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Department of the Environment, Water, Heritage and the Arts

Hotspots desktop analysis and design: Jemalong Irrigation

Final report

March 2009

INFRASTRUCTURE | MINING & INDUSTRY | DEFENCE | PROPERTY & BUILDINGS | ENVIRONMENT

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Executive Summary

The Irrigation Infrastructure Hotspots Assessment Project (Hotspots project) is a key enabling component of the $5.8 billion Sustainable Rural Water Use and Infrastructure element of the Australian Government's Water for the Future program. To conduct a Hotspots Desktop Analysis and Hotspots Assessment Design for Jemalong Irrigation ('the Project'), the Department of the Environment, Water, Heritage and the Arts (DEWHA), commissioned GHD Pty Ltd, and their sole sub consultant, Charles Sturt University's International Centre of WATER for Food Security (IC WATER), to assist with this work.

Using the data extracted from previous seepage reports and available databases, this report provides estimates of spatial water losses in the off-farm irrigation water supply systems of Jemalong Irrigation. In addition to developing the system and sub-system water balances, in line with the Technical Manual for Assessing Hotspots in Channel and Piped Irrigation Systems, a data gap analysis is also presented in this report. This data gap analysis provides the basis for a design of an on-ground Hotspots Assessment to improve the water loss information needed to quantify the most significant losses in the off-farm irrigation water supply systems. The final scope of this Hotspots Assessment will be determined in consultation with the Department.

Jemalong Irrigation, the only irrigation scheme on the Lachlan River, is located between Forbes and Condobolin in central-western New South Wales (NSW). The irrigation scheme has two divisions and three main supply channels. Division 1 has the Cadow and Warroo main supply channels, whereas Jemalong Main serves Division 2. Using the annual data of diversions and deliveries during July 2000-June 2008 for Jemalong Irrigation, a system level water balance indicates that there were around 30 percent water losses in the off-farm irrigation supply systems. A sub-system level water balance developed for July 2005-June 2006 suggests that Division 1 has conveyance losses of around 54%, whereas Division 2 has no significant water losses.

Groundwater level maps indicate that water losses are mostly occurring in the Warroo main supply channel. Anecdotal evidence also suggests the same, and indicates that there is up to 3,000 ML/yr of seepage losses in the Warroo main supply channel (depending on allocations and subsequent water diversions to the scheme). Several studies in the past have been undertaken to identify these seepage locations and to quantify the seepage loses along the Warroo main supply channel (Smith and Rose, 1993; van der Lely, 1993; TES, 1995; DLWC, 1995; LWC, 1998). The results indicated that the channel seepage loses were approximately 1,575 ML per year. Ranking of the results for different channel seepage sections showed that 50% of total channel seepage may occur over 17% of the total channel length.

This desktop analysis provides the estimates of channel seepage losses but also identifies the locations of such losses. However, to further refine the estimates of the water that can be saved by future investment in irrigation infrastructure, the accuracy of the Dethridge Wheels installed in the Jemalong Irrigation scheme needs to be reviewed. The channel dimension data required to estimate the water used in the filling

and draining of channels is lacking, and is also required for determining the contribution of rainfall and evaporation for properly developing the strategic water balance estimates. In addition, electrical resistivity surveys may assist in further defining leakage areas, and in prioritising areas for treatment.

1. Introduction

1.1 The project

The "Hotspots Desktop Analysis and Hotspots Assessment Design for Jemalong Irrigation" was carried out to identify and quantify the location, nature and extent of water losses in the Jemalong off-farm irrigation water supply systems, identify critical information gaps and design an assessment program to fill these gaps. Figure 1 presents a location map of the Jemalong irrigation scheme. The intended outcomes of this desktop analysis are the development of system and sub-system water balances in line with the Technical Manual for Assessing Hotspots in Channel and Piped Irrigation Systems. For future Departmental use, the consultants are also required to prepare a GIS-based database, using all the information gathered and generated while carrying out this project**.**

