standby bores is detailed below.

- o 12.25km of DN710 PE100 PN6.3
- o 2.5km of DN630 PE100 PN6.3
- o 2.5km of DN560 PE100 PN6.3
- o 0.9km of DN500 PE100 PN6.3

The GFI Expansion triggers release of additional irrigation land. It has been assumed that lots that are located adjacent to the main that do not require mains extension to supply, are supplied in Stage 2. The mains extension to supply area C therefore occurs in stage 3.

Separation of the Southern Borefield into a potable supply and an irrigation supply does not have a demand trigger for its timing as it is more driven by governance issues. It has been assumed this separation is to occur as part of a larger project/upgrade to the scheme such as the GFI Expansion. Accordingly, it is assumed this upgrade is to occur in stage 2.

Construction of the NBF Tank, NBF Booster Pump Station and the new Brickhouse Booster Pump Station changes the operation of the scheme and the hydraulic conditions of the borefield. Deferring these assets means that new production bores in the NBF would need to be equipped to account for the different hydraulic conditions or, if this is not possible, bore pumping equipment would need to be replaced. Accordingly, construction of these assets should coincide with the significant expansion of the NBF as proposed by the GFI expansion and a timing of stage 2 has been adopted.

Stage 3 – GFI Expansion to 100%.(+140L/s)

The extent of borefield collector main required in stage 3 for connection of 14 production bores and 2 standby bores is detailed below.

- o 1.6km of DN500 PE100 PN6.3
- o 2.5km of DN450 PE100 PN6.3
- o 2.5km of DN315 PE100 PN6.3

The Stage 3 GFI Expansion triggers release of additional irrigation land. The balance of the lots are connected to the scheme at this stage including the mains extension to supply area C.

8.4.3 Operating Strategy

The operation and control of Option 2 differs markedly from the current scheme and that proposed for Option 1. Option 2 can be separated into three hydraulic systems in addition to the Southern Borefield potable supply system.

- Northern Borefield – northern bores pump to the new NBF Tank
- Southern Borefield Irrigation – southern irrigation bores pump to Brickhouse Tank (9ML).
- Distribution System – NBF Booster Pump Station and the Brickhouse Booster Pump Station pump from their respective storages to the distribution system.

Northern Borefield System

Bores in the NBF are proposed to be controlled on water level in the NBF Tank. When water level in the NBF Tank reaches the low level setpoint a bore(s) is turned on. When water level in the NBF Tank reaches the high level setpoint a bore(s) is turned off. The bores starting and stopping sequence needs to be adjustable by the operator so that the following drivers can be managed.

- Borefield allocation.
- Balancing of abstraction from subareas.
- Management of water quality.
- Operating cost.

Southern Borefield Irrigation System

Irrigation bores in the SBF are proposed to be controlled on water level in the Brickhouse Tank. When water level in the tank reaches the low level setpoint a bore(s) is turned on. When water level in the tank reaches the high level setpoint a bore(s) is turned off. The bores starting and stopping sequence needs to be adjustable by the operator so that the following drivers can be managed.

- Borefield allocation.
- Balancing of abstraction from subareas.
- Management of water quality.
- Operating cost.

Distribution System

The distribution system consists of two controlled assets, the NBF Booster Pump Station and the Brickhouse Booster Pump Station. Both pump stations are to be variable speed controlled on downstream pressure to meet the target hydraulic level of 34m AHD.

However, having both booster pump stations set to be controlled on downstream pressure requires complicated control to avoid each pump responding to the others transition. The less complicated method would be to have one booster pump station controlled on downstream pressure (demand driven) and the other set to a fixed speed (production driven) which would result in a near constant flow rate. This would result in the respective borefields also operating as demand driven (bores turning on and off in response to water levels changes in the tank) and production driven (once the water level in the tank is within range a single bore will turn on and off).

8.4.4 Capital Cost Estimate

Quantity surveyors McGarry Associates were engaged to prepare capital cost estimates. Vendor prices were obtained for key equipment and materials.

The estimated capital costs for Option 2 by stages and expansion are detailed in Table 17 below. Total capital cost is estimated at $27.1 excluding costs to separate the SBF, GFI groundwater investigation costs and NBF overhead power extension.

Table 17 Option 2 Capital Estimate

ITEM	DESCRIPTION	Stage 1	Stage 2	Stage 3
1	**GWC NBF UPGRADE**	**$2,050,000**	**$-**	**$-**
1.1	INFILL BORES DRILLING	$1,485,599	$-	$-
1.2	EQUIP & CONNECT INFILL BORES	$313,200	$-	$-
1.3	BORE COLLECTOR MAIN	$105,305	$-	$-
1.4	SCADA / ELECTRICAL WORKS	$150,839	$-	$-
2	**GFI NBF EXTENSION - BOREFIELD WORKS**	**$-**	**$19,600,000**	**$5,470,000**
2.1	BOREFIELD INVESTIGATIONS	$-	Note 1	Note 1
2.2	EQUIP & CONNECT BORES	$-	$1,061,649	$977,719
2.3	NBF EXTENSION - BORE MAIN	$-	$12,489,370	$3,934,899
2.4	SCADA / ELECTRICAL WORKS	$-	$313,878	$289,064
2.5	DISTRIBUTION SYSTEM/GROWER CONNECTIONS	$-	$106,408	$271,198
2.6	NBF & SBF BOOSTER PUMP STATIONS	$-	$1,909,249	$-
2.7	NBF STORAGE	$-	$3,715,328	$-
2.8	OH POWER EXTENSION	$-	Note 1	Note 1
	Total	**$2,050,000**	**$19,600,000**	**$5,470,000**

NOTES

1 Works being managed or scoped by DAFWA GFI project team. Costs/estimates not repeated here.

2 Estimates subject to outcomes of groundwater investigations

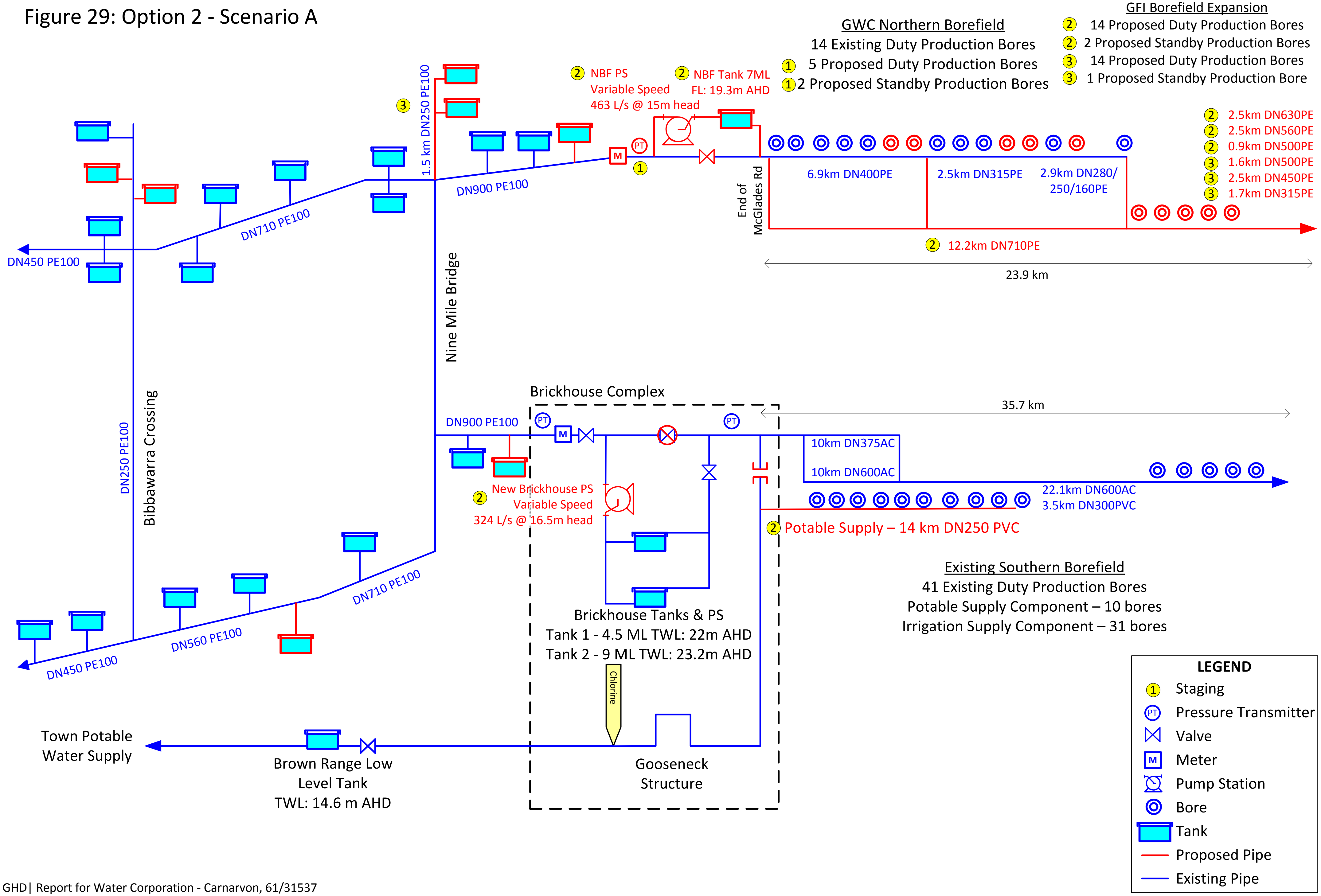
3 Assumed that insitu materials are mostly suitable for bedding and backfill of pipes

4 Location factor of 1.3 adopted. Contractor's preliminaries at 25%. Costs for project management, engineering and approvals adopted as 18.5%. Contingency of 20% adopted

5 Estimates are in $FY 2016

6 Excludes Southern Borefield potable/irrigation separation costs

Figure 29: Option 2 - Scenario A



8.4.5 O&M Estimate

Estimated power costs for Option 2 are summarised in Table 18 by stages. .

An L4 Tariff has been adopted for the NBF in the absence of negotiations being finalised with Horizon Energy on the tariff that will apply for the recent electrification.

The SBF power costs have been determined using the N2 power tariff which is the tariff that the Water Corporation is currently charged. The N2 tariff has increased sharply for 2015. If transfer of ownership of the Southern Borefield irrigation assets from the Water Corporation to GWAMCO enables negotiation to a cheaper tariff then power costs for the SBF will reduce.

Table 18. Option 2 - Power Cost Estimate

Item	Power Cost ($/yr)	Comment
Northern Borefield & NBF Booster Pump Station		
Stage 1	$260,000/yr, $0.072/kL	3.6GL/yr, L4 Tariff
Stage 2 NBF NBF Booster PS	 $357,000/yr, $0.064/kL $93,000/yr, $0.017/kL	5.6GL/yr, L4Tariff
Stage 3 NBF NBF Booster PS	 $484,000/yr, $0.064/kL $126,000/yr, $0.017/kL	7.6GL/yr, L4 Tariff
Southern Borefield		
Stage 1	$944,000/yr, $0.15/kL	5GL/yr Irrigation, 1.2GL/Yr Town, N2 Tariff
Stage 2	Potable Borefield $130,000/yr, $0.108/kL Irrigation Borefield $547,000/yr, $0.109/kL New Brickhouse Booster PS $161,000/yr, $0.032/kL	5GL/yr Irrigation, 1.2GL/Yr Town, N2 Tariff
Stage 3		5GL/yr Irrigation, 1.2GL/Yr Town, N2 Tariff

Estimated maintenance costs for Option 2 are detailed in Table 19. Historical maintenance costs were obtained from GWC and these were used to determine unit maintenance rates to be applied to the expanded scheme. The unit maintenance rates assessment is included in Appendix J. Maintenance costs for the Southern Borefield are not included here. These need to be obtained from the Water Corporation for the economic and pricing modelling.

Table 19. Option 2 - Maintenance Cost Estimate

Item	Stage 1	Stage 2	Stage 3
Northern Borefield	$25,400	$45,700	$63,800
Irrigation Scheme	$15,400	$15,500	$16,200
Scheme Wide – General Maintenance	$19,400	$54,200	$78,200
SBF Potable Water Main	-	$3,500	$3,500
NBF Tank	-	$4,400	$4,400
NBF BPS	-	$5,900	$5,900
New Brickhouse BPS	-	$6,900	$6,900
TOTAL	$60,200	$136,000	$178,700
Notes 1. Does not include GST			

8.5 Option 3 – Northern Borefield Pumps to Brickhouse Tanks

8.5.1 Overview

Option 3 is shown schematically in Figure 33. Option 3 differs from Option 1 in that both borefields pump to the Brickhouse Tanks. From the Brickhouse Tanks water is boosted to the distribution system via a new Brickhouse Booster Pump Station. The advantages of this option compared to the current operation are as follows:

- The tanks provide reserve storage, albeit limited, reducing the impact to Growers of a shutdown of either of the borefield collector mains.
- Lower power costs. Submersible borehole pumps are less efficient than normal centrifugal transfer pumps. Having part of the pumping being carried out by the more efficient transfer pumps may reduce power costs.
- Water quality management. Having both borefields pumping to the same tank provides the ability to blend the water if the water quality in one of the borefields deteriorates.

The supply to all Growers to be controlled with a flow control valve to deliver their peak daily entitlement at a constant rate over 24 hours.

NBF Collector Main

Under this option bores in the Northern Borefield are to pump to the Brickhouse Tanks. This will require a main to be constructed across the Gascoyne River. Achieving adequate protection of the pipe at the river crossing will present a challenge given the sandy material of the river bed and its depth. It is preferable that the pipe is bedded in rock for river crossings. However, if the depth to rock is too high then a cheaper alternative may be to construct the main in steel and support the pipe on piles. The river crossing has a higher security of supply risk and estimating risk.

The existing Northern Borefield collector main is proposed to be retained but will need to be duplicated and extended to accommodate the increased flow from the proposed production bores. Duplicating the main has security of supply advantages as a partial supply from the Northern Borefield will be able to be maintained in the event that one of the duplicate sections should fail

Hydraulic grade lines for the NBF collector main starting from the end of McGlades Road are shown in Figure 30 for scenario A. At borefield production rates matching the annual average rate and lower, the hydraulic grade line will intersect the level of the borefield collector main based on the pipe route adopted. This will result in the main upstream of this intersection flowing partially full or even empty. Care will need to be taken during design to ensure the following.

- Sufficient air valves are provided in the borefield collector main to enable air to enter and vent from the main.
- The pipeline is designed and installed to minimise reversal of pipeline grade.
- Bore headworks design ensures accurate meter reading for bores that are located upstream of where the hydraulic grade line intersects the pipe profile.

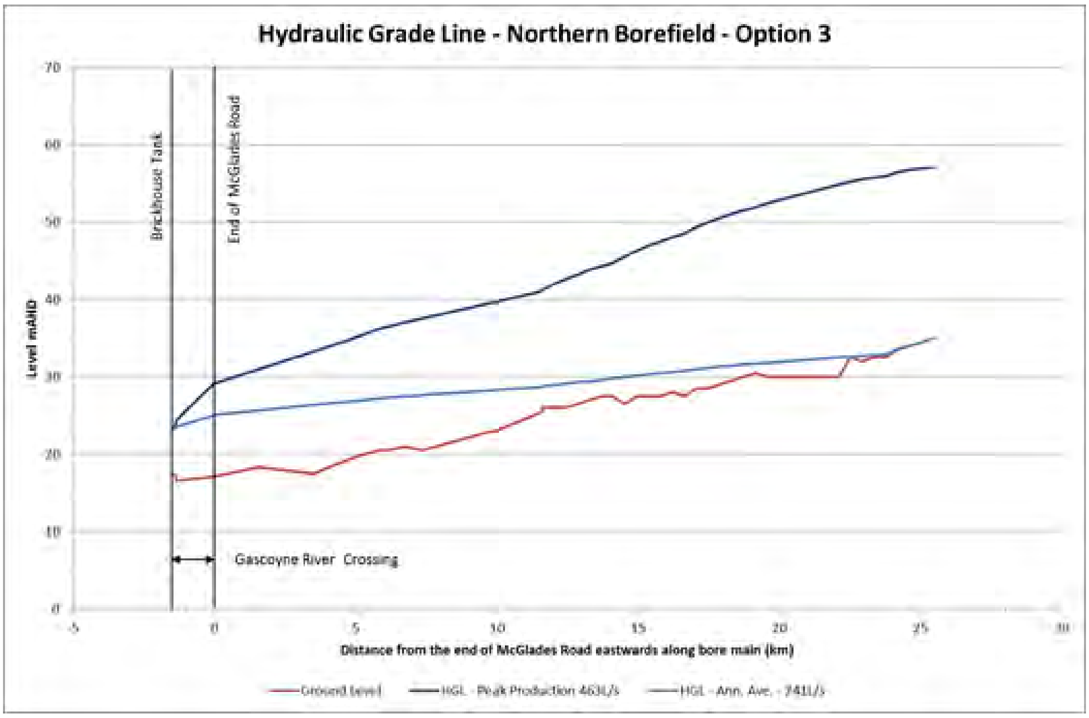


Figure 30. Option 3 - NBF - Hydraulic Grade Lines

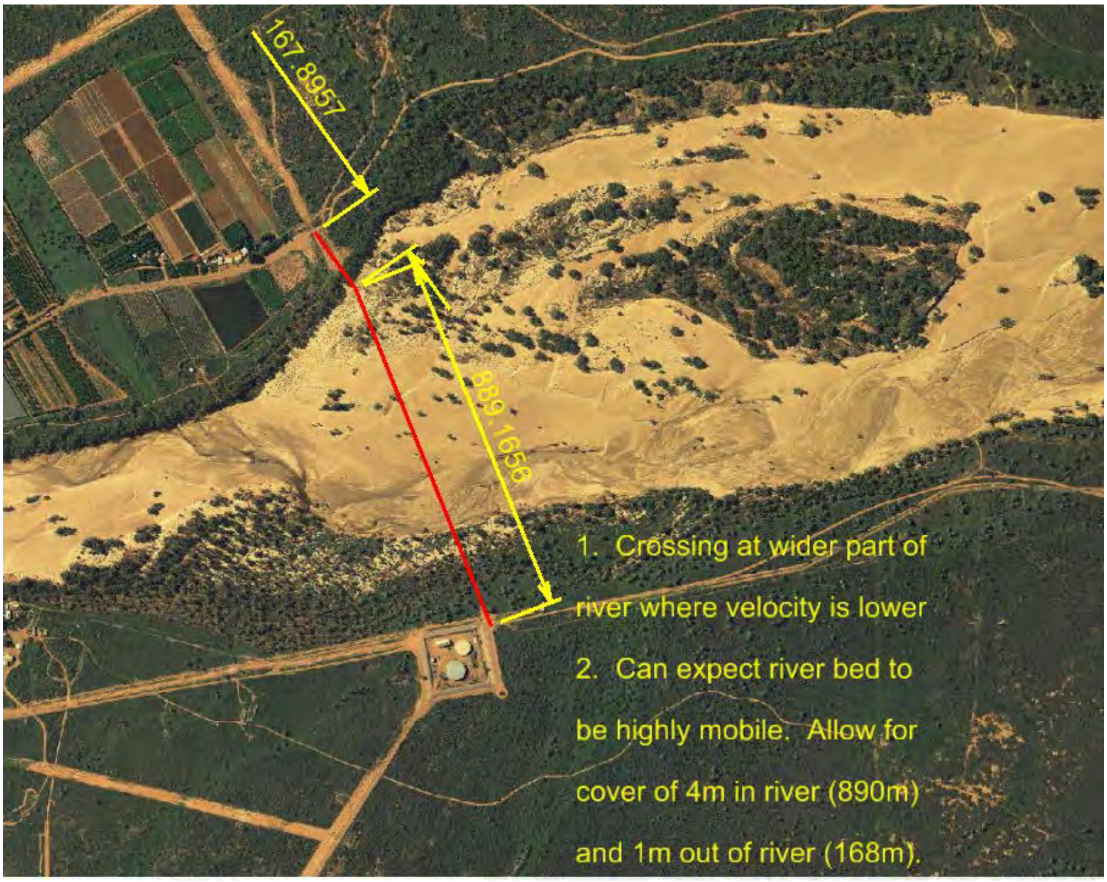


Figure 31. Adopted location of river crossing

Southern Borefield

Directing flow from the irrigation component of the Southern Borefield to the Brickhouse Tanks rather than pumping over the top of (or bypassing) the tanks as is the current practice changes the hydraulics of the borefield.

Hydraulic grade lines for the SBF collector main starting from the end of McGlades Road are shown in Figure 32 for scenario A

The Brickhouse Tanks are approximately 10m lower than the current target hydraulic level. A lower hydraulic grade line will result, meaning that at low production rates the majority of the main will be operating partially full or empty. The adequacy and frequency of air valves will need to be assessed to ensure that air can enter and vent from the main at appropriate rates.

Pumping to the lower hydraulic level of the Brickhouse tanks will result in the bores operating further to the right on their pump curve. For a number of bores, this will result in them operating outside of their recommended range in which case the pumps will need to be changed out to a smaller pump or alternatively flows throttled to a maximum flow rate. Further assessment of bores likely to be impacted and options to be addressed should be carried out if this option is adopted as the preferred option.

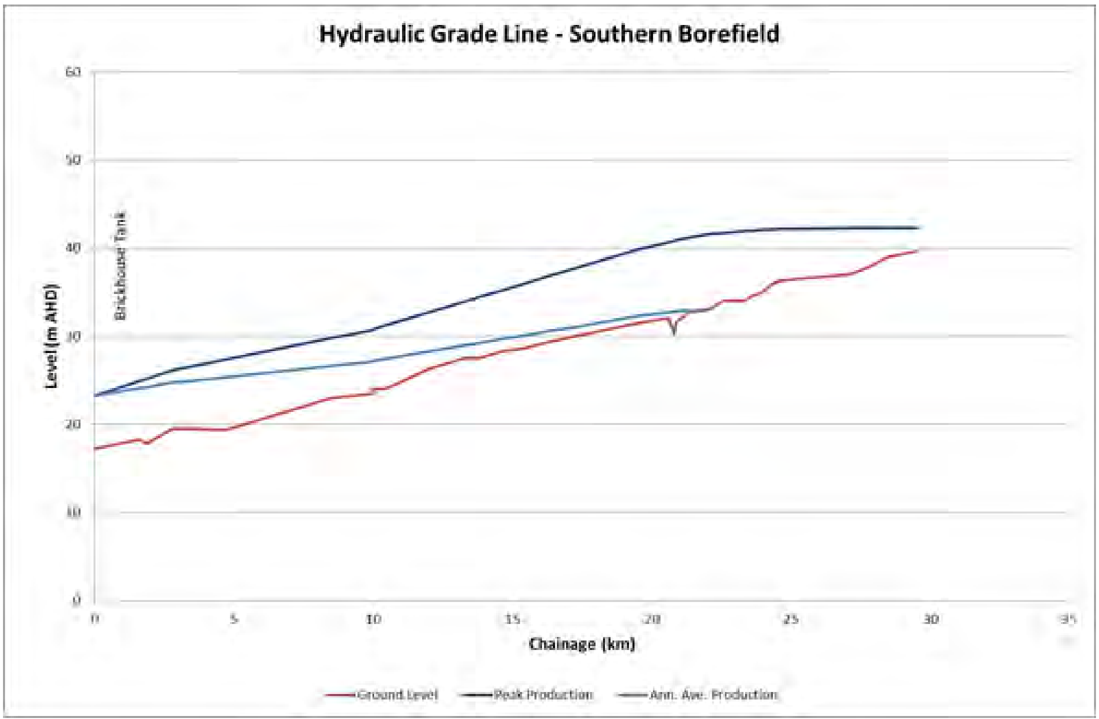


Figure 32. Option 3 - SBF - Hydraulic Grade Lines

Brickhouse Tanks and Booster Pump Station

The smaller Brickhouse Tank complex consists of two tanks as outlined in Section 4.4.1. The roof of the smaller 4.5ML tank is in poor condition and needs replacement. It is proposed that the 4.5ML tank is not brought back into operation due to the cost of replacing the roof and the operational issues of an unroofed tank. An unroofed tank will become an attraction for vermin and wildlife which would create a potential water quality risk given anecdotal reports of use of the irrigation supply for potable purposes.