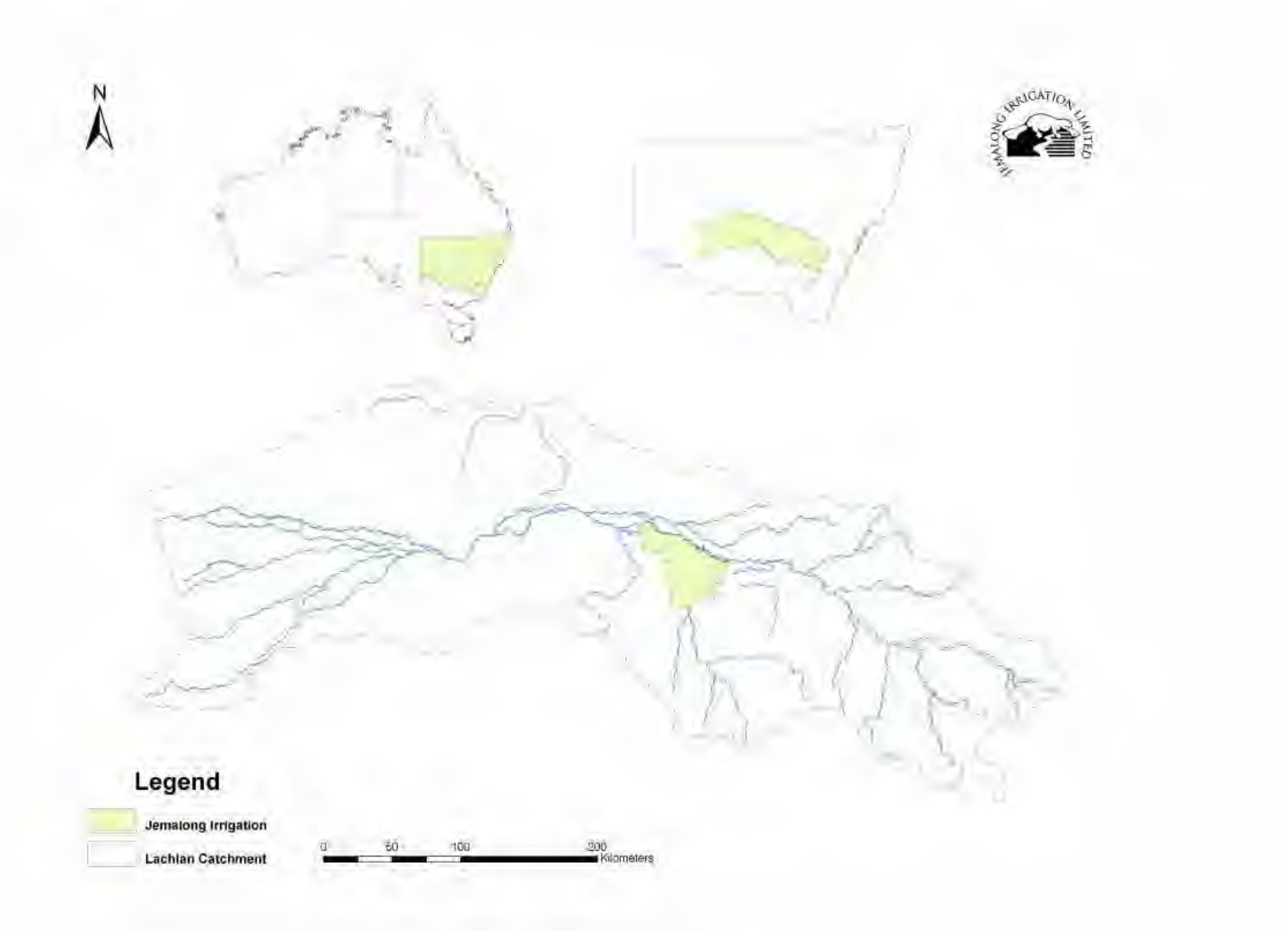

Figure 1 Location map of Jemalong Irrigation –formerly known as Jemalong and Wyldes Plains Irrigation District

On January 15, 2009, the project team, along with the representatives from DEWHA, visited the office of Jemalong Irrigation Limited (JIL), which is located 24 km west of Forbes along South Condobolin Road near the Jemalong Weir on the Lachlan River. The objectives of the visit were: (i) to meet with JIL staff to introduce the project and the project team, (ii) to familiarise the project staff with the area, crops and irrigation infrastructure, and (iii) to obtain the information and datasets required to undertake the Hotspots analysis and design.

JIL provided several reports that contain information (previous water loss testing, existing data, secondary sources or anecdotal evidence) on Hotspots (water loss) in the off-farm irrigation water supply systems. The datasets (softcopies or hardcopies) contain information on: (i) water diversions at channel offtakes, (ii) water deliveries at farm outlets, and (iii) cropped data (cropped area, sowing data, harvesting date). At present, the JIL database only contains such datasets for the last couple of years, but it can be updated from the written records for the last several years.