The 9ML Brickhouse Tank has reserve storage sufficient to maintain supply for 1.5 hours.

The existing Brickhouse PS has reached the end of its useful asset life. It is proposed, for Option 3, that the Brickhouse PS is abandoned and a new Booster PS with sun shelter is constructed at the Brickhouse Site. The new Brickhouse Booster Pump Station pumps from the 9ML Brickhouse Tank to the distribution system to achieve the target hydraulic level of 34m AHD. The pump station will need to be variable speed to accommodate the range of flows. A pump station configuration of three duty pumps and one standby pump has been recommended by the vendor based on a minimum flow rate of 10% of peak. Further consideration of the pump station configuration needs to be carried out during design development.

Key new infrastructure requirements for this option are detailed in Table 20.

Table 20. Option 3 - Scenario A – New Infrastructure Requirements

Item	Detail	Comment
Irrigation Distribution System		
Mains	1.5km DN200PE	Extension to supply new lots of the GFI Expansion
Customer Connections	12 customer assemblies and connections to the distribution mains including SCADA	Connections to supply new lots of the GFI Expansion
Northern Borefield		
GWC Borefield Development	5 duty bores and 2 standby bores. 5.5kW submersible bores.	Increases peak production capacity to 183L/s to provide a peak factor of 1.6.
GFI Expansion	28 duty bores and 3 standby bores. 5.5kW submersible bores.	Scenario A peak production capacity of 280L/s
NBF Collector Main upgrade	12.25km DN710 PN6.3 2.5km DN630PE PN6.3 2.5km DN560PE PN6.3 2.5km DN500PE PN6.3 2.5km DN450PE PN6.3 2.5km DN315PE PN6.3	
River Crossing	1.1km DN630 PE PN6.3	Estimate allows for pipe laid at cover of 4m. Pipe crossing location and method of pipe protection needs detailed engineering assessment.
Monitoring	Magflow meter	Monitoring of borefield production for regulatory and operational purposes.
Power Supply	12.5km extension of the HV power line	Part of DAFWAs GFI scope.
Southern Borefield		
New Brickhouse Booster PS	787L/s @ 16.5m	Variable speed. 3 x duty and 1 x standby. 30kW each
Potable/Irrigation Separation	14km DN250PVC	Length of main required may be reduced if new production bores can be successfully drilled in Subarea D

8.5.2 Staging

Stage 1 – GWC NBF upgrade to 183L/s

Analysis was undertaken to understand the capacity of the existing Northern Borefield infrastructure to accommodate an increase in capacity to 183L/s. Hydraulic grade lines were prepared for borefield peak production rates of 135L/s (14 bores - upgrade underway) and 183 L/s (19 bores - stage 1 upgrade) without any upgrades to the existing borefield collector main. A chart of these upgrades is included in Appendix I.

The analysis shows the following.

- The hydraulic grade line for a borefield production rate of 183L/s sits comfortably below the maximum allowable operating pressure of the installed main. This is on the basis the 5 new infill production bores and 2 new standby bores aren't concentrated at the eastern end of the existing borefield where pipe diameters are smaller but rather located to give a near even spread of bores along the main. Calculation of the hydraulic grade line should be repeated once the new production bores have been drilled.
- The maximum level the variable speed pumps in the existing 9 bores can pump to at the maximum recommended pumping rate of the bores is shown on the chart. As these values are all at or higher than the curve "Hydraulic Grade Line – 183L/s", the existing bore pumps will be capable of operating to the higher hydraulic grade line once the pump speed has been adjusted.
- The GWC NBF can be upgraded to 183L/s without upgrading the borefield collector main or the pumps in the existing bores.
- The chart also shows the ultimate hydraulic grade line at peak production of 463L/s allowing for the borefield collector main duplication and extension shown in Figure 26. As this hydraulic grade line is lower, selection of pumps for the bores to take the scheme to 135L/s and then take the scheme to 183L/s need to be made in consideration of the ultimate hydraulic grade line. Consideration will need to be made on whether to initially install fixed speed pumps which may need to be changed out when the borefield collector main upgrades are completed or installing a variable speed pump that can handle the varying hydraulic grade lines.

Stage 2 – GFI Expansion to 50% (140L/s).

Extending the NBF to increase capacity by 140L/s nearly doubles the flow through the existing NBF collector mains. This increase in flow would create excessive headloss in the existing mains DN315 and smaller and duplication of these mains with DN710PE is required at this stage.

This increase in flow increases the velocity and headloss gradient in the existing DN400PE main (the largest diameter existing main) up to 3.1m/s and 16.9m/km. The existing DN400 main is 6.9km long and increasing the flow rate in it by 140L/s will substantially increase the hydraulic grade line whereby the MAOP would be approached. Further, the resultant hydraulic grade line would be much higher than the ultimate hydraulic grade line requiring oversized bore pumps for stage 2. The DN400 main also needs to be duplicated with DN710PE at this stage.

The extent of borefield collector main required in stage 2 for connection of 14 production bores and 2 standby bores is detailed below.

- 12.25km of DN710 PE100 PN6.3
- 2.5km of DN630 PE100 PN6.3

- 2.5km of DN560 PE100 PN6.3
- 0.9km of DN500 PE100 PN6.3

The GFI Expansion triggers release of additional irrigation land. It has been assumed that lots that are located adjacent to the main that do not require mains extension to supply are supplied in Stage 2. The mains extension to supply area C therefore occurs in stage 3.

Separation of the Southern Borefield into a potable supply and an irrigation supply does not have a demand trigger for its timing as it is more driven by governance issues. It has been assumed this separation is to occur as part of a larger project/upgrade to the scheme such as the GFI Expansion. Accordingly, it is assumed this upgrade is to occur in stage 2.

Construction of the Gascoyne River Crossing to connect the NBF to the Brickhouse Tank and the new Brickhouse Booster Pump Station changes the operation of the scheme and the hydraulic conditions of the borefield. Deferring these assets means that new production bores in the NBF would need to be equipped to account for the different hydraulic conditions or, if this is not possible, bore pumping equipment would need to be replaced. Accordingly, construction of these assets should coincide with the significant expansion of the NBF as proposed by the GFI expansion and a timing of stage 2 for these assets has been adopted.

Stage 3 – GFI Expansion to 100%.(+140L/s)

The extent of borefield collector main required in stage 3 for connection of 14 production bores and 2 standby bores is detailed below.

- 1.6km of DN500 PE100 PN6.3
- 2.5km of DN450 PE100 PN6.3
- 2.5km of DN315 PE100 PN6.3

The Stage 3 GFI Expansion triggers release of additional irrigation land. The balance of the lots are connected to the scheme at this stage including the mains extension to supply area C.

8.5.3 Operating Strategy

The operation and control of Option 3 differs markedly from the current scheme and that proposed for Option 1. Option 3 can be separated into two hydraulic systems in addition to the Southern Borefield potable supply system.

- Borefield System – Bores in the NBF and irrigation bores in the SBF pump to Brickhouse Tank (9ML).
- Distribution System –Brickhouse Booster Pump Station pumps from the Brickhouse Tank (9ML) to the distribution system.

Borefield System

Bores in the NBF and irrigation bores in the SBF are proposed to be controlled on level in the NBF Tank. When water level in the tank reaches the low level setpoint a bore(s) is turned on. When water level in the tank reaches the high level setpoint a bore(s) is turned off. The bores starting and stopping sequence needs to be adjustable by the operator so that the following drivers can be managed.

- Borefield allocation.
- Balancing of abstraction from subareas.
- Management of water quality.
- Operating cost.

Distribution System

The new Brickhouse Booster Pump Station is to be variable speed controlled on downstream pressure to meet the target hydraulic level of 34m AHD. The pump station configuration needs to be such that it can supply a range of flows from the maximum flow down to the minimum flow. On the basis the minimum flow is 10% of the maximum flow vendor advice is that a minimum of three duty pumps are required. The pump station configuration needs to be further assessed during design development.

8.5.4 Capital Cost Estimate

Quantity surveyors McGarry Associates were engaged to prepare capital cost estimates. Vendor prices were obtained for key equipment and materials.

The estimated capital costs for Option 3 by stages and expansion is detailed in Table 21 below. Total capital cost is estimated at $23.5M excluding costs to separate the SBF, GFI groundwater investigation costs and NBF overhead power extension.

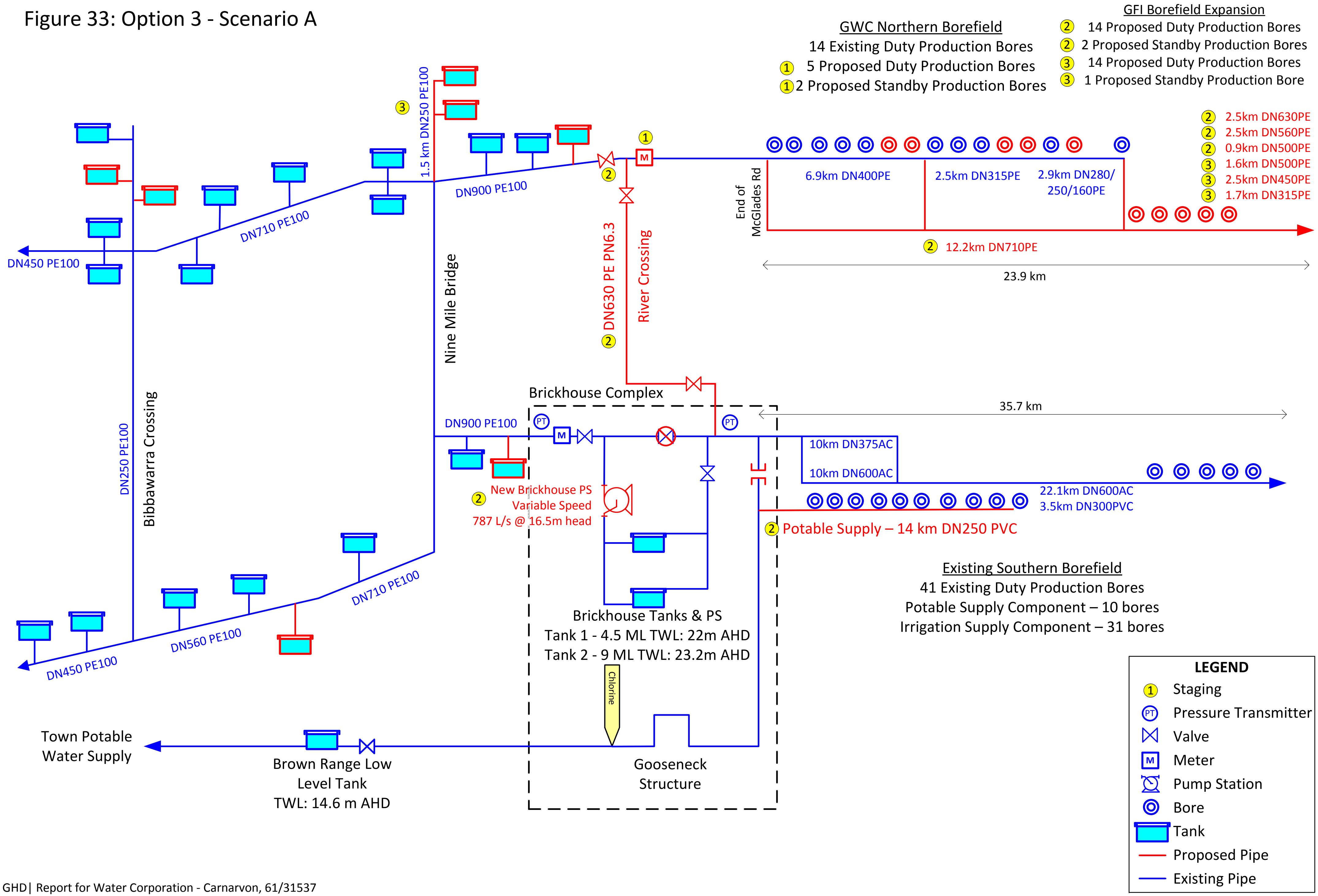
Table 21 Option 3 Capital Estimate

ITEM	DESCRIPTION	Stage 1	Stage 2	Stage 3
1	**GWC NBF UPGRADE**	**$2,040,000**	**$-**	**$-**
1.1	INFILL BORES DRILLING	$1,467,035	$-	$-
1.2	EQUIP & CONNECT INFILL BORES	$321,566	$-	$-
1.3	BORE COLLECTOR MAIN	$103,989	$-	$-
1.4	SCADA / ELECTRICAL WORKS	$148,954	$-	$-
2	**GFI NBF EXTENSION - BOREFIELD WORKS**	**$-**	**$16,050,000**	**$5,410,000**
2.1	BOREFIELD INVESTIGATIONS	$-	Note 1	Note 1
2.2	EQUIP & CONNECT BORES	$-	$1,056,916	$973,475
2.3	NBF EXTENSION - BORE MAIN	$-	$12,335,083	$3,886,745
2.4	SCADA / ELECTRICAL WORKS	$-	$310,000	$285,526
2.5	DISTRIBUTION SYSTEM/GROWER CONNECTIONS	$-	$105,094	$267,879
2.6	NBF RIVER CROSSING	$-	$979,597	$-
2.7	NEW BRICKHOUSE BOOSTER PUMP STATION	$-	$1,262,262	$-
2.8	OH POWER EXTENSION	$-	Note 1	Note 1
	Total	**$2,040,000**	**$16,050,000**	**$5,410,000**

NOTES

1 Works being managed or scoped by DAFWA GFI project team. Costs/estimates not repeated here.
2 Estimates subject to outcomes of groundwater investigations
3 Assumed that insitu materials are mostly suitable for bedding and backfill of pipes
4 Location factor of 1.3 adopted. Contractor's preliminaries at 25%. Costs for project management, engineering and approvals adopted as 18.5%. Contingency of 20% adopted generally, 50% adopted for river crossing.
5 Estimates are in $FY 2016
6 Excludes Southern Borefield potable/irrigation separation costs

Figure 33: Option 3 - Scenario A



8.5.5 O&M Estimate

Estimated power costs for Option 3 are summarised in Table 22 by stages. .

An L4 Tariff has been adopted for the NBF in the absence of negotiations being finalised with Horizon Energy on the tariff that will apply for the recent electrification.

The SBF power costs have been determined using the N2 power tariff which is the tariff that the Water Corporation is currently charged. The N2 tariff has increased sharply for 2015. If transfer of ownership of the Southern Borefield irrigation assets from the Water Corporation to GWAMCO enables negotiation to a cheaper tariff then power costs for the SBF will reduce.

Table 22. Option 3 - Power Cost Estimate

Item	Power Cost ($/yr)	Comment
Northern Borefield		
Stage 1	$260,000/yr, $0.072/kL	3.6GL/yr, L4 Tariff
Stage 2	$405,000/yr, $0.072/kL	5.6GL/yr, L4Tariff
Stage 3	$549,000/yr, $0.072/kL	7.6GL/yr, L4 Tariff
Southern Borefield		
Stage 1	$944,000/yr, $0.15/kL	5GL/yr Irrigation, 1.2GL/Yr Town, N2 Tariff
Stage 2 Stage 3	Potable Borefield $130,000/yr, $0.108/kL Irrigation Borefield $547,000/yr, $0.109/kL	5GL/yr Irrigation, 1.2GL/Yr Town, N2 Tariff
Distribution – New Brickhouse Booster Pump Station		
Stage 2	$323,000/yr, $0.030/kL	10.6GL/yr, N2 Tariff
Stage 3	$384,000/yr, $0.030/kL	10.6GL/yr, N2 Tariff

Estimated maintenance costs for Option 3 are detailed in Table 23. Historical maintenance costs were obtained from GWC and these were used to determine unit maintenance rates to be applied to the expanded scheme. The unit maintenance rates assessment is included in Appendix J. Maintenance costs for the Southern Borefield are not included here. These need to be obtained from the Water Corporation for the economic and pricing modelling.

Table 23. Option 3 - Maintenance Cost Estimate

Item	Stage 1	Stage 2	Stage 3
Northern Borefield	$25,400	$45,700	$63,800
Irrigation Scheme	$15,400	$15,500	$16,200
Scheme Wide – General Maintenance	$19,400	$48,600	$78,200
SBF Potable Water Main	-	$3,500	$3,500
New Brickhouse BPS	-	$6,900	$6,900
TOTAL	$60,200	$120,100	$164,900
Notes 1. Does not include GST			

8.6 Option Comparison - Scenario A

An option comparison for key criteria is detailed in Table 24. An economic comparison is being carried out by others. The comparison presented in Table 24 is discussed in more detail below.

Option 1 has the lowest capital cost.

Option 2 and 3 power costs are unexpectedly higher than Option 1. SBF power costs for Option 2 and Option 3 are lower as anticipated due to the SBF pumping to the lower level of Brickhouse Tank. However, as pumping to the Brickhouse Tanks results in the hydraulic grade line intersecting the collector main profile for a greater portion of the collector main route the potential operating cost savings are not fully realised.

Understandably, maintenance costs for Options 2 and 3 are higher than for Option 1 due to these options having a greater number of assets.

The security of supply provided by the tanks of Options 2 and 3 are not sufficient to maintain supply for the duration of a failure of the borefield collector main or even an extended power failure. The durations detailed in the table essentially only delay the impact of a shutdown or power failure. And as such represent a minor advantage over Option 1. Importantly, under the Gascoyne Water Customer Service Charter customers are to ensure they have on-farm storage to withstand supply interruptions of up to 3 days.

Table 24. Option Comparison for Scenario A

Option	Capital Cost	Operating Cost ($k/yr)	Maintenance Cost ($k/yr)	Security of Supply	Operability	Water Quality	Risk
Option 1	GWC NBF $2.0M GFI Exp $19.0M SBF Pot $6.3M Total $27.3M	NBF – 621 SBF Irr – 622 SBF Pot - 130 **Tot. - 1373**	NBF & Distribution - 154	No capability to maintain full supply in the event of a borefield collector main shutdown. Customers will see an impact immediately	Similar operation and control to the current system and as such operators readily familiar with.	No ability to blend water from both borefields to manage water quality, but can blend within a borefield	
Option 2	GWC NBF $2.0M GFI Exp $25.1M SBF Pot $6.3M Total $33.4M	NBF – 484 NBF BPS - 126 SBF Irr – 547 SBF BPS - 161 SBF Pot - 130 **Tot. - 1448**	NBF, Distribution & SBF new assets - 179	Inclusion of storage in the scheme provides limited ability to maintain supply during a borefield collector main shutdown. NBF collector main failure – maintain supply for 2 hours SBF Irrigation collector main failure – maintain supply for 4 hours	Consists of three supply systems with 2 booster pump stations pumping into the distribution system. This option is the most complex from an operation and control perspective	No ability to blend water from both borefields to manage water quality, but can blend within a borefield	

Option	Capital Cost	Operating Cost ($k/yr)	Maintenance Cost ($k/yr)	Security of Supply	Operability	Water Quality	Risk
Option 3	GWC NBF $2.0M GFI Exp $21.5M SBF Pot $6.3M Total $29.8M	NBF – 549 SBF Irr – 547 SBF BPS - 384 SBF Pot - 130 **Tot. - 1610**	NBF, Distribution & SBF new assets - 165	Inclusion of storage in the scheme provides limited ability to maintain supply during a borefield collector main shutdown. NBF collector main failure – maintain supply for 3 hours SBF Irrigation collector main failure – maintain supply for 4 hours	Consists of two supply systems and 1 booster pump station. Less complex than Option 2	When water quality from one borefield is poor, water from both borefields can be blended at the Brickhouse Tank. Growers would all receive a similar water quality.	Loss of the NBF collector main crossing Gascoyne River due to extreme river flow events will have a significant impact on the scheme supply.

9. Infrastructure Options – GFI Expansion Scenario B

This section presents the outcomes of the planning assessment of the infrastructure options for Scenario B for the borefield capacities detailed in Table 10

9.1 Irrigation Distribution System Upgrades

The upgrades required to the irrigation distribution system are the same for the three infrastructure options. Upgrades to the irrigation distribution system are triggered by the GFI Expansion (Stage 2) as the driver of this expansion is the release of more land for irrigation. Upgrades to the irrigation distribution system are not triggered by the GWC Borefield development stage (stage 1) as the additional production is to be distributed to the existing Growers.

Table 25 details the adopted future irrigation areas and flows for the GFI Expansion under Scenario B. The same irrigation areas are shown in Figure 34. The allocation of the peak flow rate and annual entitlement was based on the land area.

Table 25 Scenario B - GFI Expansion Irrigation Areas

Land Identifier	Peak Flow Rate (L/s)	Annual Entitlement (kL/year)
B	118.84	1,188,444
C	152.62	1,526,222
D	77.78	777,777
E	50.76	507,555
Total	400.00	4,000,000

The majority of the future irrigation areas are situated adjacent to the existing irrigation distribution system. An extension to the irrigation distribution system is required to supply areas B and C.

The hydraulic model was developed to include the above future irrigation areas. All growers, including the future irrigation areas were modelled with a FCV on their supply set as described below.