The Lachlan Catchment Management Authority (LCMA) has recently developed a GIS-based database to help support the natural resource management in the Lachlan Catchment. The database contains information relating to geology, soil, water courses, land use, rainfall, evapotranspiration, digital elevation map, and depth to watertable. The GIS-based rainfall and evapotranspiration datasets are of particular interest for the Hotspots analysis of the Jemalong Irrigation scheme.

Using the data extracted from the previous seepage reports and available databases, both from JIL and LCMA, this report provides estimates of spatial water losses in the off-farm irrigation water supply systems of the Jemalong Irrigation scheme. A data gap analysis is also presented in this report. This data gap analysis provides the basis for a design of an on-ground Hotspots Assessment to improve the water loss information needed to quantify the most significant losses in the off-farm irrigation water supply systems. The final scope of this Hotspots Assessment will be determined in consultation with DEWHA.

1.2 Jemalong irrigation scheme

The Jemalong Irrigation Scheme is the only irrigation scheme on the Lachlan River and is located between Forbes and Condobolin in central-western New South Wales (NSW), Australia. This irrigation scheme has two divisions: (i) Division 1, and (ii) Division 2. There are three main supply channels in these two management divisions. Division 1 has the Cadow and Warroo main supply channels, whereas Jemalong Main serves Division 2. The construction of this irrigation scheme started in 1934 and was completed in 1941, as part of the expansion of irrigated agriculture in the Murray-Darling Basin. Its boundaries are the Lachlan River to the north, Lake Cowal to the south and narrow hilly ranges to the east and west. The region, which is widely recognised as the lucerne growing capital of Australia, supports a diverse range of high yielding agricultural enterprises across both cropping and livestock sectors. Other than lucerne, this region also supports pasture (summer and winter), oilseeds, summer grain legumes and cereals (summer and winter).

Jemalong Irrigation Limited (JIL), a privately owned company with 119 shareholders, is responsible for managing the scheme's surface water supplies. The scheme is gravity fed and the canals are of earthen construction (Figure 2). JIL diverts surface water from the Lachlan River through a 296 km network of supply channels for delivery to 158 landholdings across an area spanning over 96,000 hectares (including irrigated and dryland farming). Although the Culturable Command Area (CCA) in the Jemalong Irrigation scheme is around 41,500 ha, the average annual area of irrigated land is around 21,730 ha. Figure 3 illustrates the scheme's surface channel network. This figure also indicates the locations of drainage escapes in the Jemalong Irrigation scheme. The total length of these escape channels is around 10 km.

Figure 2 Main Jemalong supply channel (earthen channel) for the Jemalong Irrigation scheme.

The main Jemalong supply is delivered through an unlined earthern channel.

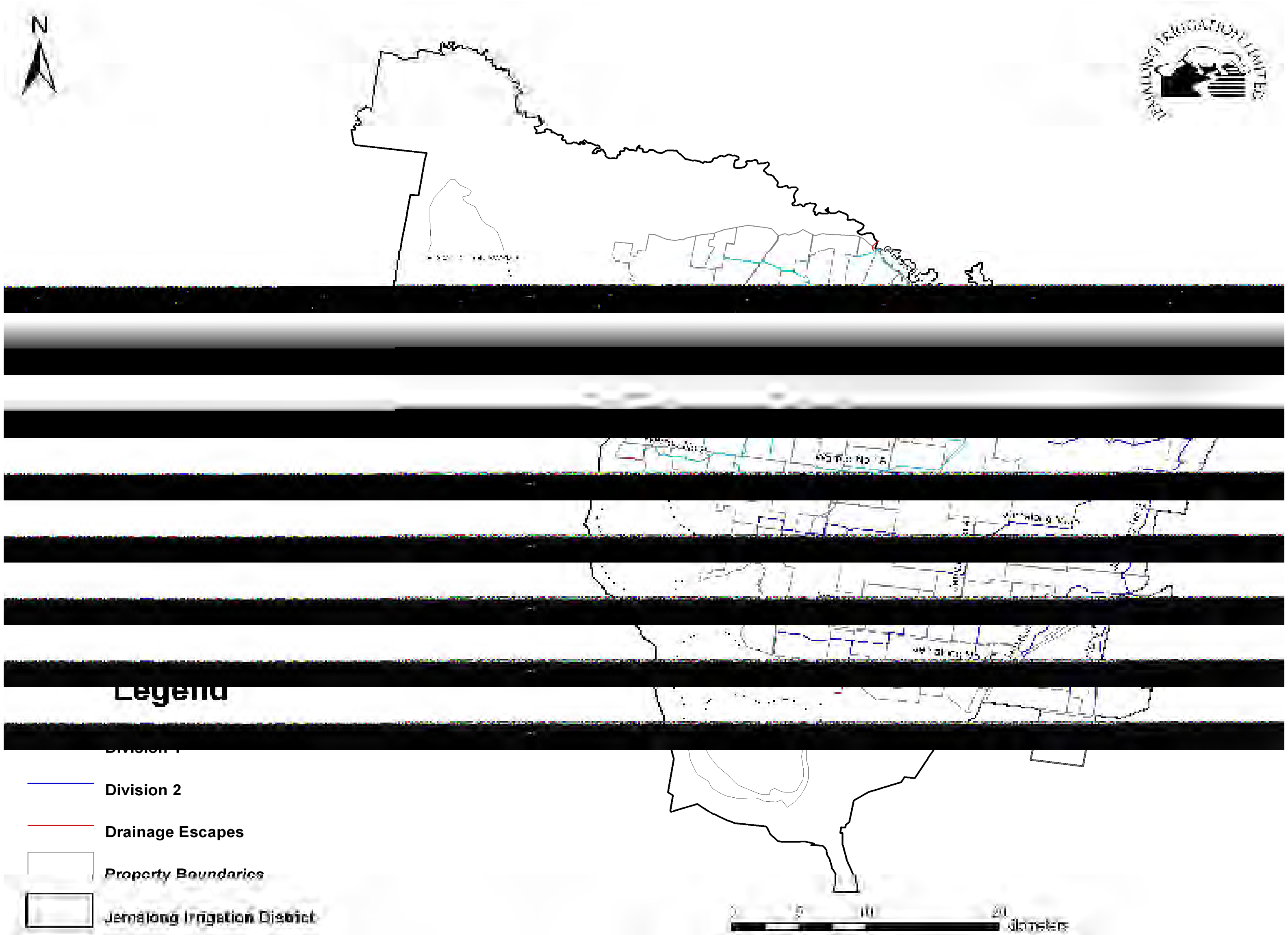

Figure 3 Supply channels and drainage escapes in the Jemalong Irrigation scheme

1.3 The physical environment

Forbes and Condobolin are close to the eastern and western boundaries respectively of the Jemalong Irrigation scheme. The meteorological data observed at these two sites shows that the long-term average annual rainfall decreases from 500 mm in the east to about 400 mm in the west. Average rainfall is distributed fairly evenly throughout the year, with January and October being the wettest months. The district's long-term average annual rainfall is around 432 mm, whereas the long-term average daily potential evapotranspiration changes from 1.3 mm (winter) to 6.6 mm (summer). The district's average annual potential evapotranspiration is almost three times higher than the average annual rainfall.

The periodic flooding, from the Lachlan River, of large areas in the Jemalong Plain has resulted in the formation of a floodway system within the Jemalong Irrigation scheme. The floodplain is characterised by well-defined and extensive prior stream formations. Some of these areas, particularly those within the Waroo Prior Stream Formation, have been extensively used for irrigation because of suitable soil types and locations. In the event of flooding, the surface drains naturally from east to west through a floodway system and discharges into the Lake Cowal and Manna/Bogandillon Creek Complex.

The soils in the irrigated alluvial floodplain include light textured brown soils, red-brown earths (RBE), transitional red-brown earths (TRBE), and non-self-mulching and self-mulching clays soils (Figure 4). The RBE and TRBE form a major group in the district and vary from sandy loams to clay loams (DLWC, 1995). A significant aspect is the dominance of sandy loam underlying the Warroo channel system.