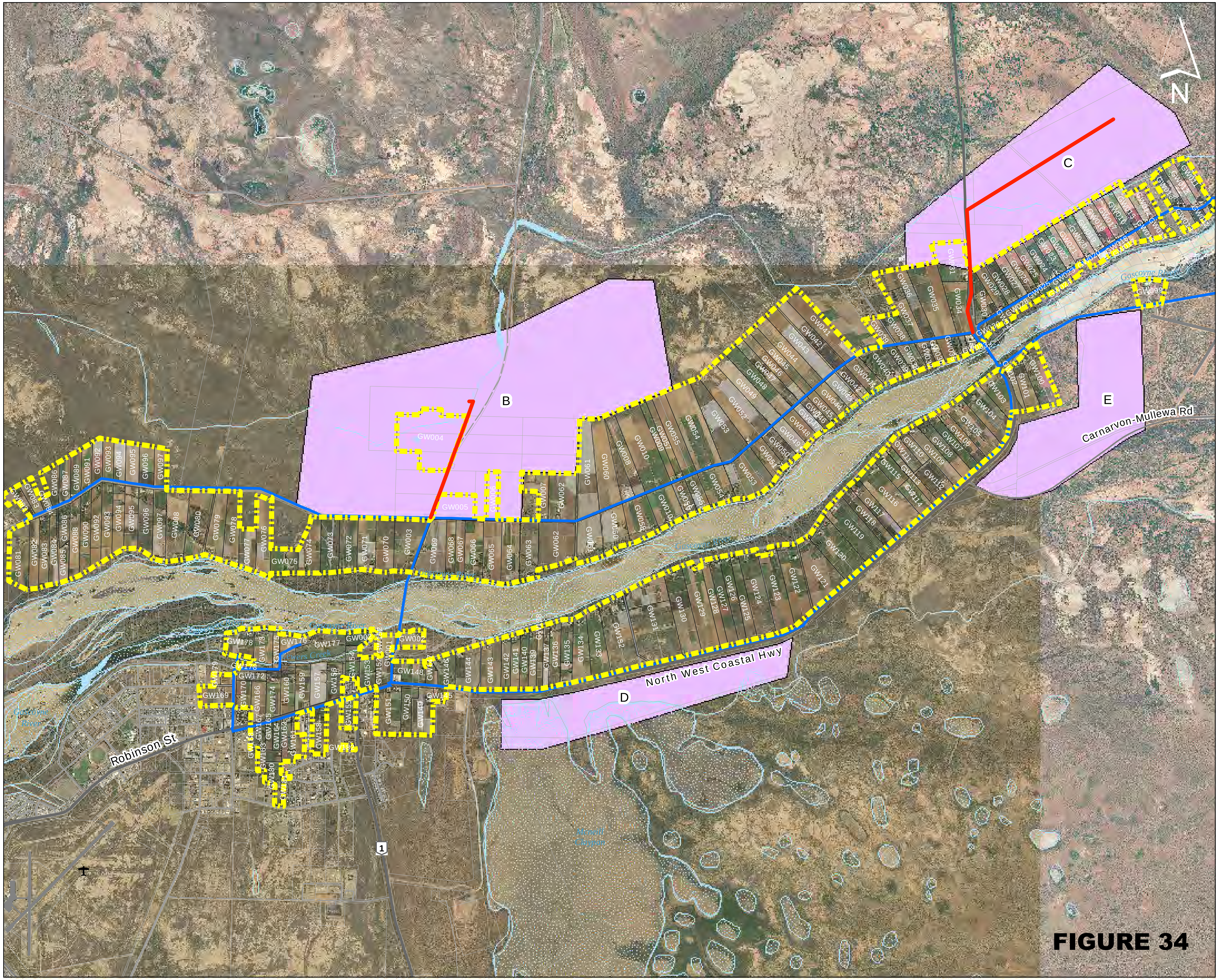


FIGURE 34

LEGEND

- Existing Irrigation Main
- New Irrigation Main
- Existing Irrigation Area
- Gascoyne Food Bowl - Generic Production Areas

Coordinate System: GDA 1994 MGA Zone 49 Vertical Datum: AHD
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Carnarvon
PERTH

AUTHOR: SELLENM0

GROUP: IPB - Spatial Systems

DATE: 27/02/2015

WATER CORPORATION

Gascoyne Water Co-op Existing & Future Irrigation Areas for NBF Expansion Peak Flow Scenario B - 400L/s

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- The FCVs for the future irrigation areas were set at the peak flow rate shown in Table 25 which sum to 400L/s, the peak flow rate of the GFI Expansion.
- The FCVs for the existing irrigation area were set based on their share of the peak production from the Southern Borefield (324L/s in LAS year) and the GWC component of the Northern Borefield (183L/s) as shown in Appendix C.

Outcomes of the hydraulic analysis are detailed below.

A hydraulic level of 36m AHD is required at the start of the irrigation distribution system which supplies pressures in the distribution system of at least 15m which is sufficient to provide 7m head at the Grower's gate and allows for headlosses through the customer assembly (including flow control valve) and the connecting pipework to the distribution system. The start of the irrigation distribution system is defined as the eastern end of McGlades Road for the Northern Borefield and the Brickhouse complex for the Southern Borefield. The target hydraulic level of 36m AHD is equal to a pressure at the Brickhouse complex of 19m.

The extensions to the distribution system required to supply the land expansion areas are detailed in Table 26.

Table 26. Distribution System Extensions – Scenario B

Land Expansion Area	Distribution System Extension	Comment	Stage
C	DN 450 PE PN8 – 1500m	Along North West Coastal Highway	2
	DN400 PE PN6.3 – 2000m	Heading north east from North West Coastal Highway	3
B	DN 355 PE PN6.3 – 1200m	Heading north along Bibbawarra Road	3
	DN 250 PE PN6.3 – 200m	Heading north along Bibbawarra Road	**3**

Hydraulic grade lines for the southern distribution main and the northern distribution main are shown in Figure 35 and Figure 36 respectively.

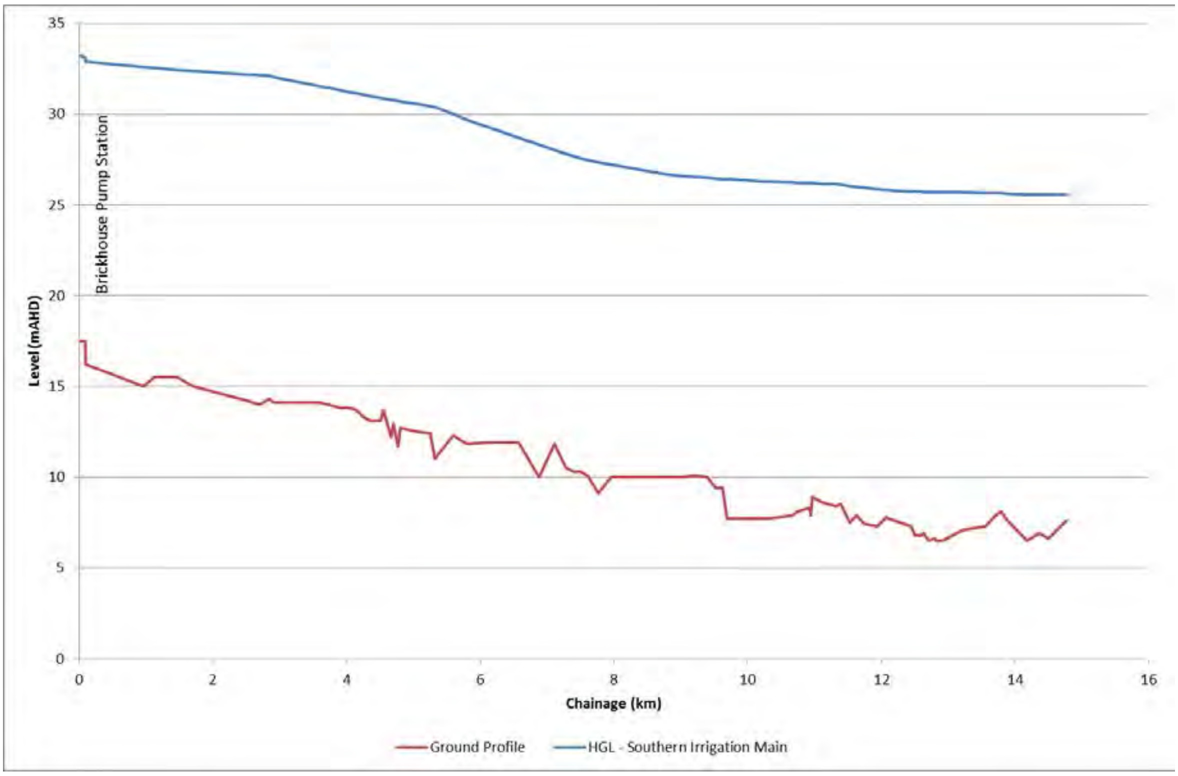


Figure 35 Hydraulic Grade Line - Southern Distribution Main

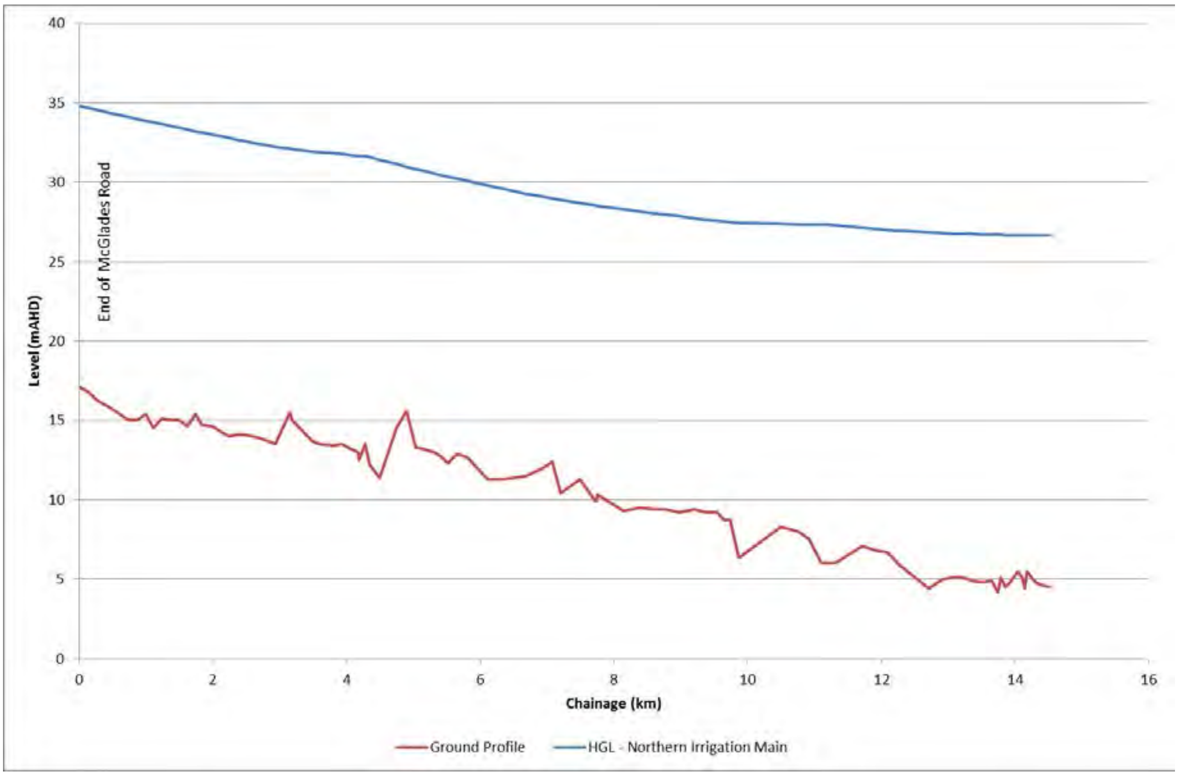


Figure 36 Hydraulic Grade Line - Northern Distribution Main

It should be noted that the system requirements and upgrades detailed above are only relevant to the Scenario B flows (907L/s) and the assumed location of new irrigation areas and their peak flow rates detailed in Table 25. Should these assumptions change and in particular should DAFWA not take an area based approach to the allocation of peak flows for the GFI Expansion or develop land in areas different to that shown on Figure 34, then hydraulic analysis may need to be repeated to determine the system requirements and upgrades required.

9.2 Northern Borefield Expansion Optimisation

High level analysis was undertaken to understand the optimum combination of borefield collector main and bore pump size.

Hydraulic gradients of 1m/km, 2m/km and 3m/km were selected for analysis. Hydraulic gradients represent the energy loss of a pipeline. Borefield collector main diameters, bore pump sizes and operating costs were determined for each of the hydraulic gradient options. The Water Corporation's estimating and financial analysis tool (ACE) was used to develop capital cost estimates and carry out financial analysis

The outcome of the analysis is detailed in Figure 37. A hydraulic gradient of 1m/km has the lowest net present value cost which has been adopted as the basis for sizing the Northern Borefield collector main for Scenario B.

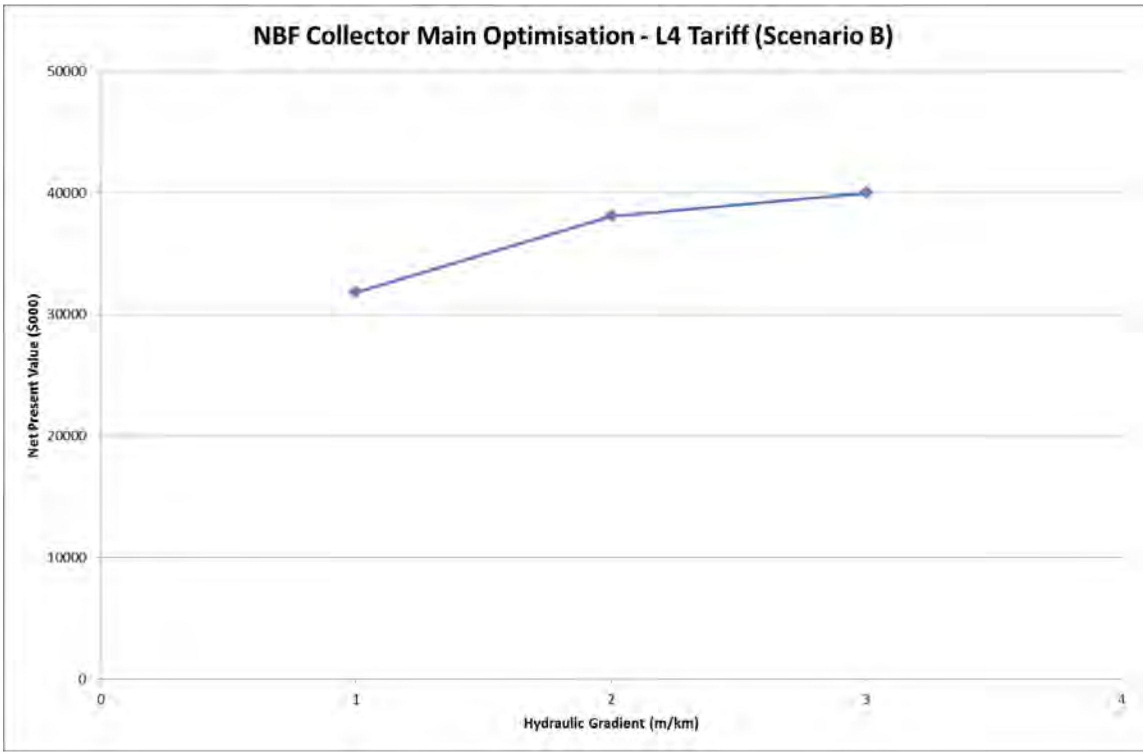


Figure 37 - NBF Collector Main Optimisation Scenario B

9.3 Option 1 – Same as Current/Base Case

9.3.1 Overview

Option 1 is shown schematically in Figure 39. Option 1 adopts the same method of operation as current in that both the Southern Borefield and the Northern Borefield pump directly into the irrigation distribution system without breaking pressure. The target hydraulic level required at the start of the distribution system is 36m AHD (19m pressure at the Brickhouse complex) which is 4m higher than the adopted target for the current system. The Southern Borefield can meet the LAS agreement irrigation supply rate and the Carnarvon Town demands at this higher hydraulic level.

The existing Northern Borefield collector main is proposed to be retained but will need to be duplicated and extended to accommodate the increased flow from the proposed production bores. Duplicating the main has security of supply advantages as a partial supply from the Northern Borefield will be able to be maintained in the event that one of the duplicate sections should fail.

Hydraulic grade lines for the NBF collector main starting from the end of McGlades Road are shown in Figure 38 for Scenario B. Even at borefield production rates much lower than the annual average rate, pressures in the main will be positive based on the pipe route adopted. Accordingly, during normal operation the collector main will flow full without the hydraulic need for air to enter and exhaust from the main as is the case with the SBF.

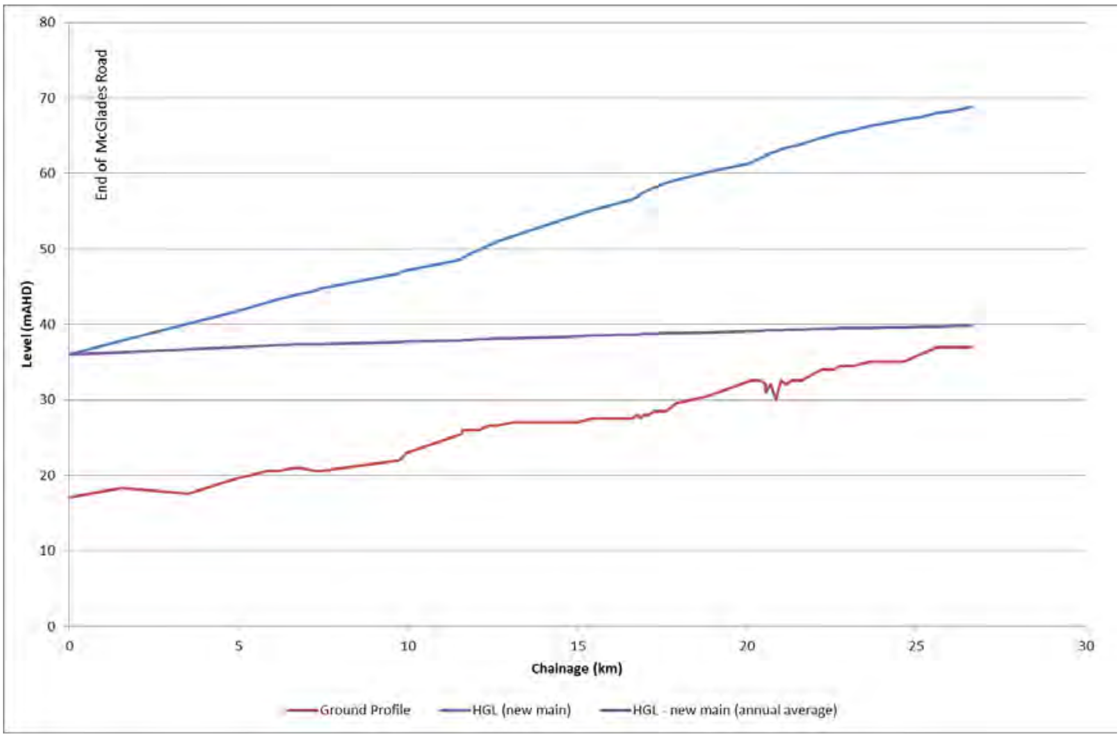


Figure 38. Option 1 - NBF - Hydraulic Grade Lines

The Brickhouse Tanks and Brickhouse Pump Station would continue to be normally bypassed in this option.

The supply to all Growers to be controlled with a flow control valve to deliver their peak daily entitlement at a constant rate over 24 hours.

Key new infrastructure requirements for this option are detailed in Table 27.

Table 27. Option 1 - Scenario B – New Infrastructure Requirements

Item	Detail	Comment
Irrigation Distribution System		
Mains	1.5km DN450PE 2.0km DN400PE 1.2km DN355PE 0.2km DN250PE	Extension to supply new lots of the GFI Expansion
Customer Connections	12 customer assemblies and connections to the distribution mains including SCADA	Connections to supply new lots of the GFI Expansion
Northern Borefield		
GWC Borefield Development	5 duty bores and 2 standby bores. 11km and 13kW submersible bores.	Increases peak production capacity to 183L/s to provide a peak factor of 1.6.
GFI Expansion	40 duty bores and 4 standby bores. 13kW submersible bores.	Scenario B peak production capacity of 400L/s
NBF Collector Main upgrade	12.25km DN800 PN6.3 5.0km DN710 PN6.3 3.5km DN630PE PN6.3 1.5km DN560PE PN6.3 1.5km DN450PE PN6.3 1.0km DN400PE PN6.3 1.0km DN355PE PN6.3 1.0km DN280PE PN6.3 0.5km DN200PE PN6.3	
Monitoring	Magflow meter and pressure transducer	Monitoring of borefield production for regulatory and operational purposes. Monitoring of pressure for borefield control.
Power Supply	15.8km extension of the HV power line	12.5km extension of the HV power line to the 24km mark is part of DAFWAs GFI scope. Additional 3.3km extension required.
Southern Borefield		

Potable/Irrigation Separation	14km DN250PVC	Length of main required may be reduced if new production bores can be successfully drilled in Subarea D

9.3.2 Staging

Stage 1 – GWC NBF upgrade to 183L/s

Analysis was undertaken to understand the capacity of the existing Northern Borefield infrastructure to accommodate an increase in capacity to 183L/s. Hydraulic grade lines were prepared for the existing Northern Borefield collector main at borefield peak production rates of 135L/s (14 bores - upgrade underway) and 183 L/s (19 bores - stage 1 upgrade). A chart of these upgrades is included in Appendix I.

The analysis shows the following.

- The hydraulic grade line for a borefield production rate of 183L/s sits comfortably below the maximum allowable operating pressure of the installed main. This is on the basis the 5 new infill production bores and 2 new standby bores aren't concentrated at the eastern end of the existing borefield where pipe diameters are smaller but rather located to give a near even spread of bores along the main. Calculation of the hydraulic grade line should be repeated once the new production bores have been drilled.
- The maximum level the variable speed pumps in the existing 9 bores can pump to at the maximum recommended pumping rate of the bores is shown on the chart. As these values are all at or higher than the curve "Hydraulic Grade Line – 183L/s", the existing bore pumps will be capable of operating to the higher hydraulic grade line once the pump speed has been adjusted.
- The GWC NBF can be upgraded to 183L/s without upgrading the borefield collector main or the pumps in the existing bores.
- The chart also shows the ultimate hydraulic grade line at peak production of 463L/s allowing for the borefield collector main duplication and extension shown in Figure 26. As this hydraulic grade line is lower, selection of pumps for the bores to take the scheme to 135L/s and then take the scheme to 183L/s need to be made in consideration of the ultimate hydraulic grade line. Consideration will need to be made on whether to initially install fixed speed pumps which may need to be changed out when the borefield collector main upgrades are completed or installing a variable speed pump that can handle the varying hydraulic grade lines.

Stage 2 – GFI Expansion to 50% (200L/s).

Extending the NBF to increase capacity by 200L/s more than doubles the flow through the existing NBF collector mains. This increase in flow would create excessive headloss in the existing mains DN315 and smaller and duplication of these mains with DN800 PE pipe is required at this stage.

An increase in capacity of 200L/s increases the velocity and headloss gradient in the existing DN400PE main (the largest diameter existing main in the NBF collector main) up to 3.6m/s and 21.2m/km. The existing DN400 main is 6.9km long and increasing the flow rate in it by 200L/s will substantially increase the hydraulic grade line whereby the MAOP would be exceeded. The DN400 main also needs to be duplicated with DN710 PE at this stage.

The extent of borefield collector main required in stage 2 for connection of 20 production bores and 2 standby bores is detailed below.

- 12.25km DN800 PN6.3
- 5.0km DN710 PN6.3
- 3.5km DN630PE PN6.3
- 1.5km DN560PE PN6.3

The GFI Expansion triggers release of additional irrigation land. It has been assumed that lots that are located adjacent to the existing distribution main, and hence do not require mains extension to supply, are supplied in Stage 2. The adopted staging of distribution mains extension is detailed in Table 26.

Separation of the Southern Borefield into a potable supply and an irrigation supply does not have a demand trigger for its timing as it is more driven by governance issues. It has been assumed this separation is to occur as part of a larger project/upgrade to the scheme such as the GFI Expansion. Accordingly, it is assumed this upgrade is to occur in stage 2.

Stage 3 – GFI Expansion to 100%.(+200L/s)

The extent of borefield collector main required in stage 3 for connection of 20 production bores and 2 standby bores is detailed below.