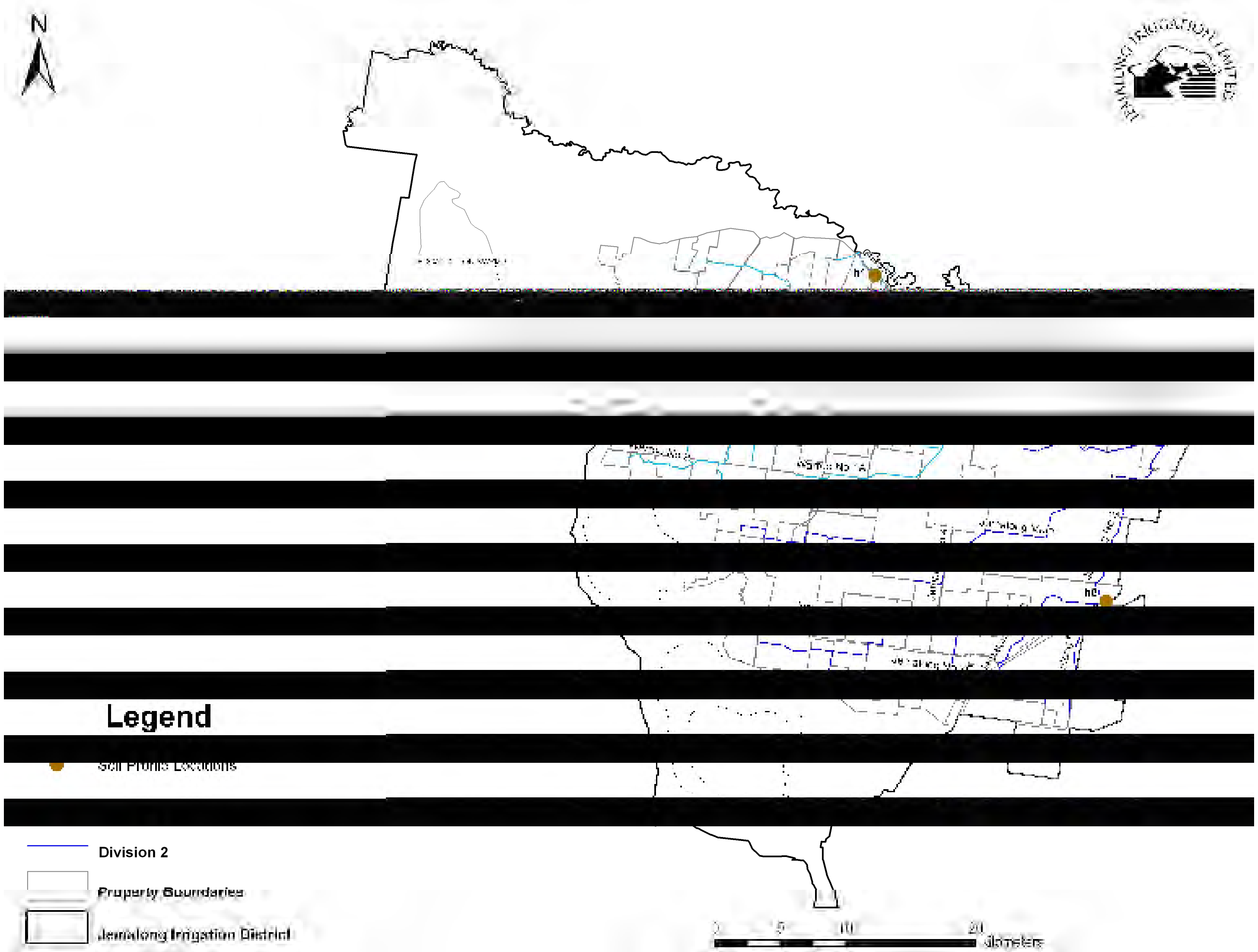

Figure 4 Spatial coverage of different soil types in the Jemalong Irrigation scheme

The Jemalong Irrigation scheme is located on a fluviatile plain, bounded by the Jemalong Range to the east, and the Manna Range to the west (DLWC, 1995). The main escape route for the groundwater is through a limited outlet in this Manna Range (Anderson et al., 1993; Lampayan, 2001). The hydrogeology underlying the district is comprised of two distinct groups of unconsolidated sediments, namely the Lachlan Formation and the Cowra Formation (Williamson, 1986). The Lachlan Formation, which is the older and deeper of the two, consists of clays, silts, sands and gravels in varying admixtures. The Cowra Formation, which overlays the Lachlan Formation, consists of moderately well sorted sand and gravel with inter-bedded layers of clays. Groundwater occurs within these unconsolidated sediments, and the Cowra Formations acts largely as an unconfined watertable aquifer, while confined conditions are likely to exist in the deeper Lachlan Formation. This groundwater resource has helped fulfil the district's irrigation as well as stock and domestic requirements during the recent drought years (Figure 5). According to the bulk entitlement for groundwater licenses at 29 January 2009, almost 30% of the entitlement is flagged for irrigation (Table 1)

Table 1 Bulk entitlement for groundwater licences in the Jemalong Irrigation scheme (as of 29 January 2009).

Purpose	Bulk entitlement (ML)	Purpose	Bulk entitlement (ML)
Domestic	1	Irrigation stock	728
Domestic horticulture	1	Mining	3650
Domestic irrigation stock	6370	Monitoring bore	0
Domestic stock	188	Recreation (groundwater)	0
Irrigation	6584	Stock	26
Irrigation domestic	1	Stock farming	7
Industrial	2296	Test bore	0

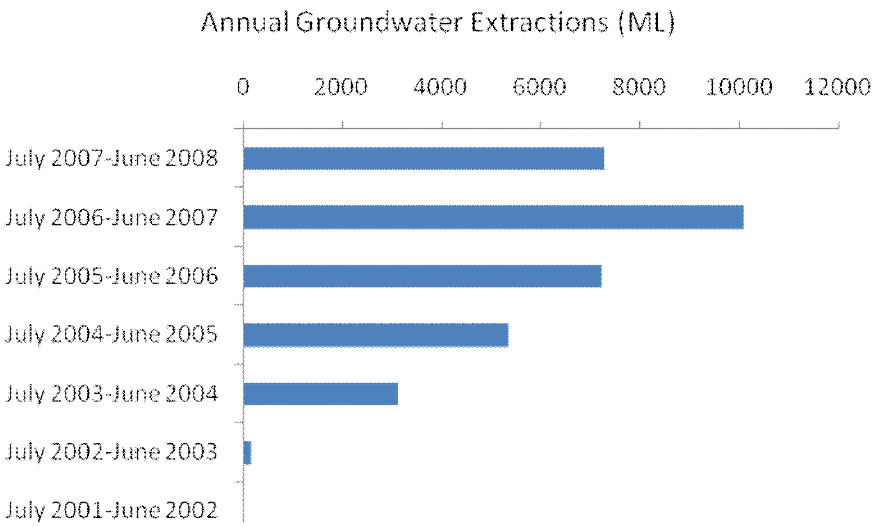

Figure 5 Annual groundwater extractions in the Jemalong Irrigation scheme.

1.4 Jemalong irrigation scheme operations

JIL holds licensed entitlements of 100,312 megalitres (ML), which includes 200 ML of high security, 1,756 ML for stock and domestic, 80,445 ML of general security, and 17,911 ML of the conveyance loss account. With the exception of the 2005-06 irrigation season, the general security allocation within the district has been zero as a result of the prevailing drought conditions. During July 2005-June 2006, general security allocation was around 18% (i.e., 14,119 ML), and the resulting conveyance loss account was 13,667 ML.

The main Jemalong canal joins the Lachlan River at the Jemalong Weir. The construction of this weir commenced in 1936 was completed and finished in 1940. The main Jemalong canal offtake (gated weir) has an acoustic ultrasonic velocity meter for measuring daily diversions (Figure 6). The mean accuracy of this meter is -3%, with -3.48 GL/year of volumetric mean error (MDBC, 2006). This indicates that that the meter underestimates the actual flows.

Figure 6 Acoustic ultrasound velocity meter installed at the main Jemalong canal offtake (gated weir).

In 2001-2002, JIL installed, calibrated and started using its own permanent gauging station: Acoustic Flowmeter For Remote Areas (AFFRA), as shown in Figure 7. Since then, this gauging station is also being used by State Water as an official measuring point of water taken by JIL. The AFFRA gauging station uses the latest available acoustic Doppler technology to continuously measure the velocity of the flow. The velocity readings are converted to flow rate (in ML/day), and these flow rates are recorded and logged at 15 minute intervals. Theiss Services Pty Ltd in Tatura downloads the data via telephone lines, and distributes it to State Water and JIL on a routine basis. Depending upon the water supplies, this AFFRA is calibrated a minimum of twice per year.

Figure 7 Acoustic Flowmeter For Remote Areas (AFFRA) gauging station for measuring diversions from the Lachlan River to the Jemalong Irrigation scheme.

To estimate the deliveries at the farm gate, Dethridge wheels were installed in the Jemalong Irrigation scheme. However, several of these wheels have recently been replaced with the locally manufactured High Volume Outlets (HVO's) shown in Figure 8. These gates can easily be linked with a Supervisory Control And Data Acquisition (SCADA) system to improve the irrigation system management and operation. Figure 9 shows the locations of Dethridge Wheels and HVO's installed in the district. The Dethridge wheels which were imposing flow limitations have been replaced with HVO's. It is reported that two high volume outlets are capable of irrigating 100 hectares per day.

Currently, there are 159 and 147 Dethridge Wheels in Division 1 and Division 2 respectively; while there are 27 and 18 HVO's in Division 1 and Division 2 respectively.

Figure 8 Locally manufactured High Volume Outlets (HVOs) installed in the Jemalong Irrigation scheme.