- 1.5km DN450PE PN6.3
- 1.0km DN400PE PN6.3
- 1.0km DN355PE PN6.3
- 1.0km DN280PE PN6.3
- 0.5km DN200PE PN6.3

The Stage 3 GFI Expansion triggers release of additional irrigation land. . The adopted staging of distribution mains extension is detailed in Table 26.

9.3.3 Operating Strategy

The proposed operating strategy for both borefields is similar to the current operation of the Southern Borefield. The irrigation component of the Southern Borefield and the Northern Borefield are to operate to maintain pressure at the start of the distribution main within a pressure range, the midpoint of which needs to be the target hydraulic level. The target hydraulic level for stage 1 is to be the same as current, which is 15m head at Brickhouse or 32m AHD. From stage 2 onwards the target hydraulic level should be 36m AHD. It is preferable that the two borefields are controlled from the same pressure transducer and operated as a single borefield however this may only be practical if the borefields are operated by the one entity.

As demands increase and the pressure drops to the lower pressure setpoint a bore is called to start. As demands decrease and the pressure rises to the upper pressure setpoint a bore is called to stop.

The pressure range is not able to be defined at this stage as it is dependent on the maximum individual bore production rate which won't be known until the GFI drilling program is complete. Further hydraulic modelling is likely to be required to confirm the pressure setpoints during the design stage.

The bores starting and stopping sequence needs to be adjustable by the operator so that the following drivers can be managed.

- Borefield allocation.

- Balancing of abstraction from subareas.
- Management of water quality.
- Operating cost.
- Power supply constraints for maximum permissible start and stop cycles per hours.

9.3.4 Capital Cost Estimate

Quantity surveyors McGarry Associates were engaged to prepare capital cost estimates. Vendor prices were obtained for key equipment and materials.

The estimated capital costs for Option 1 by stages and expansion is detailed in Table 28 below. Total capital cost is estimated at $28.30M excluding costs to separate the SBF, GFI groundwater investigation costs and NBF overhead power extension.

Table 28 Option 1 Capital Estimate

ITEM	DESCRIPTION	Stage 1	Stage 2	Stage 3
1	**GWC NBF UPGRADE**	**$ 2,020,000**	**$ -**	**$ -**
1.1	INFILL BORES DRILLING	$ 1,451,348		$ -
1.2	EQUIP & CONNECT INFILL BORES	$ 318,127	$ -	$ -
1.3	BORE COLLECTOR MAIN	$ 102,877	$ -	$ -
1.4	SCADA / ELECTRICAL WORKS	$ 147,361	$ -	$ -
2	**GFI NBF EXTENSION - BOREFIELD WORKS**	**$ -**	**$ 17,950,000**	**$ 8,290,000**
2.1	BOREFIELD INVESTIGATIONS		Note 1	Note 1
2.2	EQUIP & CONNECT BORES	$ -	$ 1,396,409	$ 1,429,760
2.3	NBF EXTENSION - BORE MAIN	$ -	$ 15,588,433	$ 5,040,234
2.4	SCADA / ELECTRICAL WORKS	$ -	$ 419,497	$ 429,516
2.5	DISTRIBUTION SYSTEM/GROWER CONNECTIONS	$ -	$ 546,319	$ 835,217
2.6	OH POWER EXTENSION		Note 7	$ 556,378
	Total	**$ 2,020,000**	**$ 17,950,000**	**$ 8,290,000**

NOTES

1 Works being managed or scoped by DAFWA GFI project team. Costs/estimates not repeated here.

2 Estimates subject to outcomes of groundwater investigations

3 Assumed that insitu materials mostly suitable for bedding and backfill of pipes

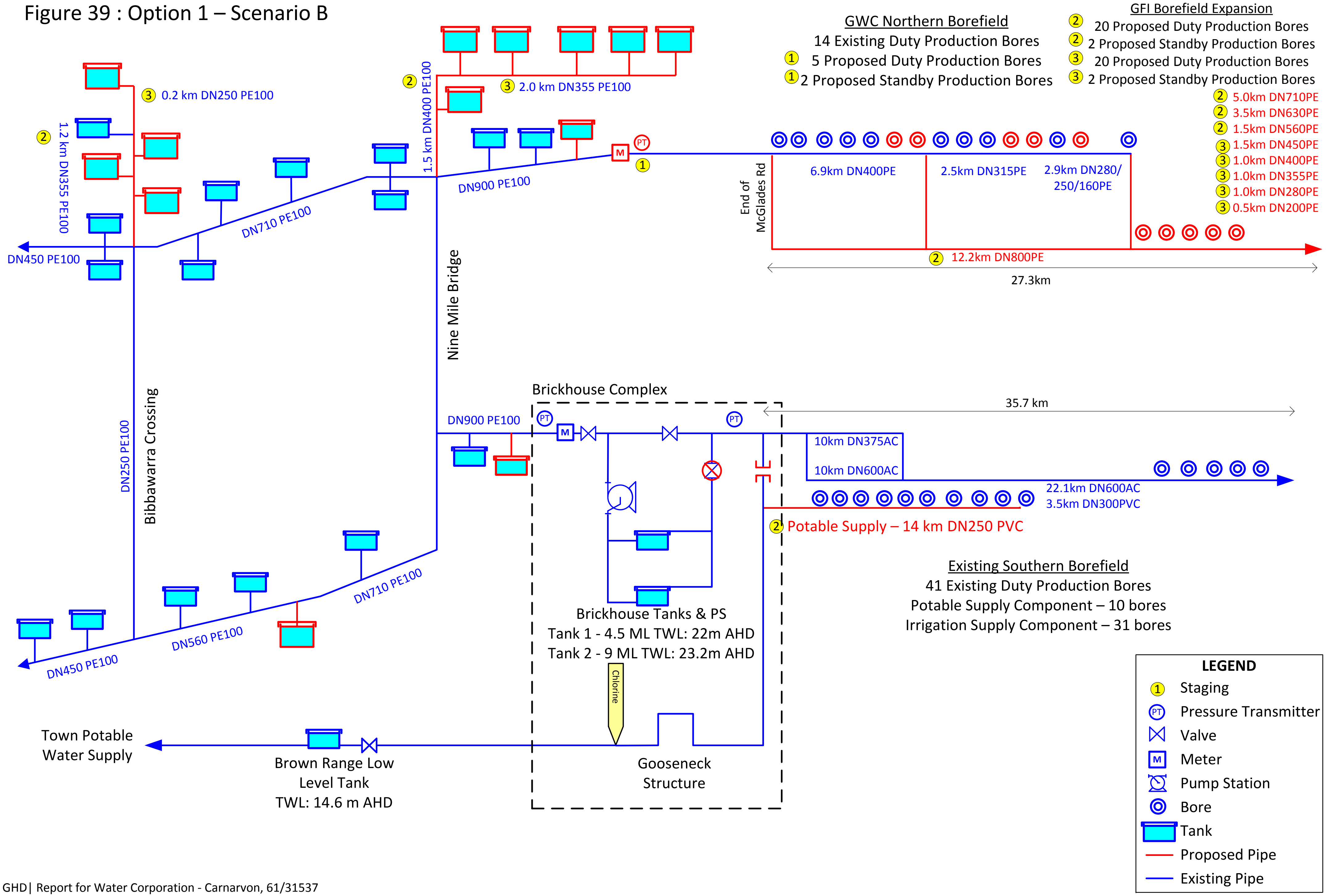
4 Location factor of 1.3 adopted. Contractor's preliminaries at 25%... Costs for project management, engineering and approvals adopted as 18.5%. Contingency of 20% adopted

5 Estimates are in $FY 2016.

6 Excludes Southern Borefield potable/irrigation separation costs

7 Works to extend OH power to the 24km mark of the NBF being managed or scoped by DAFWA GFI team. Estimate for stage 3 allows for a 3.3km extension to take total power line length to 27.3km.

Figure 39 : Option 1 – Scenario B



9.3.5 O&M Estimate

Estimated power costs for Option 1 are summarised in Table 29 by stages.

An L4 Tariff has been adopted for the NBF in the absence of negotiations being finalised with Horizon Energy on the tariff that will apply for the recent electrification.

The SBF power costs have been determined using the N2 power tariff which is the tariff that the Water Corporation is currently charged. The N2 tariff has increased sharply for 2015. If transfer of ownership of the Southern Borefield irrigation assets from the Water Corporation to GWAMCO enables negotiation to a cheaper tariff then power costs for the SBF will reduce.

Table 29. Option 1 - Power Cost Estimate

Item	Power Cost ($/yr)	Comment
Northern Borefield		
Stage 1	$260,000/yr $0.072/kL	3.6GL/yr, L4 Tariff
Stage 2	$578,000/yr $0.086/kL	5.6GL/yr, L4 Tariff
Stage 3	$652,000/yr $0.086/kL	7.6GL/yr, L4 Tariff
Southern Borefield		
Stage 1	$944,000/yr, $0.15/kL	5GL/yr Irrigation, 1.2GL/Yr Town, N2 Tariff
Stage 2	Potable Borefield $130,000/yr, $0.108/kL Irrigation Borefield $622,000/yr, $0.124/kL	5GL/yr Irrigation, 1.2GL/Yr Town, N2 Tariff
Stage 3		5GL/yr Irrigation, 1.2GL/Yr Town, N2 Tariff

Estimated annual maintenance costs for Option 1 are detailed in Table 30. Historical maintenance costs were obtained from GWC and these were used to determine unit maintenance rates to be applied to the expanded scheme. The unit maintenance rates assessment is included in Appendix J. Maintenance costs for the Southern Borefield are not included here. These need to be obtained from the Water Corporation for the economic and pricing modelling.

Table 30. Option 1 – Annual Maintenance Cost Estimate

Item	Stage 1	Stage 2	Stage 3
Northern Borefield	$25,400	$54,200	$77,800
Irrigation Scheme	$15,400	$16,400	$17,200
Scheme Wide – General Maintenance	$19,400	$44,200	$71,000
SBF Potable Water Main	-	$3,500	$3,500
TOTAL	$60,200	$118,200	$169,500
Notes 1. Does not include GST			

9.4 Option 2 – New Northern Storage and 2 Booster Pump Stations

9.4.1 Overview

Option 2 is shown schematically in Figure 42. Option 2 differs from Option 1 in that both borefields pump to ground tanks from which water is supplied to the distribution system from transfer pump stations equipped with typical centrifugal pumps. The NBF pumps to a new ground tank located adjacent to the end of McGlades Street upstream of the distribution system. The SBF irrigation component is to be directed to the Brickhouse Tanks. The advantages of this option are twofold:

- The tanks provide reserve storage, albeit limited, reducing the impact to Growers of a shutdown of either of the borefield collector mains.
- Lower power costs. Submersible borehole pumps are less efficient than normal centrifugal transfer pumps. Having part of the pumping being carried out by the more efficient transfer pumps may reduce power costs.

The supply to all Growers to be controlled with a flow control valve to deliver their peak daily entitlement at a constant rate over 24 hours.

NBF Collector Main

The existing Northern Borefield collector main is proposed to be retained but will need to be duplicated and extended to accommodate the increased flow from the proposed production bores. Duplicating the main has security of supply advantages as a partial supply from the Northern Borefield will be able to be maintained in the event that one of the duplicate sections should fail

Hydraulic grade lines for the NBF collector main starting from the end of McGlades Road are shown in Figure 40 for scenario B. At borefield production rates matching the annual average rate and lower the hydraulic grade line will intersect the level of the borefield collector main based on the pipe route adopted. This will result in the main upstream of this intersection flowing partially full or even empty. Care will need to be taken during design to ensure the following.

- Sufficient air valves are provided in the borefield collector main to enable air to enter and vent from the main.
- The pipeline is designed and installed to minimise reversal of pipeline grade.
- Minimum cover to avoid flotation of the pipe in high groundwater areas.
- Bore headworks design ensures accurate meter reading for bores that are located upstream of where the hydraulic grade line intersects the pipe profile, which may involve installation of pressure sustaining valves to maintain minimum pressure within the bore headworks arrangement.

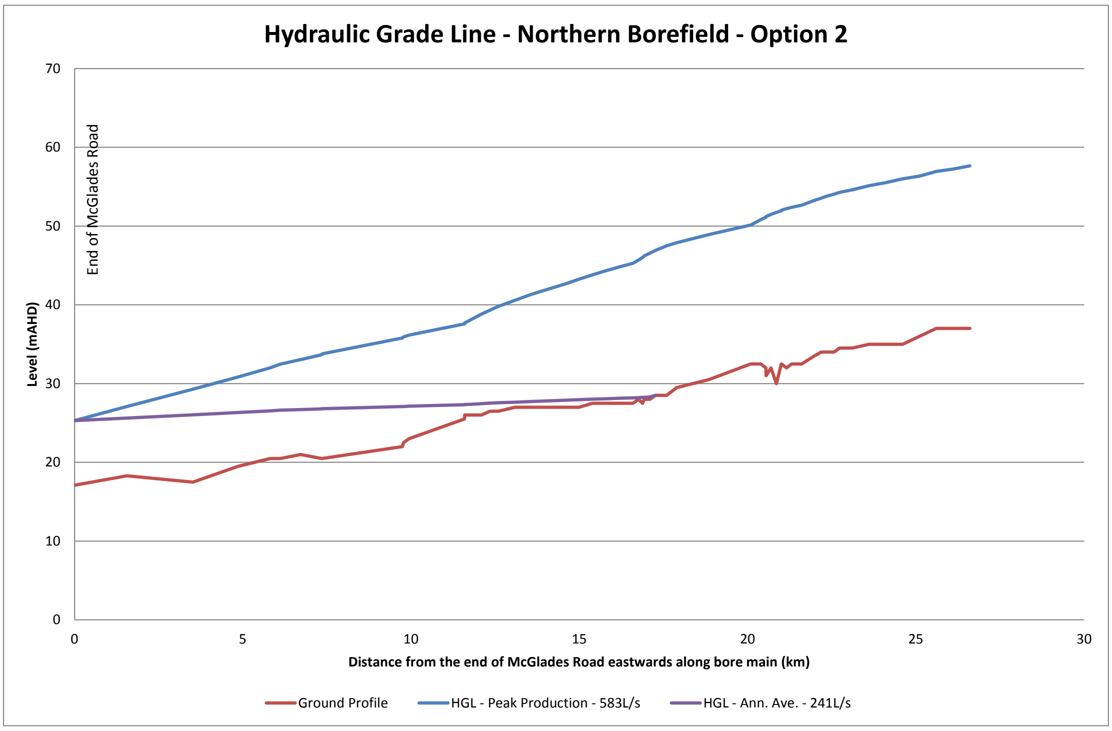


Figure 40. Option 2 - NBF - Hydraulic Grade Lines

NBF Tank and Booster Pump Station

The proposed capacity of the new NBF Tank is 9ML on the basis of the following.

Control storage – 3.9ML. Volume required to manage starting and stopping of NBF bores

Reserve storage – 4.3ML – Provides 2 hours reserve storage at the ultimate peak production rate (463L/s) sufficient to make operational changes and advise Growers to reduce demands.

Unusable Storage – 0.8ML

Ground levels adjacent to the end of McGlades Street upstream of the distribution system are in the order of 17.5m AHD, below the 1:100yr flood level of 18.8m AHD. The estimate allows for fill to be placed to raise ground elevation to 19.3m AHD to avoid flooding of the site and in particular the booster pump station.

The NBF Booster Pump Station pumps from the NBF Tank to the distribution system to achieve the target hydraulic level of 36m AHD. The pump station will need to be variable speed to accommodate the range of flows. A pump station configuration of four duty pumps and one standby pump has been recommended by the vendor based on a minimum flow rate of 10% of peak. Further consideration of the pump station configuration needs to be carried out during design development.

Southern Borefield

Directing flow from the irrigation component of the Southern Borefield to the Brickhouse Tanks rather than pumping over the top of (or bypassing) the tanks as is the current practice changes the hydraulics of the borefield.

Hydraulic grade lines for the SBF collector main starting from the end of McGlades Road are shown in Figure 41 for scenario B

The Brickhouse Tanks are approximately 10m lower than the current target hydraulic level. A lower hydraulic grade line will result, meaning that at low production rates the majority of the main will be operating partially full or empty. The adequacy and frequency of air valves will need to be assessed to ensure that air can enter and vent from the main at appropriate rates.

Pumping to the lower hydraulic level of the Brickhouse tanks will result in the bores operating further to the right on their pump curve. For a number of bores, this will result in them operating outside of their recommended range in which case the pumps will need to be changed out to a smaller pump or alternatively flows throttled to a maximum flow rate. Further assessment of bores likely to be impacted and options to be addressed should be carried out if this option is adopted as the preferred option.

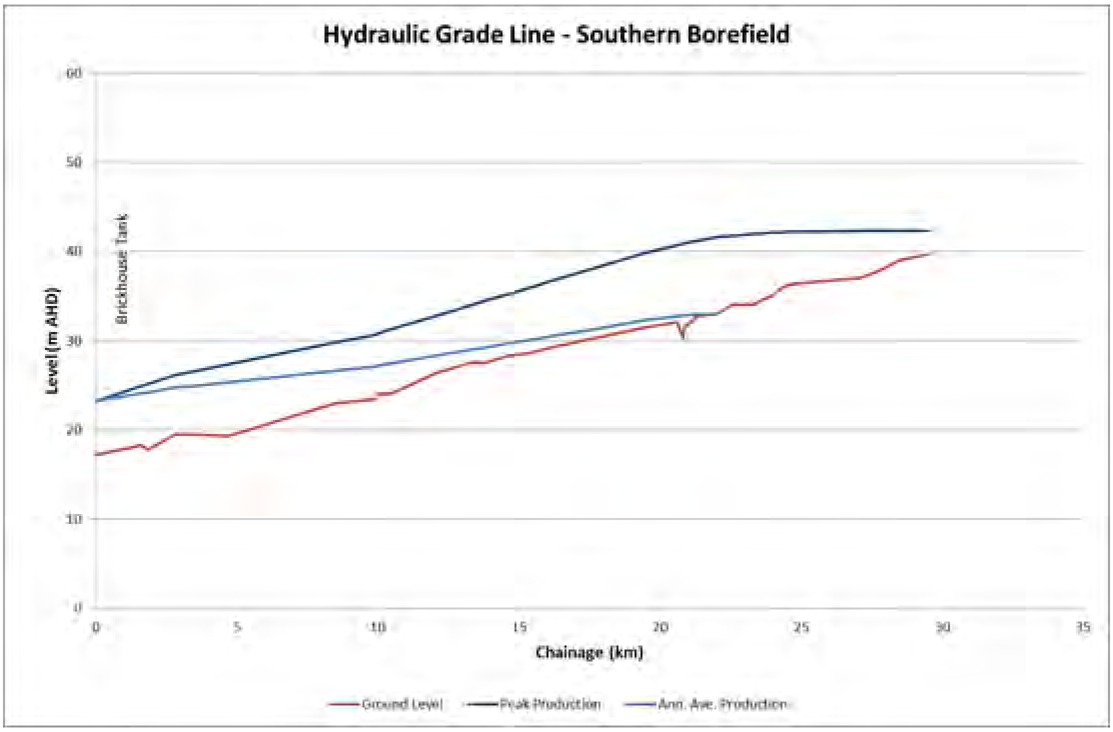


Figure 41. Option 2 - SBF - Hydraulic Grade Lines

Brickhouse Tanks and Booster Pump Station

The smaller Brickhouse Tank complex consists of two tanks as outlined in Section 4.4.1. The roof of the smaller 4.5ML tank is in poor condition and needs replacement. It is proposed that the 4.5ML tank is not brought back into operation due to the cost of replacing the roof and the operational issues of an unroofed tank. An unroofed tank will become an attraction for vermin and wildlife which would create a potential water quality risk given anecdotal reports of use of the irrigation supply for potable purposes.

The 9ML Brickhouse Tank has reserve storage sufficient to maintain supply for 4 hours.

The existing Brickhouse PS has reached the end of its useful asset life. It is proposed, for Option 2, that the Brickhouse PS is abandoned and a new Booster PS with sun shelter is constructed at the Brickhouse Site. The new Brickhouse Booster Pump Station pumps from the 9ML Brickhouse Tank to the distribution system to achieve the target hydraulic level of 36m AHD. The pump station will need to be variable speed to accommodate the range of flows. A pump station configuration of three duty pumps and one standby pump has been recommended by the vendor based on a minimum flow rate of 10% of peak. Further consideration of the pump station configuration needs to be carried out during design development.

Key new infrastructure requirements for this option are detailed in Table 31.

Table 31. Option 2 - Scenario B – New Infrastructure Requirements

Item	Detail	Comment
Irrigation Distribution System		
Mains	1.5km DN450PE 2.0km DN400PE 1.2km DN355PE 0.2km DN250PE	Extension to supply new lots of the GFI Expansion
Customer Connections	12 customer assemblies and connections to the distribution mains including SCADA	Connections to supply new lots of the GFI Expansion
Northern Borefield		
GWC Borefield Development	5 duty bores and 2 standby bores. 11 kW submersible bores.	Increases peak production capacity to 183 L/s to provide a peak factor of 1.6.
GFI Expansion	40 duty bores and 4 standby bores. 11 kW submersible bores.	Scenario B peak production capacity of 400 L/s
NBF Collector Main upgrade	12.25km DN800 PN6.3 5.0km DN710 PN6.3 3.5km DN630PE PN6.3 1.5km DN560PE PN6.3 1.5km DN450PE PN6.3 1.0km DN400PE PN6.3 1.0km DN355PE PN6.3 1.0km DN280PE PN6.3 0.5km DN200PE PN6.3	
Monitoring	Magflow meter and pressure transducer	Monitoring of borefield production for regulatory and operational purposes. Monitoring of pressure for NBF Booster pump station control.
Power Supply	15.8km extension of the HV power line	12.5km extension of the HV power line to the 24km mark is part of DAFWAs GFI scope. Additional 3.3km extension required.
NBF Tank	9ML Ground Tank	

NBF Booster Pump Station	583 L/s @ 16.7 m Head	Variable speed. 4 x duty and 1 x standby. 37 kW each
Southern Borefield		
New Brickhouse Booster PS	324L/s @ 18.5m	Variable speed. 3 x duty and 1 x standby. 30kW each
Potable/Irrigation Separation	14km DN250PVC	Length of main required may be reduced if new production bores can be successfully drilled in Subarea D

9.4.2 Staging

Stage 1 – GWC NBF upgrade to 183L/s

Analysis was undertaken to understand the capacity of the existing Northern Borefield infrastructure to accommodate an increase in capacity to 183L/s. Hydraulic grade lines were prepared for borefield peak production rates of 135L/s (14 bores - upgrade underway) and 183 L/s (19 bores - stage 1 upgrade). A chart of these upgrades is included in Appendix I.

The analysis shows the following.