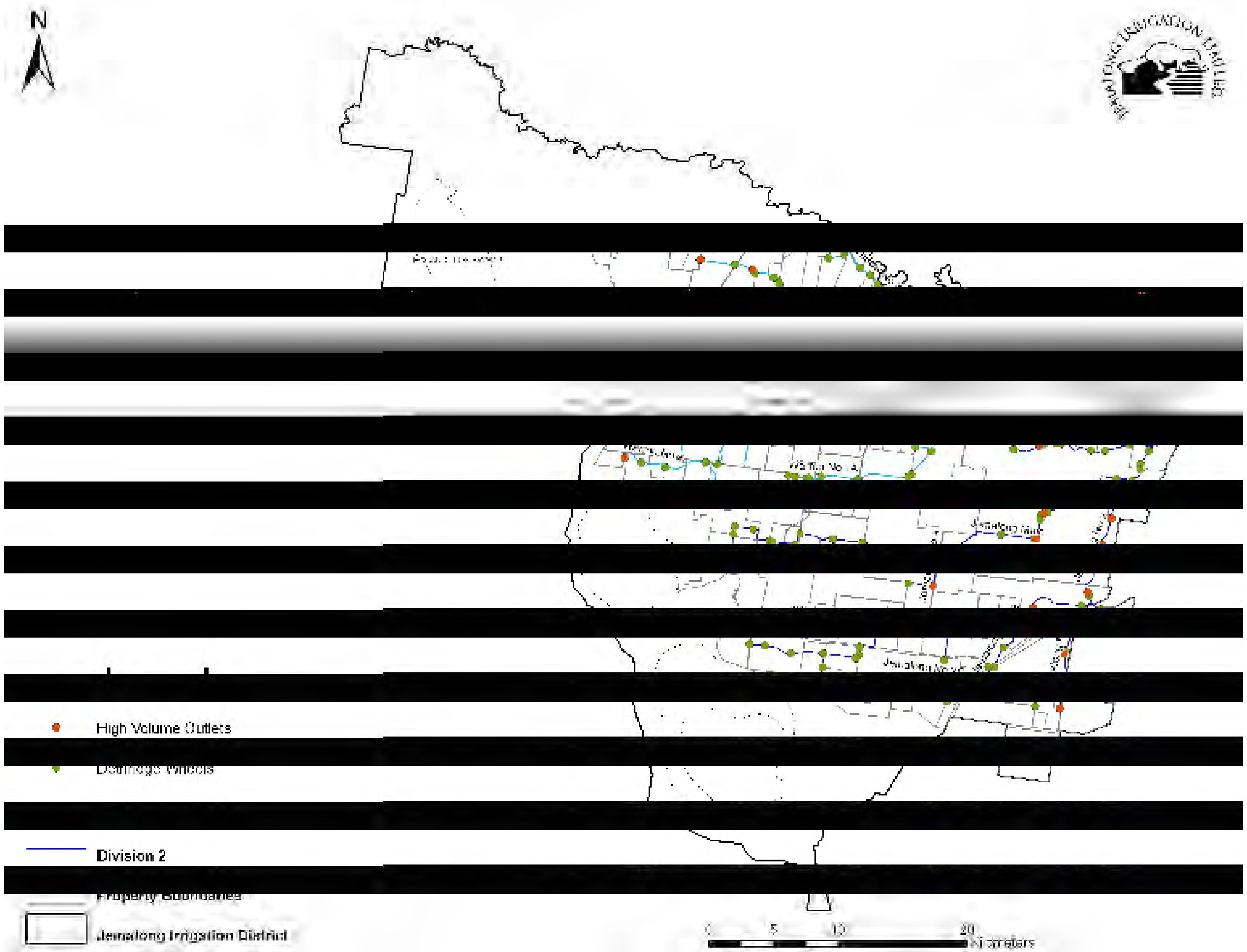

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Figure 9 Locations of Dethridge Wheels and High Volume Outlets installed in the Jemalong Irrigation scheme

2. Desktop Analysis

In line with the Technical Manual for Assessing Hotspots in Channel and Piped Irrigation Systems, water balances at the system and sub-system levels were developed to identify and quantify the location, nature and extent of water losses (evaporation, leakage, seepage and operational) in the off-farm irrigation water supply systems.