- The hydraulic grade line for a borefield production rate of 183L/s sits comfortably below the maximum allowable operating pressure of the installed main. This is on the basis the 5 new infill production bores and 2 new standby bores aren't concentrated at the eastern end of the existing borefield where pipe diameters are smaller but rather located to give a near even spread of bores along the main. Calculation of the hydraulic grade line should be repeated once the new production bores have been drilled.
- The maximum level the variable speed pumps in the existing 9 bores can pump to at the maximum recommended pumping rate of the bores is shown on the chart. As these values are all at or higher than the curve "Hydraulic Grade Line – 183L/s", the existing bore pumps will be capable of operating to the higher hydraulic grade line once the pump speed has been adjusted.
- The GWC NBF can be upgraded to 183L/s without upgrading the borefield collector main or the pumps in the existing bores.
- The chart also shows the ultimate hydraulic grade line at peak production of 583L/s allowing for the borefield collector main duplication and extension shown in Figure 26. As this hydraulic grade line is lower, selection of pumps for the bores to take the scheme to 135L/s and then take the scheme to 183L/s need to be made in consideration of the ultimate hydraulic grade line. Consideration will need to be made on whether to initially install fixed speed pumps which may need to be changed out when the borefield collector main upgrades are completed or installing a variable speed pump that can handle the varying hydraulic grade lines.

Stage 2 – GFI Expansion to 50% (200L/s).

Extending the NBF to increase capacity by 200L/s more than doubles the flow through the existing NBF collector mains. This increase in flow would create excessive headloss in the existing mains DN315 and smaller and duplication of these mains with DN800 PE pipe is required at this stage.

An increase in capacity of 200L/s increases the velocity and headloss gradient in the existing DN400PE main (the largest diameter existing main in the NBF collector main) up to 3.6m/s and

21.2m/km. The existing DN400 main is 6.9km long and increasing the flow rate in it by 200L/s will substantially increase the hydraulic grade line whereby the MAOP would be exceeded. The DN400 main also needs to be duplicated with DN710PE at this stage.

The extent of borefield collector main required in stage 2 for connection of 20 production bores and 2 standby bores is detailed below.

- 12.25km DN800 PN6.3
- 5.0km DN710 PN6.3
- 3.5km DN630PE PN6.3
- 1.5km DN560PE PN6.3

The GFI Expansion triggers release of additional irrigation land. It has been assumed that lots that are located adjacent to the existing distribution main, and hence do not require mains extension to supply, are supplied in Stage 2. The adopted staging of distribution mains extension is detailed in Table 26.

Separation of the Southern Borefield into a potable supply and an irrigation supply does not have a demand trigger for its timing as it is more driven by governance issues. It has been assumed this separation is to occur as part of a larger project/upgrade to the scheme such as the GFI Expansion. Accordingly, it is assumed this upgrade is to occur in stage 2.

Construction of the NBF Tank, NBF Booster Pump Station and the new Brickhouse Booster Pump Station changes the operation of the scheme and the hydraulic conditions of the borefield. Deferring these assets means that new production bores in the NBF would need to be equipped to account for the different hydraulic conditions or, if this is not possible, bore pumping equipment would need to be replaced. Accordingly, construction of these assets should coincide with the significant expansion of the NBF as proposed by the GFI expansion and a timing of stage 2 has been adopted.

Stage 3 – GFI Expansion to 100%.(+200L/s)

The extent of borefield collector main required in stage 3 for connection of 20 production bores and 2 standby bores is detailed below.

- 1.5km DN450PE PN6.3
- 1.0km DN400PE PN6.3
- 1.0km DN355PE PN6.3
- 1.0km DN280PE PN6.3
- 0.5km DN200PE PN6.3

The Stage 3 GFI Expansion triggers release of additional irrigation land. The adopted staging of distribution mains extension is detailed in Table 26.

9.4.3 Operating Strategy

The operation and control of Option 2 differs markedly from the current scheme and that proposed for Option 1. Option 2 can be separated into three hydraulic systems in addition to the Southern Borefield potable supply system.

- Northern Borefield – northern bores pump to the new NBF Tank
- Southern Borefield Irrigation – southern irrigation bores pump to Brickhouse Tank (9ML).
- Distribution System – NBF Booster Pump Station and the Brickhouse Booster Pump Station pump from their respective storages to the distribution system.

Northern Borefield System

Bores in the NBF are proposed to be controlled on water level in the NBF Tank. When water level in the NBF Tank reaches the low level setpoint a bore(s) is turned on. When water level in the NBF Tank reaches the high level setpoint a bore(s) is turned off. The bores starting and stopping sequence needs to be adjustable by the operator so that the following drivers can be managed.

- Borefield allocation.
- Balancing of abstraction from subareas.
- Management of water quality.
- Operating cost.

Southern Borefield Irrigation System

Irrigation bores in the SBF are proposed to be controlled on water level in the Brickhouse Tank. When water level in the tank reaches the low level setpoint a bore(s) is turned on. When water level in the tank reaches the high level setpoint a bore(s) is turned off. The bores starting and stopping sequence needs to be adjustable by the operator so that the following drivers can be managed.

- Borefield allocation.
- Balancing of abstraction from subareas.
- Management of water quality.
- Operating cost.

Distribution System

The distribution system consists of two controlled assets, the NBF Booster Pump Station and the Brickhouse Booster Pump Station. Both pump stations are to be variable speed controlled on downstream pressure to meet the target hydraulic level of 36m AHD.

However, having both booster pump stations set to be controlled on downstream pressure requires complicated control to avoid each pump responding to the others transition. The less complicated method would be to have one booster pump station controlled on downstream pressure (demand driven) and the other set to a fixed speed (production driven) which would result in a near constant flow rate. This would result in the respective borefields also operating as demand driven (bores turning on and off in response to water levels changes in the tank) and production driven (once the water level in the tank is within range a single bore will turn on and off).

9.4.4 Capital Cost Estimate

Quantity surveyors McGarry Associates were engaged to prepare capital cost estimates. Vendor prices were obtained for key equipment and materials.

The estimated capital costs for Option 2 by stages and expansion are detailed in Table 32 below. Total capital cost is estimated at $35.5M excluding costs to separate the SBF, GFI groundwater investigation costs and NBF overhead power extension.

Table 32 Option 2 Capital Estimate

ITEM	DESCRIPTION	Stage 1	Stage 2	Stage 3
1	**GWC NBF UPGRADE**	**$ 2,070,000**	**$-**	**$-**
1.1	INFILL BORES DRILLING	$ 1,484,447	$-	$-
1.2	EQUIP & CONNECT INFILL BORES	$ 325,383	$-	$-
1.3	BORE COLLECTOR MAIN	$ 105,223	$-	$-
1.4	SCADA / ELECTRICAL WORKS	$ 150,722	$-	$-
2	**GFI NBF EXTENSION - BOREFIELD WORKS**	**$-**	**$ 24,980,000**	**$ 8,440,000**
2.1	BOREFIELD INVESTIGATIONS	$-	Note 1	Note 1
2.2	EQUIP & CONNECT BORES	$-	$ 1,427,167	$ 1,463,658
2.3	NBF EXTENSION - BORE MAIN	$-	$ 15,931,789	$ 5,159,731
2.4	SCADA / ELECTRICAL WORKS	$-	$ 428,737	$ 439,700
2.5	DISTRIBUTION SYSTEM/GROWER CONNECTIONS	$-	$ 587,926	$ 824,690
2.6	NBF & SBF BOOSTER PUMP STATIONS	$-	$ 1,982,824	$ -
2.7	NBF STORAGE	$-	$ 4,626,486	$ -
2.8	OH POWER EXTENSION	$-	Note 7	$ 556,379
	Total	**$ 2,070,000**	**$ 24,980,000**	**$ 8,440,000**

NOTES

1 Works being managed or scoped by DAFWA GFI project team. Costs/estimates not repeated here.

2 Estimates subject to outcomes of groundwater investigations

3 Assumed that insitu materials are mostly suitable for bedding and backfill of pipes

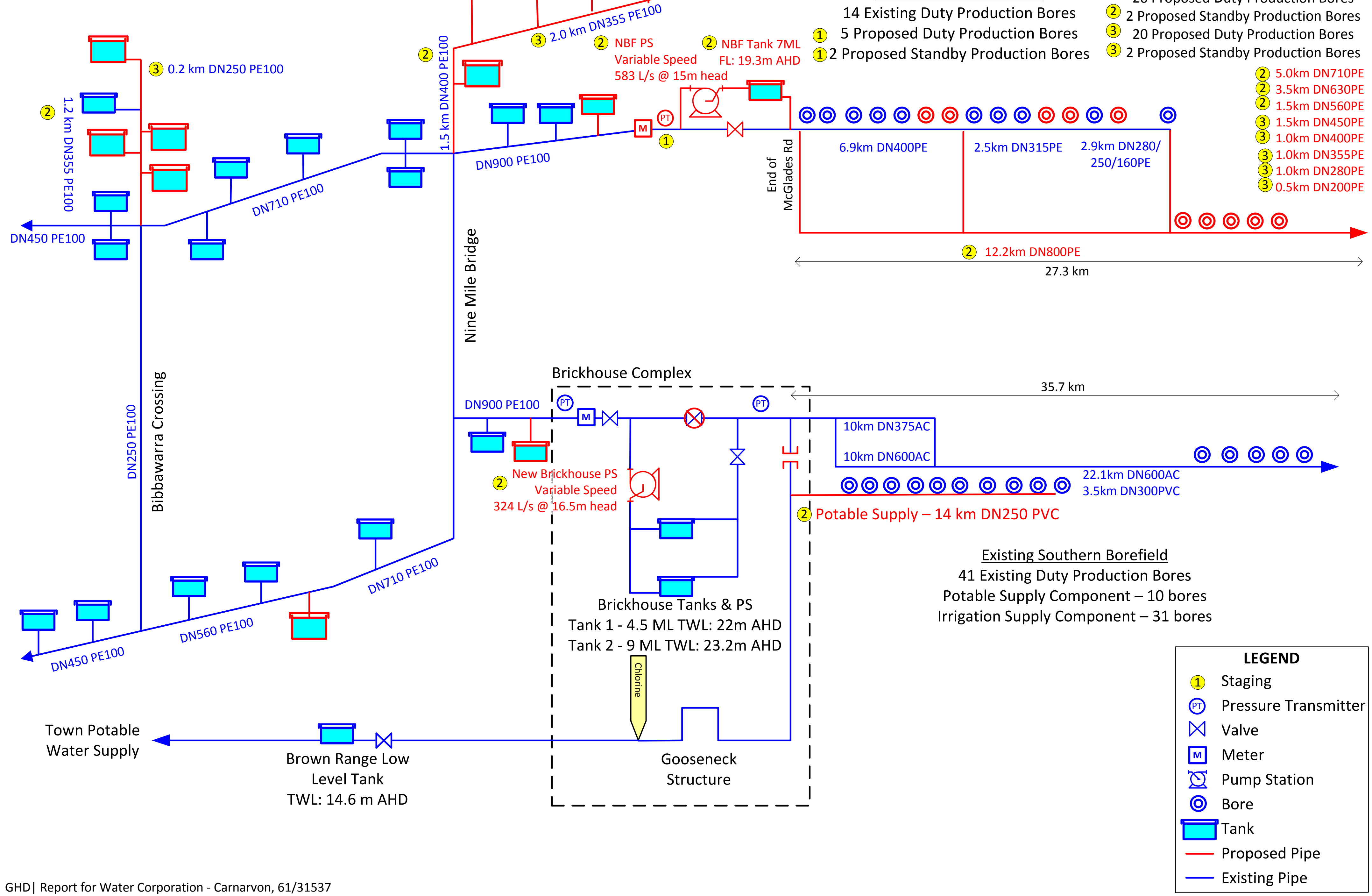
4 Location factor of 1.3 adopted. Contractor's preliminaries at 25%. Costs for project management, engineering and approvals adopted as 18.5%. Contingency of 20% adopted

5 Estimates are in $FY 2016

6 Excludes Southern Borefield potable/irrigation separation costs

7 Works to extend OH power to the 24km mark of the NBF being managed or scoped by DAFWA GFI team. Estimate for stage 3 allows for a 3.3km extension to take total power line length to 27.3km.

Figure 42 : Option 2 – Scenario B



9.4.5 O&M Estimate

Estimated power costs for Option 2 are summarised in Table 33 by stages. .

An L4 Tariff has been adopted for the NBF in the absence of negotiations being finalised with Horizon Energy on the tariff that will apply for the recent electrification.

The SBF power costs have been determined using the N2 power tariff which is the tariff that the Water Corporation is currently charged. The N2 tariff has increased sharply for 2015. If transfer of ownership of the Southern Borefield irrigation assets from the Water Corporation to GWAMCO enables negotiation to a cheaper tariff then power costs for the SBF will reduce.

Table 33. Option 2 - Power Cost Estimate

Item	Power Cost ($/yr)	Comment
Northern Borefield & NBF Booster Pump Station		
Stage 1	$260,000/yr $0.072/kL	3.6GL/yr, L4 Tariff
Stage 2 NBF NBF Booster PS	 $444,000/yr, $0.078/kL $106,000/yr, $0.019/kL	5.6GL/yr, L4 Tariff
Stage 3 NBF NBF Booster PS	 $591,000/yr, $0.078/kL $144,000/yr, $0.019/kL	7.6GL/yr, L4 Tariff
Southern Borefield		
Stage 1	$944,000/yr, $0.15/kL	5GL/yr Irrigation, 1.2GL/Yr Town, N2 Tariff
Stage 2	Potable Borefield $130,000/yr, $0.108/kL Irrigation Borefield $547,000/yr, $0.109/kL New Brickhouse Booster PS $187,000/yr, $0.037/kL	5GL/yr Irrigation, 1.2GL/Yr Town, N2 Tariff
Stage 3		5GL/yr Irrigation, 1.2GL/Yr Town, N2 Tariff

Estimated maintenance costs for Option 2 are detailed in Table 34. Historical maintenance costs were obtained from GWC and these were used to determine unit maintenance rates to be applied to the expanded scheme. The unit maintenance rates assessment is included in Appendix J. Maintenance costs for the Southern Borefield are not included here. These need to be obtained from the Water Corporation for the economic and pricing modelling.

Table 34. Option 2 - Maintenance Cost Estimate

Item	Stage 1	Stage 2	Stage 3
Northern Borefield	$25,400	$52,900	$77,800
Irrigation Scheme	$15,400	$16,200	$17,200
Scheme Wide – General Maintenance	$19,400	$54,200	$78,200
SBF Potable Water Main	-	$3,500	$3,500
NBF Tank	-	$5,600	$5,600
NBF BPS	-	$7,400	$7,400
New Brickhouse BPS	-	$6,900	$6,900
TOTAL	$60,200	$146,600	$196,500
Notes 1. Does not include GST			

9.5 Option 3 – Northern Borefield Pumps to Brickhouse Tanks

9.5.1 Overview

Option 3 is shown schematically in Figure 46. Option 3 differs from Option 1 in that both borefields pump to the Brickhouse Tanks. From the Brickhouse Tanks water is boosted to the distribution system via a new Brickhouse Booster Pump Station. The advantages of this option compared to the current operation are as follows:

- The tanks provide reserve storage, albeit limited, reducing the impact to Growers of a shutdown of either of the borefield collector mains.
- Lower power costs. Submersible borehole pumps are less efficient than normal centrifugal transfer pumps. Having part of the pumping being carried out by the more efficient transfer pump may reduce power costs.
- Water quality management. Having both borefields pumping to the same tank provides the ability to blend the water if the water quality in one of the borefields deteriorates.

The supply to all Growers to be controlled with a flow control valve to deliver their peak daily entitlement at a constant rate over 24 hours.

NBF Collector Main

Under this option bores in the Northern Borefield are to pump to the Brickhouse Tanks. This will require a main to be constructed across the Gascoyne River. Achieving adequate protection of the pipe at the river crossing will present a challenge given the sandy material of the river bed and its depth. It is preferable that the pipe is bedded in rock for river crossings. However, if the depth to rock is too high then a cheaper alternative may be to construct the main in steel and support the pipe on piles. The river crossing has a higher security of supply risk and estimating risk.

The existing Northern Borefield collector main is proposed to be retained but will need to be duplicated and extended to accommodate the increased flow from the proposed production bores. Duplicating the main has security of supply advantages as a partial supply from the Northern Borefield will be able to be maintained in the event that one of the duplicate sections should fail

Hydraulic grade lines for the NBF collector main starting from the end of McGlades Road are shown in Figure 43 for scenario B. At borefield production rates matching the annual average rate and lower, the hydraulic grade line will intersect the level of the borefield collector main based on the pipe route adopted. This will result in the main upstream of this intersection flowing partially full or even empty. Care will need to be taken during design to ensure the following.

- Sufficient air valves are provided in the borefield collector main to enable air to enter and vent from the main.
- The pipeline is designed and installed to minimise reversal of pipeline grade.
- Bore headworks design ensures accurate meter reading for bores that are located upstream of where the hydraulic grade line intersects the pipe profile.

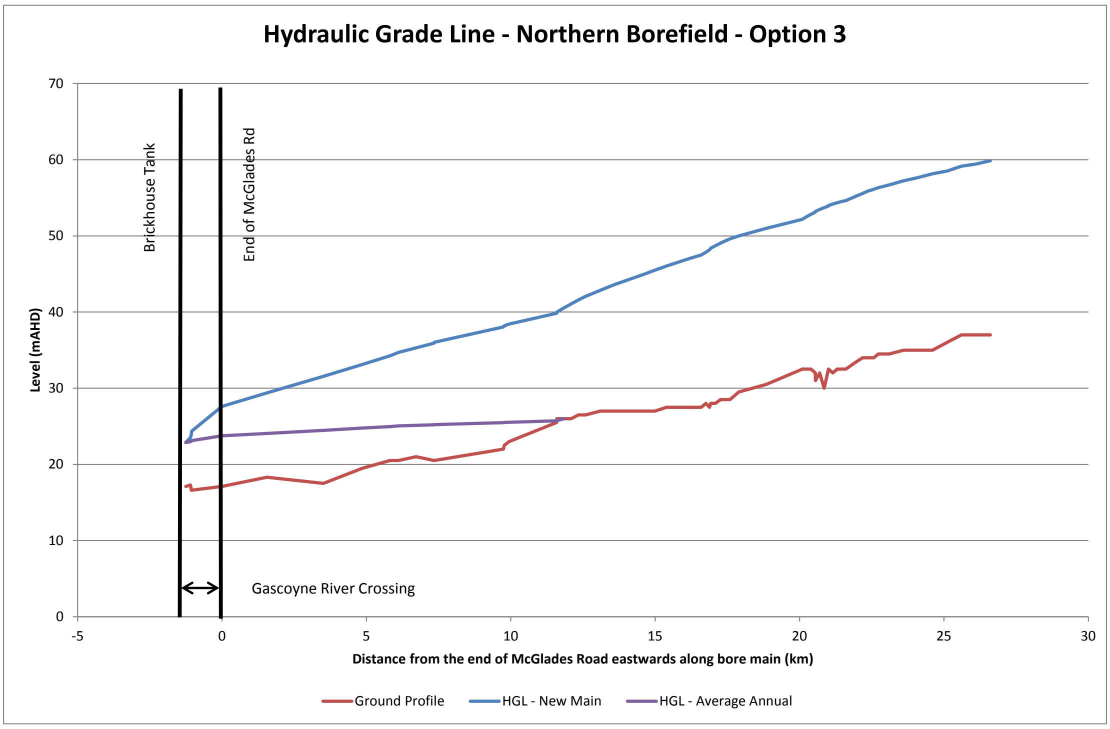


Figure 43. Option 3 - NBF - Hydraulic Grade Lines

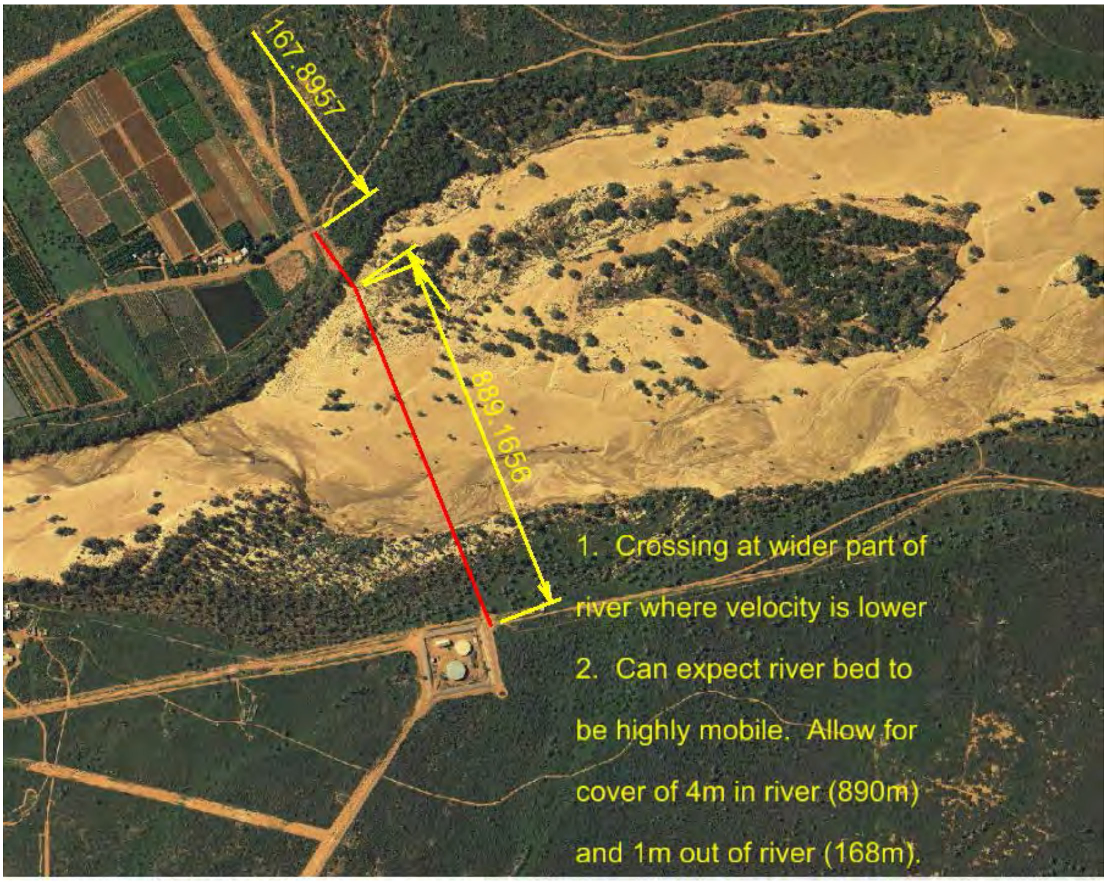


Figure 44. Adopted location of river crossing

Southern Borefield

Directing flow from the irrigation component of the Southern Borefield to the Brickhouse Tanks rather than pumping over the top of (or bypassing) the tanks as is the current practice changes the hydraulics of the borefield.

Hydraulic grade lines for the SBF collector main starting from the end of McGlades Road are shown in Figure 45 for scenario B

The Brickhouse Tanks are approximately 10m lower than the current target hydraulic level. A lower hydraulic grade line will result, meaning that at low production rates the majority of the main will be operating partially full or empty. The adequacy and frequency of air valves will need to be assessed to ensure that air can enter and vent from the main at appropriate rates.

Pumping to the lower hydraulic level of the Brickhouse tanks will result in the bores operating further to the right on their pump curve. For a number of bores, this will result in them operating outside of their recommended range in which case the pumps will need to be changed out to a smaller pump or alternatively flows throttled to a maximum flow rate. Further assessment of bores likely to be impacted and options to be addressed should be carried out if this option is adopted as the preferred option.

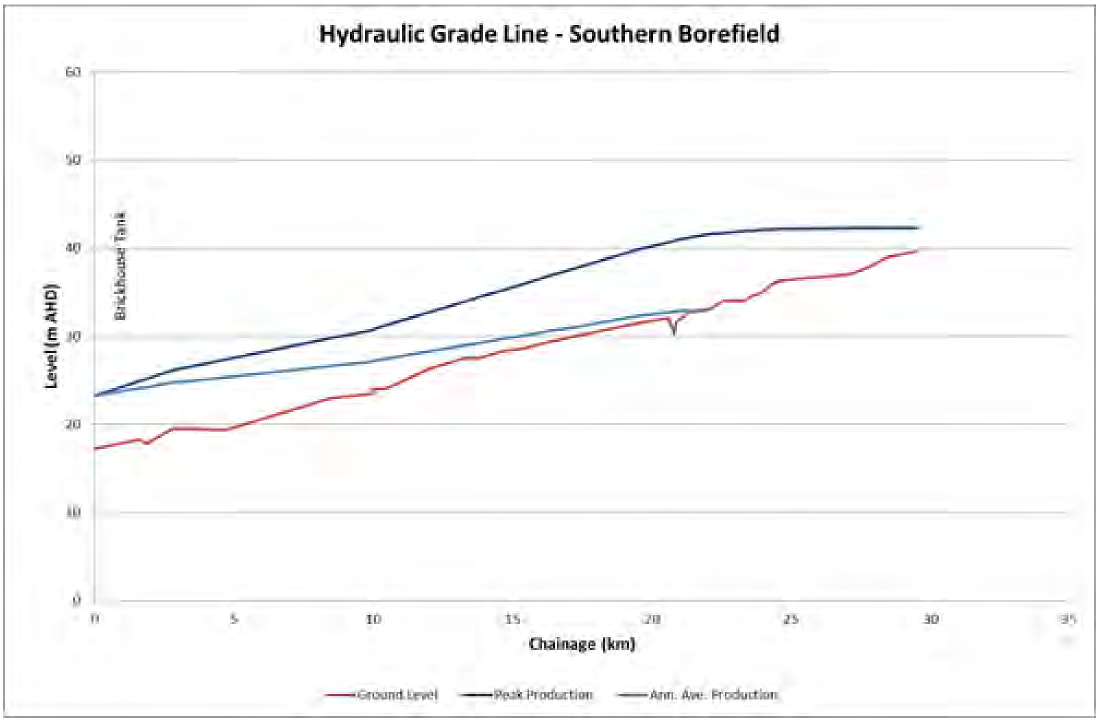


Figure 45. Option 3 - SBF - Hydraulic Grade Lines

Brickhouse Tanks and Booster Pump Station

The smaller Brickhouse Tank complex consists of two tanks as outlined in Section 4.4.1. The roof of the smaller 4.5ML tank is in poor condition and needs replacement. It is proposed that the 4.5ML tank is not brought back into operation due to the cost of replacing the roof and the operational issues of an unroofed tank. An unroofed tank will become an attraction for vermin and wildlife which would create a potential water quality risk given anecdotal reports of use of the irrigation supply for potable purposes.

The 9ML Brickhouse Tank has reserve storage sufficient to maintain supply for 1.25 hours.

The existing Brickhouse PS has reached the end of its useful asset life. It is proposed, for Option 3, that the Brickhouse PS is abandoned and a new Booster PS with sun shelter is constructed at the Brickhouse Site. The new Brickhouse Booster Pump Station pumps from the

9ML Brickhouse Tank to the distribution system to achieve the target hydraulic level of 36m AHD. The pump station will need to be variable speed to accommodate the range of flows. A pump station configuration of four duty pumps and one standby pump has been recommended by the vendor based on a minimum flow rate of 10% of peak. Further consideration of the pump station configuration needs to be carried out during design development.

Key new infrastructure requirements for this option are detailed in Table 35.

Table 35. Option 3 - Scenario B – New Infrastructure Requirements

Item	Detail	Comment
Irrigation Distribution System		
Mains	1.5km DN450PE 2.0km DN400PE 1.2km DN355PE 0.2km DN250PE	Extension to supply new lots of the GFI Expansion
Customer Connections	12 customer assemblies and connections to the distribution mains including SCADA	Connections to supply new lots of the GFI Expansion
Northern Borefield		
GWC Borefield Development	5 duty bores and 2 standby bores. 11 kW submersible bores.	Increases peak production capacity to 183 L/s to provide a peak factor of 1.6.
GFI Expansion	40 duty bores and 4 standby bores. 11 kW submersible bores.	Scenario B peak production capacity of 400 L/s
NBF Collector Main upgrade	12.25km DN800 PN6.3 5.0km DN710 PN6.3 3.5km DN630PE PN6.3 1.5km DN560PE PN6.3 1.5km DN450PE PN6.3 1.0km DN400PE PN6.3 1.0km DN355PE PN6.3 1.0km DN280PE PN6.3 0.5km DN200PE PN6.3	
River Crossing	1.1km DN710 PE PN6.3	Estimate allows for pipe laid at cover of 4m. Pipe crossing location and method of pipe protection needs detailed engineering assessment.

Monitoring	Magflow meter and pressure transducer	Monitoring of borefield production for regulatory and operational purposes. Monitoring of pressure for NBF Booster pump station control.
Power Supply	15.8km extension of the HV power line	12.5km extension of the HV power line to the 24km mark is part of DAFWAs GFI scope. Additional 3.3km extension required.
Southern Borefield		
New Brickhouse Booster PS	907L/s @ 18.5m	Variable speed. 4 x duty and 1 x standby. 30kW each
Potable/Irrigation Separation	14km DN250PVC	Length of main required may be reduced if new production bores can be successfully drilled in Subarea D

9.5.2 Staging

Stage 1 – GWC NBF upgrade to 183L/s

Analysis was undertaken to understand the capacity of the existing Northern Borefield infrastructure to accommodate an increase in capacity to 183L/s. Hydraulic grade lines were prepared for borefield peak production rates of 135L/s (14 bores - upgrade underway) and 183 L/s (19 bores - stage 1 upgrade) without any upgrades to the existing borefield collector main. A chart of these upgrades is included in Appendix I.

The analysis shows the following.

- The hydraulic grade line for a borefield production rate of 183L/s sits comfortably below the maximum allowable operating pressure of the installed main. This is on the basis the 5 new infill production bores and 2 new standby bores aren't concentrated at the eastern end of the existing borefield where pipe diameters are smaller but rather located to give a near even spread of bores along the main. Calculation of the hydraulic grade line should be repeated once the new production bores have been drilled.
- The maximum level the variable speed pumps in the existing 9 bores can pump to at the maximum recommended pumping rate of the bores is shown on the chart. As these values are all at or higher than the curve "Hydraulic Grade Line – 183L/s", the existing bore pumps will be capable of operating to the higher hydraulic grade line once the pump speed has been adjusted.
- The GWC NBF can be upgraded to 183L/s without upgrading the borefield collector main or the pumps in the existing bores.
- The chart also shows the ultimate hydraulic grade line at peak production of 583L/s allowing for the borefield collector main duplication and extension shown in Figure 26.

As this hydraulic grade line is lower, selection of pumps for the bores to take the scheme to 135L/s and then take the scheme to 183L/s need to be made in consideration of the ultimate hydraulic grade line. Consideration will need to be made on whether to initially install fixed speed pumps which may need to be changed out when the borefield collector main upgrades are completed or installing a variable speed pump that can handle the varying hydraulic grade lines.

Stage 2 – GFI Expansion to 50% (200L/s).

Extending the NBF to increase capacity by 200L/s more than doubles the flow through the existing NBF collector mains. This increase in flow would create excessive headloss in the existing mains DN315 and smaller and duplication of these mains with DN800 PE pipe is required at this stage.

An increase in capacity of 200L/s increases the velocity and headloss gradient in the existing DN400PE main (the largest diameter existing main in the NBF collector main) up to 3.6m/s and 21.2m/km. The existing DN400 main is 6.9km long and increasing the flow rate in it by 200L/s will substantially increase the hydraulic grade line whereby the MAOP would be exceeded. The DN400 main also needs to be duplicated with DN710PE at this stage.

The extent of borefield collector main required in stage 2 for connection of 20 production bores and 2 standby bores is detailed below.

- 12.25km DN800 PN6.3
- 5.0km DN710 PN6.3
- 3.5km DN630PE PN6.3
- 1.5km DN560PE PN6.3

The GFI Expansion triggers release of additional irrigation land. It has been assumed that lots that are located adjacent to the existing distribution main, and hence do not require mains extension to supply, are supplied in Stage 2. The adopted staging of distribution mains extension is detailed in Table 26.

Separation of the Southern Borefield into a potable supply and an irrigation supply does not have a demand trigger for its timing as it is more driven by governance issues. It has been assumed this separation is to occur as part of a larger project/upgrade to the scheme such as the GFI Expansion. Accordingly, it is assumed this upgrade is to occur in stage 2.

Construction of the Gascoyne River Crossing to connect the NBF to the Brickhouse Tank and the new Brickhouse Booster Pump Station changes the operation of the scheme and the hydraulic conditions of the borefield. Deferring these assets means that new production bores in the NBF would need to be equipped to account for the different hydraulic conditions or, if this is not possible, bore pumping equipment would need to be replaced. Accordingly, construction of these assets should coincide with the significant expansion of the NBF as proposed by the GFI expansion and a timing of stage 2 for these assets has been adopted.

Stage 3 – GFI Expansion to 100%.(+200L/s)

The extent of borefield collector main required in stage 3 for connection of 20 production bores and 2 standby bores is detailed below.

- 1.5km DN450PE PN6.3
- 1.0km DN400PE PN6.3
- 1.0km DN355PE PN6.3
- 1.0km DN280PE PN6.3
- 0.5km DN200PE PN6.3

The Stage 3 GFI Expansion triggers release of additional irrigation land. The adopted staging of distribution mains extension is detailed in Table 26.

9.5.3 Operating Strategy

The operation and control of Option 3 differs markedly from the current scheme and that proposed for Option 1. Option 3 can be separated into two hydraulic systems in addition to the Southern Borefield potable supply system.

- Borefield System – Bores in the NBF and irrigation bores in the SBF pump to Brickhouse Tank (9ML).
- Distribution System –Brickhouse Booster Pump Station pumps from the Brickhouse Tank (9ML) to the distribution system.

Borefield System

Bores in the NBF and irrigation bores in the SBF are proposed to be controlled on level in the NBF Tank. When water level in the tank reaches the low level setpoint a bore(s) is turned on. When water level in the tank reaches the high level setpoint a bore(s) is turned off. The bores starting and stopping sequence needs to be adjustable by the operator so that the following drivers can be managed.

- Borefield allocation.
- Balancing of abstraction from subareas.
- Management of water quality.
- Operating cost.

Distribution System

The new Brickhouse Booster Pump Station is to be variable speed controlled on downstream pressure to meet the target hydraulic level of 36m AHD. The pump station configuration needs to be such that it can supply a range of flows from the maximum flow down to the minimum flow. On the basis the minimum flow is 10% of the maximum flow vendor advice is that a minimum of three duty pumps are required. The pump station configuration needs to be further assessed during design development.

9.5.4 Capital Cost Estimate

Quantity surveyors McGarry Associates were engaged to prepare capital cost estimates. Vendor prices were obtained for key equipment and materials.

The estimated capital costs for Option 3 by stages and expansion is detailed in Table 36 below. Total capital cost is estimated at $30.8M excluding costs to separate the SBF, GFI groundwater investigation costs and NBF overhead power extension.

Table 36 Option 3 Capital Estimate

ITEM	DESCRIPTION	Stage 1	Stage 2	Stage 3
1	**GWC NBF UPGRADE**	**$2,040,000**	**$-**	**$-**
1.1	INFILL BORES DRILLING	$1,467,035	$-	$-
1.2	EQUIP & CONNECT INFILL BORES	$321,566	$-	$-
1.3	BORE COLLECTOR MAIN	$103,989	$-	$-
1.4	SCADA / ELECTRICAL WORKS	$148,954	$-	$-
2	**GFI NBF EXTENSION - BOREFIELD WORKS**	**$-**	**$20,520,000**	**$ 8,280,000**
2.1	BOREFIELD INVESTIGATIONS	$-	Note 1	Note 1
2.2	EQUIP & CONNECT BORES	$-	$ 1,465,064	$ 1,385,899
2.3	NBF EXTENSION - BORE MAIN	$-	$ 15,725,812	$ 5,089,179
2.4	SCADA / ELECTRICAL WORKS	$-	$ 423,194	$ 433,687
2.5	DISTRIBUTION SYSTEM/GROWER CONNECTIONS	$-	$ 577,104	$ 816,714
2.6	NBF RIVER CROSSING	$-	$ 973,547	$ -
2.7	NEW BRICKHOUSE BOOSTER PUMP STATION	$-	$ 1,353,588	$ -
2.8	OH POWER EXTENSION	$-	Note 7	$ 556,379
	Total	**$2,040,000**	**$20,520,000**	**$ 8,280,000**

NOTES

1 Works being managed or scoped by DAFWA GFI project team. Costs/estimates not repeated here.

2 Estimates subject to outcomes of groundwater investigations

3 Assumed that insitu materials are mostly suitable for bedding and backfill of pipes

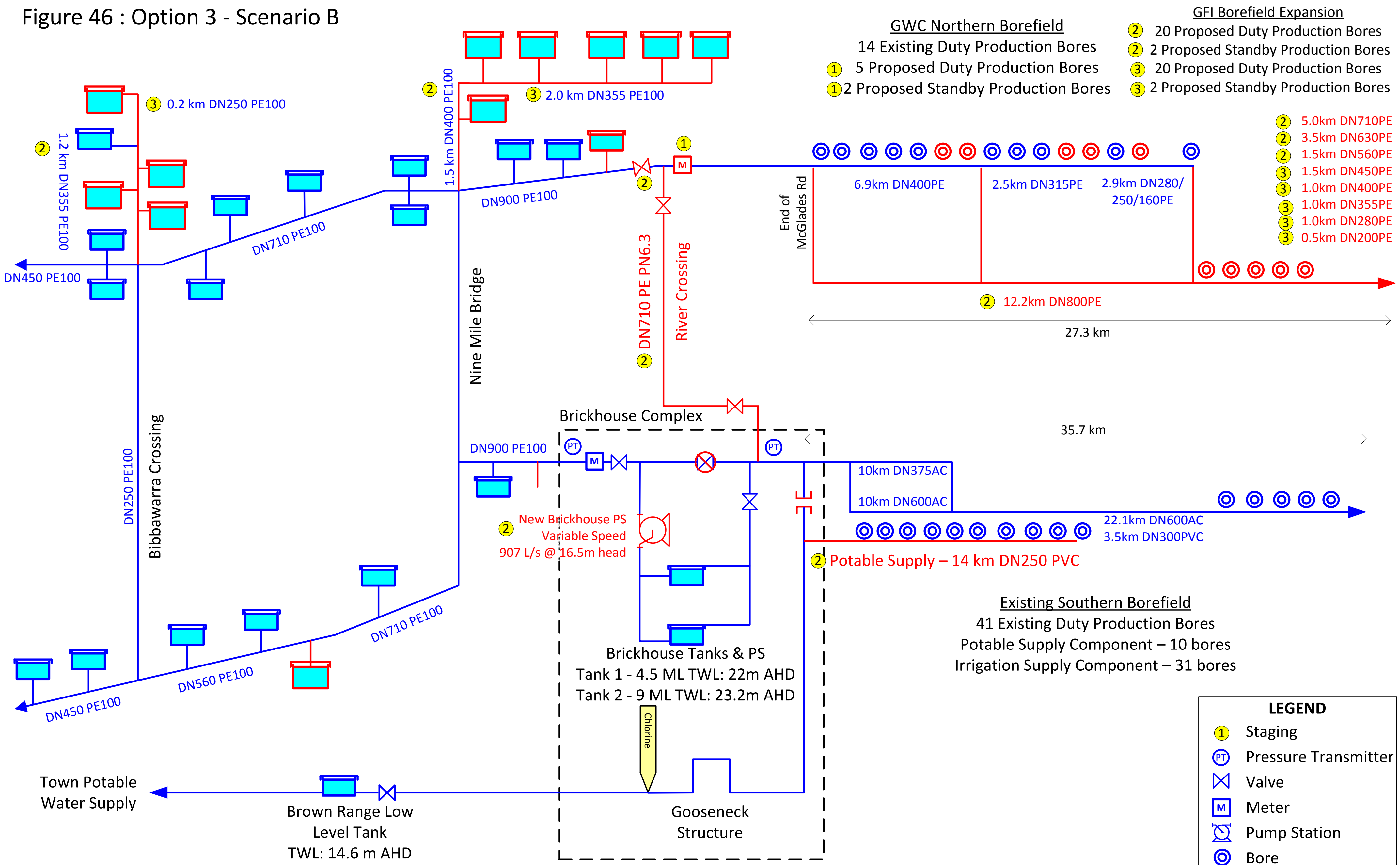
4 Location factor of 1.3 adopted. Contractor's preliminaries at 25%. Costs for project management, engineering and approvals adopted as 18.5%. Contingency of 20% adopted generally, 50% adopted for river crossing.

5 Estimates are in $FY 2016

6 Excludes Southern Borefield potable/irrigation separation costs

7 Works to extend OH power to the 24km mark of the NBF being managed or scoped by DAFWA GFI team. Estimate for stage 3 allows for a 3.3km extension to take total power line length to 27.3km.

Figure 46 : Option 3 - Scenario B



9.5.5 O&M Estimate

Estimated power costs for Option 3 are summarised in Table 37 by stages.

An L4 Tariff has been adopted for the NBF in the absence of negotiations being finalised with Horizon Energy on the tariff that will apply for the recent electrification.

The SBF power costs have been determined using the N2 power tariff which is the tariff that the Water Corporation is currently charged. The N2 tariff has increased sharply for 2015. If transfer of ownership of the Southern Borefield irrigation assets from the Water Corporation to GWAMCO enables negotiation to a cheaper tariff then power costs for the SBF will reduce.

Table 37. Option 3 - Power Cost Estimate

Item	Power Cost ($/yr)	Comment
Northern Borefield		
Stage 1	$260,000/yr, $0.072/kL	3.6GL/yr, L4 Tariff
Stage 2	$426,000/yr, $0.076/kL	5.6GL/yr, L4Tariff
Stage 3	$578,000/yr, $0.076/kL	7.6GL/yr, L4 Tariff
Southern Borefield		
Stage 1	$944,000/yr, $0.15/kL	5GL/yr Irrigation, 1.2GL/Yr Town, N2 Tariff
Stage 2	Potable Borefield $130,000/yr, $0.108/kL Irrigation Borefield $547,000/yr, $0.109/kL	5GL/yr Irrigation, 1.2GL/Yr Town, N2 Tariff
Stage 3		
Distribution – New Brickhouse Booster Pump Station		
Stage 2	$373,000/yr, $0.035/kL	10.6GL/yr, N2 Tariff
Stage 3	$442,000/yr, $0.035/kL	12.6GL/yr, N2 Tariff

Estimated maintenance costs for Option 3 are detailed in Table 38. Historical maintenance costs were obtained from GWC and these were used to determine unit maintenance rates to be applied to the expanded scheme. The unit maintenance rates assessment is included in Appendix J. Maintenance costs for the Southern Borefield are not included here. These need to be obtained from the Water Corporation for the economic and pricing modelling.

Table 38. Option 3 - Maintenance Cost Estimate

Item	Stage 1	Stage 2	Stage 3
Northern Borefield	$25,400	$54,200	$77,800
Irrigation Scheme	$15,400	$16,400	$17,200
Scheme Wide – General Maintenance	$19,400	$48,600	$74,600
SBF Potable Water Main	-	$3,500	$3,500
New Brickhouse BPS	-	$7,900	$7,900
TOTAL	$60,200	$130,500	$181,000
Notes 1. Does not include GST			

9.6 Option Comparison - Scenario B

An option comparison for key criteria is detailed in Table 39. An economic comparison is being carried out by others. The comparison presented in Table 39 is discussed in more detail below.

Option 1 has the lowest capital cost.

Option 2 and 3 power costs are unexpectedly higher than Option 1. SBF power costs for Option 2 and Option 3 are lower as anticipated due to the SBF pumping to the lower level of Brickhouse Tank. However, as pumping to the Brickhouse Tanks results in the hydraulic grade line intersecting the collector main profile for a greater portion of the collector main route the potential operating cost savings are not fully realised.

Understandably, maintenance costs for Options 2 and 3 are higher than for Option 1 due to these options having a greater number of assets.

The security of supply provided by the tanks of Options 2 and 3 are not sufficient to maintain supply for the duration of a failure of the borefield collector main or even an extended power failure. The durations detailed in the table essentially only delay the impact of a shutdown or power failure and represent a minor advantage over Option 1. Importantly, under the Gascoyne Water Customer Service Charter customers are to ensure they have on-farm storage to withstand supply interruptions of up to 3 days.

Table 39. Option Comparison for Scenario B

Option	Capital Cost	Operating Cost ($k/yr)	Maintenance Cost ($k/yr)	Security of Supply	Operability	Water Quality	Risk
Option 1	GWC NBF $2.0M GFI Exp $26.2M SBF Pot $6.3M Total $34.6M	NBF – 652 SBF Irr – 622 SBF Pot - 130 **Tot. - 1404**	NBF & Distribution - 170	No capability to maintain full supply in the event of a borefield collector main shutdown. Customers will see an impact immediately	Similar operation and control to the current system and as such operators readily familiar with.	No ability to blend water from both borefields to manage water quality, but can blend within a borefield	
Option 2	GWC NBF $2.0M GFI Exp $33.4M SBF Pot $6.3M Total $41.8M	NBF – 591 NBF BPS - 144 SBF Irr – 547 SBF BPS - 187 SBF Pot - 130 **Tot. - 1599**	NBF, Distribution & SBF new assets - 196	Inclusion of storage in the scheme provides limited ability to maintain supply during a borefield collector main shutdown. NBF collector main failure – maintain supply for 2 hours SBF Irrigation collector main failure – maintain supply for 4 hours	Consists of three supply systems with 2 booster pump stations pumping into the distribution system. This option is the most complex from an operation and control perspective	No ability to blend water from both borefields to manage water quality, but can blend within a borefield	

Option	Capital Cost	Operating Cost ($k/yr)	Maintenance Cost ($k/yr)	Security of Supply	Operability	Water Quality	Risk
Option 3	GWC NBF $2.0M GFI Exp $28.8M SBF Pot $6.3M Total $37.1M	NBF – 578 SBF Irr – 547 SBF BPS - 442 SBF Pot - 130 **Tot. - 1697**	NBF, Distribution & SBF new assets - 181	Inclusion of storage in the scheme provides limited ability to maintain supply during a borefield collector main shutdown. NBF collector main failure – maintain supply for 2 hours SBF Irrigation collector main failure – maintain supply for 3.5 hours	Consists of two supply systems and 1 booster pump station. Less complex than Option 2	When water quality from one borefield is poor, water from both borefields can be blended at the Brickhouse Tank. Growers would all receive a similar water quality.	Loss of the NBF collector main crossing Gascoyne River due to extreme river flow events will have a significant impact on the scheme supply.

10. Key Findings

10.1 Existing Irrigation Scheme

- Flow regulation at each Grower's customer assembly is required to ensure an equitable supply.
- Flow regulation is achievable by either self-regulation or with the use of flow control valves.

10.2 Flow Control Valves

- Alternative flow control valves exist that are superior to the flow control valves installed.
- It is difficult to justify the expenditure required to change flow control valves without first disproving the effectiveness of the existing flow control valves.
- Rather than re-install the 90 DN50 flow control valves previously removed, GWC should consider using Maric Flow control valves (DN50 - $132 supply).
- Changes in peak production will require an adjustment of the flow control valve settings. Having a single peak production rate from the SBF regardless of LAS declaration will reduce the need to adjust the flow control valves.
- Providing a minimum flow rate to smaller entitlement Growers has the potential to distort the equitable share of peak production. For the current scheme a minimum flow rate of 0.5L/s (30L/min) results in the balance of growers receiving 95% of their share of the peak

10.3 GWC Borefield Development

- The existing northern borefield collector main and installed bore pumps can accommodate an upgrade to 183L/s without upgrade of the collector main or change in bore pumps.

10.4 GFI Expansion

- For Scenario A, a target hydraulic level of 34m AHD is required at the start of the irrigation distribution to provide an acceptable level of service to existing growers and expansion areas.
- For Scenario B, a target hydraulic level of 36m AHD is required at the start of the irrigation distribution to provide an acceptable level of service to existing growers and expansion areas.
- The existing collector main should be duplicated to meet capacity requirements – in addition, the duplication provides security of supply benefits.
- The optimum borefield collector main size is one that achieves a hydraulic gradient of 1m/km.
- "Option 1 – Same operation as current" is the least capital cost option for both scenarios.
- "Option 2 – NBF pumps to new NBF Tank and 2 Booster PSs" is the highest capital cost option (+$6M approx. for Scenario A and +$7M approx. for Scenario B).

- "Option 3 – NBF pumps to Brickhouse Tanks" is approximately $3M more expensive than Option 1 for Scenario A and $3.5M more expensive for Scenario B.
- Under Options 2 and 3, the SBF bores pump directly to the Brickhouse Tanks. As a result of the changed hydraulic conditions, a number of bore pumps will require throttling or replacement.
- Options 2 and 3 have higher operating and maintenance costs than Option 1 for both scenarios.

10.5 Southern Borefield Separation

- To separate the southern borefield into a potable component and an irrigation component, the Water Corporation have identified 10 bores are required to meet current town demands which requires a 14km DN250 main.
- The length of DN250 main required may be able to be reduced to 10km if a new production bore(s) can be drilled in Subarea D with a capacity of 5L/s or more.

11. GFI review – Further Work Required

The following further work is recommended prior to design development

1. Confirmation of the Northern Borefield Collector Main pipe diameters and lengths upon confirmation of production bore maximum recommended pumping rates and production bore locations.
2. Transient analysis to determine the water hammer pressure envelope and requirements for water hammer mitigation.
3. Detailed steady state hydraulic modelling of the Northern Borefield including GFI Expansion to determine, together with finalised bore drawdown and static groundwater level ranges, the bore operating range for pump and drive type selection and to confirm control parameters.
4. Documentation of the functional requirements for the Northern Borefield including GFI Expansion to establish the basis of design for SCADA and bore equipping.

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Appendices

Appendix A Property Allocation, Meter Size, Peak instantaneous supply of existing irrigation system

GW001	35,000	50	1.46	GW034	30,000	80	1.26	GW072	48,000	80	2.01
GW002	5,000	50	0.21	GW035	15,000	100	0.63	GW073	50,000	50	2.09
GW003	40,000	50	1.67	GW036	55,000	80	2.30	GW074	40,000	80	1.67
GW004	47,000	100	1.97	GW037	11,000	80	0.46	GW075	70,000	50	2.93
GW005	72,000	80	3.01	GW038	55,000	80	2.30	GW076	55,000	80	2.30
GW006	5,000	50	0.21	GW039	25,000	50	1.05	GW077	50,000	80	2.09
GW007	35,000	50	1.46	GW040	27,000	150	0.92	GW078	47,000	80	1.97
GW008	100,000	80	4.19	GW041	110,000	100	4.60	GW079	60,000	80	2.51
GW009	52,000	50	2.18	GW042	129,000	80	5.40	GW080	50,000	80	2.09
GW010	280,000	150	11.72	GW043	76,000	100	3.18	GW081	83,000	80	3.47
GW011	5,000	50	0.21	GW044	52,000	100	2.18	GW082	40,000	50	1.67
GW012	5,000	50	0.21	GW045	55,000	80	2.30	GW083	46,000	80	1.93
GW013	29,000	80	1.21	GW046	39,000	80	1.63	GW084	58,000	50	2.43
GW014	37,000	50	1.55	GW047	44,000	80	1.84	GW085	40,000	50	1.67
GW015	55,000	50	2.30	GW048	33,000	100	1.38	GW086	67,000	80	2.80
GW016	48,000	50	2.01	GW049	5,000	100	0.21	GW087	50,000	50	2.09
GW017	70,000	50	2.93	GW050	30,000	50	1.26	GW088	8,000	80	0.33
GW018	37,000	50	1.55	GW051	18,000	50	0.75	GW089	5,000	50	0.21
GW019	50,000	50	2.09	GW052	100,000	100	2.09	GW090	45,000	80	1.88
GW020	10,000	50	0.42	GW053	35,000	150	1.46	GW091	17,000	50	0.71
GW021	7,000	50	0.29	GW054	245,000	150	10.25	GW092	20,000	80	0.84
GW022	15,000	50	0.63	GW055	62,000	80	2.60	GW093	5,000	80	0.21
GW023	70,000	50	2.93	GW056	35,000	50	1.46	GW094	19,000	80	0.80
GW024	50,000	50	2.09	GW057	73,000	80	3.06	GW095	50,000	80	2.09
GW025	25,000	50	1.05	GW058	71,000	80	2.97	GW096	100,000	80	4.19
GW026	10,000	50	0.42	GW059	5,000	50	N/A	GW097	15,000	80	0.63
GW027	56,000	50	2.34	GW060	75,000	150	3.14	GW098	50,000	80	2.09
GW028	47,000	50	1.97	GW061	45,000	150	1.88	GW099	5,000	50	0.21
GW029	35,000	50	1.46	GW062	277,000	150	11.59	GW100	67,000	80	2.80
GW030	46,000	50	1.93	GW063	5,000	80	0.21	GW101	26,000	50	1.09
GW031	29,000	80	1.21	GW064	19,000	80	0.80	GW102	15,000	50	0.63
GW032	5,000		0.84	GW065	20,000	80	0.84	GW103	44,000	50	1.84
GW033	5,000		0.21	GW066	29,000	80	1.21	GW104	42,000	80	1.76

GW105	75,000	80	3.14	GW142	25,000	80	1.05	GW179	5,000	50	0.21
GW106	20,000	50	0.84	GW143	16,000	80	0.67	GW180	73,000	50	3.06
GW107	58,000	50	2.43	GW144	30,000	80	1.26	GW181	8,000	50	0.33
GW108	70,000	80	2.93	GW145	20,000	50	0.84	GW182	5,000	50	0.21
GW109	50,000	80	2.09	GW146	55,000	50	2.30	**Total allocation (kL/year)**	**8,063,000**	**Total instantaneous flow (L/s)**	**341.57**
GW110	30,000	50	1.26	GW147	5,000	50	0.21				
GW111	34,000	50	1.42	GW148	15,000	50	0.63				
GW112	74,000	80	3.10	GW149	66,000	80	2.76				
GW113	23,000	80	0.96	GW150	100,000	50	4.19				
GW114	57,000	50	2.39	GW151	30,000	80	1.26				
GW115	50,000	50	2.09	GW152	5,000	50	0.21				
GW116	70,000	100	2.93	GW153	51,000	50	2.13				
GW117	9,000	80	0.38	GW154	70,000	50	2.93				
GW118	44,000	80	1.84	GW155	35,000	50	1.46				
GW119	86,000	100	4.65	GW156	48,000	50	2.01				
GW120	200,000	100	8.37	GW157	50,000	50	2.09				
GW121	27,000	100	1.13	GW158	72,000	50	3.01				
GW122	60,000	100	2.51	GW159	50,000	50	2.09				
GW123	5,000	100	0.21	GW160	54,000	50	2.26				
GW124	35,000	100	1.46	GW161	36,000	50	1.51				
GW125	38,000	80	1.59	GW162	30,000	50	1.26				
GW126	45,000	80	1.88	GW163	60,000	50	2.51				
GW127	60,000	80	2.51	GW164	80,000	50	3.35				
GW128	40,000	50	1.67	GW165	42,000	50	1.76				
GW129	40,000	100	1.67	GW166	30,000	80	1.26				
GW130	30,000	100	1.26	GW167	13,000	50	0.54				
GW131	26,000	150	1.09	GW168	47,000	50	1.97				
GW132	30,000		1.26	GW169	61,000	50	2.55				
GW133	12,000	80	5.65	GW170	30,000	50	1.26				
GW134	111,000	80	4.65	GW171	8,000	50	0.33				
GW135	14,000	80	0.59	GW172	48,000	50	2.01				
GW136	37,000	50	1.55	GW173	12,000	50	0.50				
GW137	43,000	50	1.80	GW174	36,000	50	1.51				
GW138	40,000	50	1.67	GW175	8,000	50	0.33				
GW139	17,000	50	0.71	GW176	15,000	50	0.63				
GW140	35,000	50	1.46	GW177	5,000	80	0.21				
GW141	38,000	50	1.59	GW178	5,000	80	0.21				

Appendix B Flow Control Valves settings for all plantations (including future areas) under the GFBI Northern Borefield 270 L/s expansion scenario

Grower	Flow Rate (L/s)	Grower	Flow Rate (L/s)	Grower	Flow Rate (L/s)	Grower	Flow Rate (L/s)	Grower	Flow Rate (L/s)	Grower	Flow Rate (L/s)
GW001	0.62	GW033	0.31	GW066	1.79	GW098	3.09	GW130	1.85	GW162	1.85
GW002	0.31	GW034	1.85	GW067	1.85	GW099	0.31	GW131	1.30	GW163	3.70
GW003	1.23	GW035	12.44	GW068	2.47	GW100	4.14	GW132	1.85	GW164	4.94
GW004	2.90	GW036	3.40	GW069	2.47	GW101	1.61	GW133	8.33	GW165	2.28
GW005	4.45	GW037	0.68	GW070	0.62	GW102	0.93	GW134	6.24	GW166	1.85
GW006	0.31	GW038	3.40	GW071	2.90	GW103	2.72	GW135	0.86	GW167	0.80
GW007	2.16	GW039	1.54	GW072	2.96	GW104	2.59	GW136	2.28	GW168	2.90
GW008	11.25	GW040	1.36	GW073	3.09	GW105	4.63	GW137	2.65	GW169	3.77
GW009	7.61	GW041	6.79	GW074	2.47	GW106	1.23	GW138	2.47	GW170	0.31
GW010	31.97	GW042	7.96	GW075	4.32	GW107	3.58	GW139	1.05	GW171	0.49
GW011	3.70	GW043	4.69	GW076	3.40	GW108	4.32	GW140	2.16	GW172	2.96
GW012	3.70	GW044	3.21	GW077	3.09	GW109	3.09	GW141	2.35	GW173	0.74
GW013	6.36	GW045	3.40	GW078	2.90	GW110	1.85	GW142	1.54	GW174	2.22
GW014	2.28	GW046	2.41	GW079	3.70	GW111	2.10	GW143	2.84	GW175	0.49
GW015	3.40	GW047	2.72	GW080	3.09	GW112	4.57	GW144	0.31	GW176	0.93
GW016	2.96	GW048	2.04	GW081	5.12	GW113	1.42	GW145	1.23	GW177	0.31
GW017	4.32	GW049	3.09	GW082	2.47	GW114	3.52	GW146	3.40	GW178	0.31
GW018	2.28	GW050	1.85	GW083	2.84	GW115	3.09	GW147	0.31	GW179	0.31
GW019	3.09	GW051	1.11	GW084	3.58	GW116	4.32	GW148	0.93	GW180	4.51
GW020	1.97	GW052	3.09	GW085	2.47	GW117	1.79	GW149	4.07	GW181	0.49
GW021	4.33	GW053	6.90	GW086	4.14	GW118	2.72	GW150	6.17	GW182	0.31
GW022	7.36	GW054	19.67	GW087	1.85	GW119	7.16	GW151	1.85	C5b	9.14
GW023	11.43	GW055	8.23	GW088	0.49	GW120	12.35	GW152	0.31	D1	56.72
GW024	12.06	GW056	2.16	GW089	1.54	GW121	1.36	GW153	3.15	D2	52.84
GW025	1.54	GW057	8.91	GW090	3.40	GW122	3.70	GW154	4.32	E1	22.16
GW026	0.62	GW058	4.38	GW091	1.05	GW123	0.31	GW155	2.16	E1	24.67
GW027	7.52	GW060	4.68	GW092	1.23	GW124	2.16	GW156	2.96	**Total**	**776 L/s**
GW028	7.98	GW061	2.78	GW093	0.31	GW125	2.35	GW157	3.09		
GW029	4.87	GW062	17.10	GW094	1.17	GW126	2.78	GW158	4.45		
GW030	2.84	GW063	0.31	GW095	3.09	GW127	3.70	GW159	3.09		
GW031	2.10	GW064	1.17	GW096	6.17	GW128	2.47	GW160	3.33		

Appendix C Flow Control Valves settings for all Growers (including future areas) under the GFBI Northern Borefield 400 L/s expansion scenario

Grower	Flow Rate (L/s)	Grower	Flow Rate (L/s)	Grower	Flow Rate (L/s)	Grower	Flow Rate (L/s)	Grower	Flow Rate (L/s)	Grower	Flow Rate (L/s)
GW001	0.62	GW035	12.44	GW070	0.62	GW104	2.59	GW138	2.47	GW172	2.96
GW002	0.31	GW036	3.40	GW071	2.90	GW105	4.63	GW139	1.05	GW173	0.74
GW003	1.23	GW037	0.68	GW072	2.96	GW106	1.23	GW140	2.16	GW174	2.22
GW004	2.90	GW038	3.40	GW073	3.09	GW107	3.58	GW141	2.35	GW175	0.49
GW005	4.45	GW039	1.54	GW074	2.47	GW108	4.32	GW142	1.54	GW176	0.93
GW006	0.31	GW040	1.36	GW075	4.32	GW109	3.09	GW143	2.84	GW177	0.31
GW007	2.16	GW041	6.79	GW076	3.40	GW110	1.85	GW144	0.31	GW178	0.31
GW008	11.25	GW042	7.96	GW077	3.09	GW111	2.10	GW145	1.23	GW179	0.31
GW009	7.61	GW043	4.69	GW078	2.90	GW112	4.57	GW146	3.40	GW180	4.51
GW010	31.97	GW044	3.21	GW079	3.70	GW113	1.42	GW147	0.31	GW181	0.49
GW011	3.70	GW045	3.40	GW080	3.09	GW114	3.52	GW148	0.93	GW182	0.31
GW012	3.70	GW046	2.41	GW081	5.12	GW115	3.09	GW149	4.07	C5b	6.49
GW013	6.36	GW047	2.72	GW082	2.47	GW116	4.32	GW150	6.17	D1	40.27
GW014	2.28	GW048	2.04	GW083	2.84	GW117	1.79	GW151	1.85	D2	37.51
GW015	3.40	GW049	3.09	GW084	3.58	GW118	2.72	GW152	0.31	E1	15.73
GW016	2.96	GW050	1.85	GW085	2.47	GW119	7.16	GW153	3.15	E1	17.51
GW017	4.32	GW051	1.11	GW086	4.14	GW120	12.35	GW154	4.32	E1	17.51
GW018	2.28	GW052	3.09	GW087	1.85	GW121	1.36	GW155	2.16	B4	6.13
GW019	3.09	GW053	6.90	GW088	0.49	GW122	3.70	GW156	2.96	B5	13.24
GW020	1.97	GW054	19.67	GW089	1.54	GW123	0.31	GW157	3.09	B12	7.20
GW021	4.33	GW055	8.23	GW090	3.40	GW124	2.16	GW158	4.45	B13	5.96
GW022	7.36	GW056	2.16	GW091	1.05	GW125	2.35	GW159	3.09	C4a	10.04
GW023	11.43	GW057	8.91	GW092	1.23	GW126	2.78	GW160	3.33	C5a	16.00
GW024	12.06	GW058	4.38	GW093	0.31	GW127	3.70	GW161	2.22	C5a	22.58
GW025	1.54	GW060	4.68	GW094	1.17	GW128	2.47	GW162	1.85	C5a	22.84
GW026	0.62	GW061	2.78	GW095	3.09	GW129	4.32	GW163	3.70	C5a	37.33
GW027	7.52	GW062	17.10	GW096	6.17	GW130	1.85	GW164	4.94	C5a	37.33
GW028	7.98	GW063	0.31	GW097	0.93	GW131	1.30	GW165	2.28	B3	86.41
GW029	4.87	GW064	1.17	GW098	3.09	GW132	1.85	GW166	1.85	**Total**	**907 L/s**
GW030	2.84	GW065	1.23	GW099	0.31	GW133	8.33	GW167	0.80		
GW031	2.10	GW066	1.79	GW100	4.14	GW134	6.24	GW168	2.90		
GW032	1.23	GW067	1.85	GW101	1.61	GW135	0.86	GW169	3.77		
GW033	0.31	GW068	2.47	GW102	0.93	GW136	2.28	GW170	0.31		
GW034	1.85	GW069	2.47	GW103	2.72	GW137	2.65	GW171	0.49		

Appendix D Southern Borefield Information

Borefield	Bore Name	Sub-Area	Top of Casing (mAHD)	Rest Water Level (mBTOC)	Rest Level (mAHD)	Long Term Drawdown (m)	Historical Pumped Water Level (mAHD)	Pump Type	Recommended Flow Rate (kL/day)	Notes
Southern Borefield	02/76	B	19.97	8.40	11.57	?	-0.5	Grundfos SP 46-4	960	
Southern Borefield	18/02	B	18.71	12.49	6.22	-0.8	5.00	Grundfos	850	
Southern Borefield	02/81	C	19.15	4.23	14.92	-5.99	2.50	Turbo Master 6LM1	930	
Southern Borefield	06/82	C	19.31	8.76	10.55	1.85	-2.50	Turbo Master	600	
Southern Borefield	07/82	C	19.31	10.55	8.76	4.26	7.50	Grundfos SP 46-4	1000	
Southern Borefield	20/01 (04/70)	C	19.19	4.14	15.05	12.12	7.50	Grundfos SP 30-7	500	
Southern Borefield	20/02	C	20.57	10.30	10.27	-13.31	-5.00	N/A	200	
Southern Borefield	03/73	D	14.28	7.60	6.676	6.68	12.50	Turbo Master 6 MM1	1200	
Southern Borefield	18/01 (19/74)	D	20.77	8.90	11.87	-0.33	N/A	N/A	65	Unequipped
Southern Borefield	17/02	D	22.40	10.25	12.15	-12.85	-7.50	Grundfos	350	
Southern Borefield	1/07 (02/84)	E	23.14	2.90	20.24	6.24	10.00	Turbo Master	3000	
Southern Borefield	19/01 (02/73)	E	18.05	8.63	9.417	6.68	15.00	Grundfos SP 17-5	350	
Southern Borefield	21/02	E	26.2	13.40	12.80	-16.9	-5.00	N/A	510	
Southern Borefield	03/79	F	24.78	7.00	17.78	?	5.00	Southern Cross 7 NAD	1440	
Southern Borefield	03/82	F	23.65	6.50	17.15	6.05	2.50	Grundfos MS6000	1700	
Southern Borefield	10/84	F	24.50	3.13	21.37	3.01	15.00	Grundfos SP 46-4	2500	
Southern Borefield	11/01 (14/74)	F	31.68	8.10	23.58	10.63	10.00	Grundfos SP 77-5	1900	
Southern Borefield	19/02	F	28.74	10.10	18.64	-6.76	0.00	Grundfos	200	
Southern Borefield	13/74	G	32.93	6.03	26.90	?	17.50	Turbo Master V/Turbine	1152	
Southern Borefield	01/82	G	27.48	4.46	23.02	14.44	17.50	Southern Cross 4NAH-900 2F	2500	
Southern Borefield	11/84	G	29.12	3.20	25.92	13.92	12.50	Southern Cross NAD 5-Stage	1200	
Southern Borefield	12/01	G	32.58	9.17	23.41	-12.05	10.00	Grundfos SP 30-10	650	
Southern Borefield	13/01 (09/74)	G	32.93	6.40	26.53	10.09	11.00	Grundfos SP 125-4-AA	3200	
Southern Borefield	01/87	H	36.72	12.65	24.07	0.07	5.00	Turbo Master 8HME	5000	
Southern Borefield	09/92	H	35.42	14.60	20.82	-0.7	5.00	Southern Cross 7 NAB 4C 94	700	
Southern Borefield	02/93	H	28.2	9.06	19.14	-15.08	15.00	Grundfos 5 NAH	1500	
Southern Borefield	14/01 (22/74)	H	36.53	11.08	25.45	7.61	10.00	Grundfos SP 60-8	1300	
Southern Borefield	10/92	J	35.68	14.74	20.94	-11.37	5.00	Turbo Master	1200	
Southern Borefield	01/93	J	40.91	15.50	25.41	-11.59	-17.50	Grundfos SP 60-8	1500	
Southern Borefield	21/94	J	37.65	13.10	24.55	4.38	10.00	Grundfos 30-6	600	
Southern Borefield	15/01 (12/74)	J	35.82	8.10	27.72	15.77	15.00	Grundfos SP 60-7	1250	
Southern Borefield	16/01 (16/74)	J	39.82	11.10	28.72	15.87	15.00	Grundfos SP 46-6	750	
Southern Borefield	16/77	K	30.64	3.10	27.54	?	12.50	Grundfos SP 46-5	729.6	Unequipped
Southern Borefield	13/84	K	32.42	4.90	27.52	7.42	20.00	Grundfos SP 46-4	2500	Unequipped
Southern Borefield	17/01 (19/74)	K	41.01	10.50	30.51	21.23	19.00	Grundfos SP 46-5	700	Unequipped
Southern Borefield	01/94	L	25.98	5.25	20.73	-2.32	20.00	Turbo Master SE 3-6	5000	Unequipped
Southern Borefield	15/94	L	34.80	4.60	30.20	4.074	15.00	Turbo Master SE 3-6	2800	Unequipped

Southern Borefield	18/94	L	45.48	15.45	30.03	18.19	15.00	Southern Cross NAHS	3000	
Southern Borefield	19/94	L	43.00	17.25	25.75	-16.04	7.50	Grundfos 30-6	550	
Southern Borefield	20/94	L	44.26	14.72	29.54	-13.67	12.50	Grundfos	550	
Southern Borefield	16/02	L	44.57	17.20	27.37	0.92	15.00	Grundfos	1000	

Appendix E Northern Borefield Information

Borefield	Bore Name	Sub-Area	Ground Level (mAHD)	Rest Level (mAHD)	Rest level (mbgl)	Long Term Drawdown (mAHD)	Long term draw down (mbgl)	Historical Pumped Water Level (mAHD)	historical pumped water level (mbgl)	Pump Type	Recommended Flow Rate (kL/day)	Current Flow Rate (L/s)	Notes
Northern Borefield	B01/10	D	23.00	12.20	10.80	-6	29	-1.44	24.44	Grundfos SP 60-8-B	691	8	
Northern Borefield	B02/10	C	16.75	7.88	8.87	-10.25	27	-9.55	26.3	Grundfos SP 95-5	1555	17.9	
Northern Borefield	B03/10	C	20.25	11.20	9.05	5.25	15	5.89	14.36	Grundfos SP 60-8-B	916	10.6	
Northern Borefield	B04/10	D	26.50	N/A	N/A		N/A	N/A	N/A	None	150	1.74	Unequipped
Northern Borefield	B17/10	D	26.25	12.39	13.862	0.25	26	11.77	14.48	Grundfos SP 30-7	259	3	Bore pump, headworks and pipe removed
Northern Borefield	B18/10	B	19.25	6.55	12.70	-18.75	38	-13.47	32.72	Grundfos SP 46-7	717	8.3	
Northern Borefield	B19/10	C	20.75	10.50	10.25	-0.25	21	3.22	17.53	Grundfos SP 95-5	2497	29	
Northern Borefield	B20/10	C	18.75	8.33	10.42	-6.25	25	-4.9	23.65	Grundfos SP 30-7	432	5	
Northern Borefield	B21/10	C	18.75	8.56	10.19	-10.25	29	-4.14	22.89	Grundfos SP 30-6	294	3.4	
Northern Borefield	B31/10	B	17.50	5.11	12.39	-12.5	30	N/A	N/A	None	130	1.5	Unequipped
Northern Borefield	B37/10	C	23.00	13.63	9.37	N/A	N/A	N/A	N/A	None	0	0	Unequipped
Northern Borefield	B38/10	C	21.75	10.68	11.08	-16.25	38	1.49	20.26	Grundfos SP 30-7	259	3.2	Bore pump, headworks and pipe removed
Northern Borefield	B39/10	D	22.25	11.62	10.63	-12	35	N/A	N/A	None	104	1.2	Unequipped
Northern Borefield	B40/10	D	24.75	13.74	11.01	3.25	19	N/A	N/A	None	199	2.3	Unequipped
Northern Borefield	B11/13	D	24.25	6.08	18.17	-18.25	43	-6.71	30.96	N/A	1037	12	DAFWA bore
Northern Borefield	B01/14	N/A	N/A	32.00	11.41	-10.75	35	N/A	N/A	None	199	2.3	Unequipped
Northern Borefield	B02/14	B	13.50	15.00	13.05	N/A	15-17	-0.53	14.03	N/A	864	10	
Northern Borefield	B03/14	C	19.75	18.00	12.49	-4.5	18	N/A	N/A	N/A	1987	23	

Peak Production Capacity	390	L/s
SBF (22ML/d)	255	L/s
NBF	135	L/s

Scheme Peak Factor	1.52

Mimimum Flow (L/s)	**0.50**	**1**	**1.5**
No of Growers at Min. Flow	28	49	86

A	B	C	D	E	F	G	H	I
Customer	Entitlement kL/yr	Peak Entitlement - excluding minimum flow rate	Minimum flow 0.5L/s	Peak factor	Minimum flow 1L/s	Peak factor	Minimum flow 1.5L/s	Peak factor
GW002	5,000	0.24	0.50	3.15	1.00	6.31	1.50	9.46
GW006	5,000	0.24	0.50	3.15	1.00	6.31	1.50	9.46
GW011	5,000	0.24	0.50	3.15	1.00	6.31	1.50	9.46
GW012	5,000	0.24	0.50	3.15	1.00	6.31	1.50	9.46
GW032	5,000	0.24	0.50	3.15	1.00	6.31	1.50	9.46
GW033	5,000	0.24	0.50	3.15	1.00	6.31	1.50	9.46
GW049	5,000	0.24	0.50	3.15	1.00	6.31	1.50	9.46
GW059	5,000	0.24	0.50	3.15	1.00	6.31	1.50	9.46
GW063	5,000	0.24	0.50	3.15	1.00	6.31	1.50	9.46
GW089	5,000	0.24	0.50	3.15	1.00	6.31	1.50	9.46
GW093	5,000	0.24	0.50	3.15	1.00	6.31	1.50	9.46
GW099	5,000	0.24	0.50	3.15	1.00	6.31	1.50	9.46
GW123	5,000	0.24	0.50	3.15	1.00	6.31	1.50	9.46
GW147	5,000	0.24	0.50	3.15	1.00	6.31	1.50	9.46
GW152	5,000	0.24	0.50	3.15	1.00	6.31	1.50	9.46
GW177	5,000	0.24	0.50	3.15	1.00	6.31	1.50	9.46
GW178	5,000	0.24	0.50	3.15	1.00	6.31	1.50	9.46
GW179	5,000	0.24	0.50	3.15	1.00	6.31	1.50	9.46
GW182	5,000	0.24	0.50	3.15	1.00	6.31	1.50	9.46
GW021	7,000	0.34	0.50	2.25	1.00	4.51	1.50	6.76
GW088	8,000	0.39	0.50	1.97	1.00	3.94	1.50	5.91
GW171	8,000	0.39	0.50	1.97	1.00	3.94	1.50	5.91
GW175	8,000	0.39	0.50	1.97	1.00	3.94	1.50	5.91
GW181	8,000	0.39	0.50	1.97	1.00	3.94	1.50	5.91
GW117	9,000	0.43	0.50	1.75	1.00	3.50	1.50	5.26
GW020	10,000	0.48	0.50	1.58	1.00	3.15	1.50	4.73
GW026	10,000	0.48	0.50	1.58	1.00	3.15	1.50	4.73
GW070	10,000	0.48	0.50	1.58	1.00	3.15	1.50	4.73
GW037	11,000	0.53	0.52	1.50	1.00	2.87	1.50	4.30
GW133	12,000	0.58	0.57	1.50	1.00	2.63	1.50	3.94
GW173	12,000	0.58	0.57	1.50	1.00	2.63	1.50	3.94
GW167	13,000	0.63	0.62	1.50	1.00	2.43	1.50	3.64
GW135	14,000	0.68	0.67	1.50	1.00	2.25	1.50	3.38
GW022	15,000	0.72	0.71	1.50	1.00	2.10	1.50	3.15
GW035	15,000	0.72	0.71	1.50	1.00	2.10	1.50	3.15
GW097	15,000	0.72	0.71	1.50	1.00	2.10	1.50	3.15
GW102	15,000	0.72	0.71	1.50	1.00	2.10	1.50	3.15
GW148	15,000	0.72	0.71	1.50	1.00	2.10	1.50	3.15
GW176	15,000	0.72	0.71	1.50	1.00	2.10	1.50	3.15
GW143	16,000	0.77	0.76	1.50	1.00	1.97	1.50	2.96
GW091	17,000	0.82	0.81	1.50	1.00	1.86	1.50	2.78
GW139	17,000	0.82	0.81	1.50	1.00	1.86	1.50	2.78
GW051	18,000	0.87	0.86	1.50	1.00	1.75	1.50	2.63
GW064	19,000	0.92	0.90	1.50	1.00	1.66	1.50	2.49
GW094	19,000	0.92	0.90	1.50	1.00	1.66	1.50	2.49
GW065	20,000	0.97	0.95	1.50	1.00	1.58	1.50	2.37
GW092	20,000	0.97	0.95	1.50	1.00	1.58	1.50	2.37
GW106	20,000	0.97	0.95	1.50	1.00	1.58	1.50	2.37
GW145	20,000	0.97	0.95	1.50	1.00	1.58	1.50	2.37
GW113	23,000	1.11	1.09	1.50	1.04	1.42	1.50	2.06
GW025	25,000	1.21	1.19	1.50	1.13	1.42	1.50	1.89
GW039	25,000	1.21	1.19	1.50	1.13	1.42	1.50	1.89
GW142	25,000	1.21	1.19	1.50	1.13	1.42	1.50	1.89
GW101	26,000	1.26	1.24	1.50	1.17	1.42	1.50	1.82
GW131	26,000	1.26	1.24	1.50	1.17	1.42	1.50	1.82
GW040	27,000	1.30	1.29	1.50	1.22	1.42	1.50	1.75
GW121	27,000	1.30	1.29	1.50	1.22	1.42	1.50	1.75
GW013	29,000	1.40	1.38	1.50	1.31	1.42	1.50	1.63
GW031	29,000	1.40	1.38	1.50	1.31	1.42	1.50	1.63
GW066	29,000	1.40	1.38	1.50	1.31	1.42	1.50	1.63
GW034	30,000	1.45	1.43	1.50	1.35	1.42	1.50	1.58

Water Corporation

MEMORANDUM

DATE: 20th January 2015

TO: Paul Vanderwal, Vijay Moorthy

CC: Peter Speers

FROM: Gouraw Undale

SUBJECT: **Carnarvon Southern Borefield Separation – High Level Assessment**

---

1. Background

The Carnarvon Southern Borefield contains 41 bores which supplies water to the Town and Irrigator's. The entire borefield pumps water into a single collector main and flow is separated at the Brickhouse pump station and dedicated mains goes to the Town and Irrigation supply. Layout of the Southern Borefield is shown in Figure 1.

A high level assessment was carried out to understand the number of bores required to be reserved for Town water supply if the Southern borefield is split into two to supply Town and Irrigators separately. High level cost estimation was carried out using Water Corporation Asset Cost Estimation (ACE) software.

2. Reference

The *Carnarvon Water Supply System – Capacity Review* (September 2012, #7962392) document was relied upon for Town demands, growths, Bore yields, etc. in this analysis.

3. Known issues in the Southern Borefield

The following issues were identified for the bores in the Capacity Review Report:

- Bore 20/02 contains a measurable amount of Arsenic. Currently, Bore 20/02 is manually operated and used only when all other bores are operating.
- Monitoring data shows that the salinity levels in Basins K & L are on an upward trend.
- There are six bores (03/82, 03/79, 01/07, 03/73, 11/84, 01/82) which are at risk of failure due to corrosion in the bore casing.
- Air entrapment caused by cascading water has resulted in a reduction of supply capacities from bores 15/94, 1/94, 18/94, 20/01, 19/01 and 11/01.

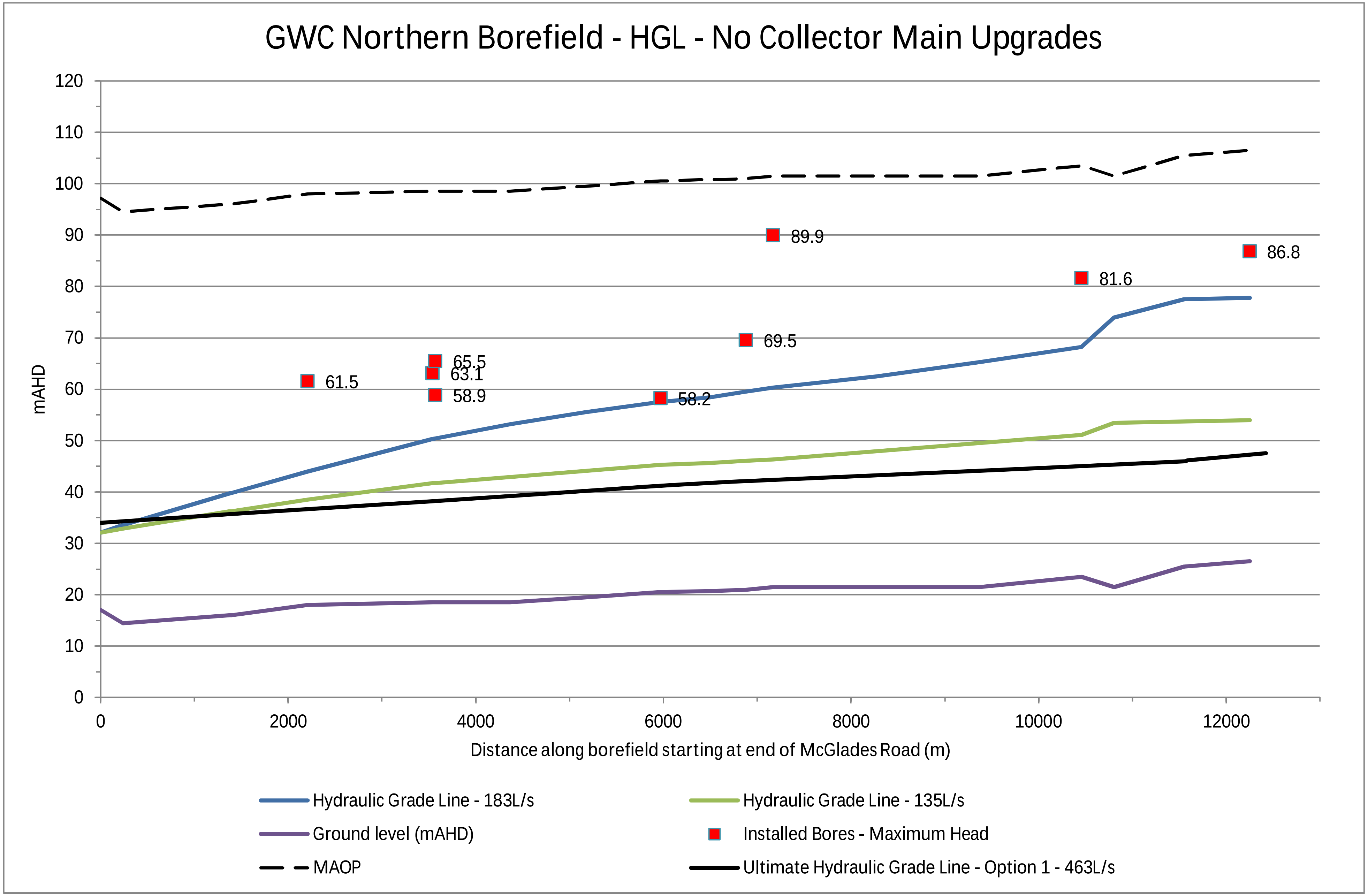
COST SUMMARY
FOR
THE CONSTRUCTION OF CARNARVON IRRIGATION SCHEME - POTABLE WATER SUPPLY MAIN

ITEM	DESCRIPTION	Rates	Rates with Location Factor	Rates with Escalation	Rates with Contingency
1.1	CONTRACTORS PRELIMS	$ 678,166.45	$ 851,017.58	$ 885,317.85	$ 1,062,381.42
2	SBF POTABLE WATER MAIN	$ 2,640,254.98	$ 3,319,126.54	$ 3,452,903.98	$ 4,143,484.77
3	SBF POTABLE WATER MAIN - BORE CONNECTIONS	$ 72,410.82	$ 84,943.77	$ 88,367.43	$ 106,040.92
	Total	$ 3,390,832.24	$ 4,255,087.89	$ 4,426,589.26	$ 5,311,907.11
5	NON-DIRECTS	$ 627,303.97	$ 787,191.26	$ 818,919.01	$ 982,702.82
5.1	PROJECT MANAGEMENT & CONTRACT MANAGEMENT	$ 339,083.22	$ 425,508.79	$ 442,658.93	$ 531,190.71
5.2	ENGINEERING	$ 203,449.93	$ 255,305.27	$ 265,595.36	$ 318,714.43
5.3	Other	$ 84,770.81	$ 106,377.20	$ 110,664.73	$ 132,797.68
	TOTAL INCLUDING CONSTRUCTION COSTS AND NON-DIRECTS	$ 4,018,136.21	$ 5,042,279.16	$ 5,245,508.27	$ 6,294,609.93

Name of Tenderer:

Signature of Tenderer: Date:

Appendix I – Northern Borefield Staging



G:\61\31537\Technical\Calculations\NBF Expansion Option 1 - Using FCVs only (280 L per s)\Current operating borefield + nbf expansion - Scenario 1.xlsx

Appendix J – GWC Maintenance Costs Summary

Account Codes	8688-1	8688-2	8688-3	8688-4	8681	8682	8687	8211-1	8211-2	8211-3	8211-4	8211-5	8212	8213	8480
	New Mains	**New Line Valves**	**New Spur Lines**	**New Meters & Scada**	**Gen Maint + CCW**	**Old A-C Pipeline**	**Small Plant & Equipment**	**NBF Gensets**	**NBF Bores & H/works**	**NBF Pipes & Valves**	**NBF Access Road**	**NBF Scada**	**NBF Monitoring**	**Borefield Electrification**	**Vehicle Maint**
1 Jul-31 Dec 2012 Actual	$86.00	$0.00	$166.00	$2,699.00	$17,538.00	$29,321.00	$0.00	$1,027.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
1 Jul-31 Dec 2012 Budget	$10,452.00	$870.00	$432.00	$3,480.00	$8,706.00	$6,966.00	$0.00	$4,350.00	$870.00	$870.00	$3,480.00	$870.00	$0.00	$0.00	$0.00
1 Jan-30 Jun 2013 Actual	$3,445.25	$690.00	$1,954.75	$993.00	$16,922.25	$4,238.50	$2,946.75	$1,738.50	$160.50	$636.00	$288.50	$0.00	$0.00	$0.00	$1,696.75
1 Jan-30 Jun 2013 Budget	$10,452.00	$870.00	$432.00	$3,480.00	$8,706.00	$6,966.00	$4,350.00	$870.00	$870.00	$3,480.00	$870.00	$870.00	$0.00	$0.00	$0.00
Total 2012-13 FY Actual	**$3,531.25**	**$690.00**	**$2,120.75**	**$3,692.00**	**$34,460.25**	**$33,559.50**	**$2,946.75**	**$2,765.50**	**$160.50**	**$636.00**	**$288.50**	**$0.00**	**$0.00**	**$0.00**	**$1,696.75**
Total 2012-13 FY Budget	**$20,904.00**	**$1,740.00**	**$864.00**	**$6,960.00**	**$17,412.00**	**$13,932.00**	**$4,350.00**	**$5,220.00**	**$1,740.00**	**$4,350.00**	**$4,350.00**	**$1,740.00**	**$0.00**	**$0.00**	**$0.00**
1 Jul-31 Dec 2013 Actual	$2,563.00	$491.00	$217.00	$557.00	$19,076.50	$0.00	$0.00	$14,686.00	$508.00	$232.00	$677.50	$0.00	$0.00	$0.00	$0.00
1 Jul-31 Dec 2013 Budget	$10,452.00	$870.00	$432.00	$3,480.00	$8,706.00	$6,966.00	$4,350.00	$4,350.00	$870.00	$870.00	$3,480.00	$870.00	$0.00	$0.00	$0.00
1 Jan-30 Jun 2014 Actual	$5,786.00	$2,268.00	$436.00	$139.00	$16,212.00	$0.00	$180.00	$16,314.00	$1,440.00	$3,377.00	$857.00	$0.00	$3,216.00	$0.00	$126.00
1 Jan-30 Jun 2014 Budget	$10,452.00	$870.00	$432.00	$3,480.00	$8,706.00	$6,966.00	$4,350.00	$870.00	$870.00	$3,480.00	$870.00	$870.00	$145.00	$0.00	$0.00
Total 2013-14 FY Actual	**$8,349.00**	**$2,759.00**	**$653.00**	**$696.00**	**$35,288.50**	**$0.00**	**$180.00**	**$31,000.00**	**$1,948.00**	**$3,609.00**	**$1,534.50**	**$0.00**	**$3,216.00**	**$0.00**	**$126.00**
Total 2013-14 FY Budget	**$20,904.00**	**$1,740.00**	**$864.00**	**$6,960.00**	**$17,412.00**	**$13,932.00**	**$8,700.00**	**$5,220.00**	**$1,740.00**	**$4,350.00**	**$4,350.00**	**$1,740.00**	**$145.00**	**$0.00**	**$0.00**
1 Jul-31 Dec 2014 Actual	$3,596.00	$928.00	$491.00	$1,384.00	$22,753.00	$0.00	$0.00	$18,625.00	$3,063.00	$1,775.00	$337.00	$0.00	$0.00	$0.00	$0.00
1 Jul-31 Dec 2014 Budget	$10,452.00	$870.00	$432.00	$3,480.00	$8,706.00	$6,966.00	$4,350.00	$4,350.00	$870.00	$870.00	$3,480.00	$870.00	$0.00	$0.00	$0.00
1 Jan-30 June 2015 Actual	$0.00	$0.00	$0.00	$0.00	$1,846.00	$0.00	$0.00	$463.00	$0.00	$0.00	$0.00	$0.00	$495.00	$0.00	$0.00
1 Jan-30 June 2015 Budget	$10,452.00	$870.00	$432.00	$3,480.00	$8,706.00	$6,966.00	$4,350.00	$870.00	$870.00	$3,480.00	$870.00	$870.00	$145.00	$0.00	$0.00
Total 2014-15 FY Actual	**$3,596.00**	**$928.00**	**$491.00**	**$1,384.00**	**$24,599.00**	**$0.00**	**$0.00**	**$19,088.00**	**$3,063.00**	**$1,775.00**	**$337.00**	**$0.00**	**$495.00**	**$0.00**	**$0.00**
Total 2014-15 FY Budget	**$20,904.00**	**$1,740.00**	**$864.00**	**$6,960.00**	**$17,412.00**	**$13,932.00**	**$8,700.00**	**$5,220.00**	**$1,740.00**	**$4,350.00**	**$4,350.00**	**$1,740.00**	**$145.00**	**$0.00**	**$0.00**
Average Budget	$20,904.00	$1,740.00	$864.00	$6,960.00	$17,412.00	$13,932.00	$8,700.00	$5,220.00	$1,740.00	$4,350.00	$4,350.00	$1,740.00	$145.00	$0.00	$0.00
Average Actual	$5,158.75	$1,459.00	$1,088.25	$1,924.00	$31,449.25	$11,186.50	$1,042.25	$17,617.83	$1,723.83	$2,006.67	$720.00	$0.00	$1,237.00	$0.00	$607.58
Max Actual	$8,349.00	$2,759.00	$2,120.75	$3,692.00	$35,288.50	$33,559.50	$2,946.75	$31,000.00	$3,063.00	$3,609.00	$1,534.50	$0.00	$3,216.00	$0.00	$1,696.75
Unit	km	No	Item	per Grower	Item	Item	Item	Item	Bores	km	km	Bores	Bores	Item	Item
Quantity	32.1	58.0	1.0	181.0	1.0	0.0	1.0	0.0	9.0	12.3	12.3	9.0	9.0	1.0	1.0
Maintenance Rate ($ per unit)	**$259.71**	**$47.57**	**$2,120.75**	**$20.40**	**$35,288.50**	**$0.00**	**$2,946.75**	**$0.00**	**$340.33**	**$294.61**	**$125.27**	**$193.33**	**$357.33**	**$0.00**	**$1,696.75**

Key

Green	**Irrigation Scheme**
Orange	**Borefield**
Blue	**Scheme Wide**
Yellow	**Not to be included**

GHD

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Rev No.	Author	Reviewer		Approved for Issue		
		Name	Signature	Name	Signature	Date
1	J. Regan/ B. Klemm	S. Farquharson	S. Farquharson	S. Farquharson	S. Farquharson	13/2/2015
2	J. Regan/ B. Klemm	S. Farquharson	S. Farquharson	S. Farquharson	S. Farquharson	18/02/2015
3	J. Regan/ B. Klemm	S. Farquharson	[signature]	S. Farquharson	[signature]	11/03/15

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