2.1 Data availability

To develop a strategic water balance for the Jemalong Irrigation scheme, a specific set of datasets are required. A brief description (availability, quality) of the datasets, provided by JIL to undertake the Hotspots analysis and design, is provided below:

Data Required	Data availability/quality
Entitlements and allocations	July 2001 to June 2008
Total length and width of supply channels	Width of supply channels not available
Total length and width of open drains	Width of open drains not available
Maps of the overall supply and drainage system network	GIS-based dataset of the overall supply and drainage system network is available. Additionally, this database includes properties, paddocks, outlets, roads and soil layers.
Water supplies	
River diversions	July 2001 to June 2008
Groundwater extractions	July 1993 to June 2008
Authorized consumptions	
Water deliveries (metered)	July 2001 to June 2008 with missing data
Water deliveries (unmetered)	No record found
System losses	
Channel filling	No record found
Evaporation from channels	No record found
Channel seepage/leakage	Several reports are available, but they are only for one main channel
Operational	No record found
Drainage escapes	No drainage escapes has been reported since July 2001 in the environmental reports of the Jemalong Irrigation
Unexplained	July 2001 to June 2008
Climate	In the surrounding areas of the Jemalong

Data Required	Data availability/quality
	Irrigationscheme , the following weather stations of the Bureau of Meteorology exist: (i) Bogan Gate Post Office, (ii) Burcher Post Office, (iii) Caragabal Post Office, (iv) Condobolin (Borambil Park), (v) Condobolin Agriculture Research Station, (vi) Condobolin Retirement Village, (viii) Condobolin Soil Conservation, (ix) Cookeys Plains, (x) Marsden (Merungle), (xi) Warroo (Geeron) and (xii) Forbes (Camp Street)
Evaporation	Historical data from SILO database
Rainfall	Historical data from SILO database
Drainage	
Irrigation and rainfall runoff to drains	N/A
Evaporation from drains	N/A
Rainfall on drains	N/A
Shallow groundwater	
Piezometric data— watertable behaviour	GIS-based database since 2000 (four time a year)
Groundwater pumping	No record found
Recharge	No record found
Lateral outflow /inflow	No record found
Capillary rise	No record found
Leakage between aquifers	No record found
Aquifer water quality	No record found
Deep groundwater	
Deep leakage	No record found
Lateral outflow	No record found
Deep pumping	July 1993 to June 2008
Crop water demand and use (desirable)	July 2001 to June 2008 with missing data

2.2 System level water balance

A system level water balance of the Jemalong Irrigation scheme was developed to quantify the extent of water losses in the off-farm irrigation water supply systems. For this purpose, the data of annual diversions, deliveries and conveyance losses from July 2001 to June 2008 was extracted from JIL's Annual Environmental Reports (JIL 2002; JIL 2003; JIL 2004; JIL 2005; JIL 2006; JIL 2007; JIL 2008). Table 2 presents the annual diversions, deliveries and conveyance losses during July 2001-June 2008 for the scheme, whereas Table 3 presents the monthly breakdown of the annual diversions.

Table 4 presents crop water use against the annual diversions in the Jemalong Irrigation scheme. Even during the recent drought when around 20% water allocations were made available, the farmers reverted to their historical preference of primarily growing lucerne.

On average during July 2001-June 2008, there was 9,141 ML (30%) of water losses in the off-farm irrigation supply systems; which are approximately equivalent to the average conveyance loss account. During July 2001-June 2002, when 85,191 ML of diversions were made from the Lachlan River, the conveyance losses were only 21,403 ML (25%). On the other hand, when there are low diversions, the conveyance losses are a higher proportion of flow (e.g., for total diversions of 3,470 ML during July 2004-June 2005, the conveyance losses were 65%). However, when the channels were run in full capacity, like during the low flow year of July 2006-June 2007 when the total diversions were 7,180 ML, the conveyance losses reduced to 39%.

Generally, JIL regards conveyance losses as any water diverted for which no invoice is raised; but these losses may take the following forms:

» Channels filling – occurring when water is used to fill and drain channels.

» Evaporation – occurring from the water surface area in channels.

» Channel seepage – occurring through the beds (bottom and sides) of the irrigation channels.

» Leakage – occurring through cracks and fissures in channel banks and channel structures.

» Metering inaccuracy – occurring when water is: (i) diverted from the Lachlan River, and (ii) delivered at the farm gate, using inadequate (e.g., Dethridge wheels) and/or inaccurate metres (e.g., using meter for flows that are outside its calibration limit).

» Unrecorded usage – occurring when water supplied to JIL's members for no charge to: (i) carry out weedicide application, and (ii) use it for stock and domestic purposes, etc.

» Drainage escapes – occurring when water leaves the channel system of the Jemalong Irrigation scheme. No drainage escapes has been reported since July 2001 in JIL's environmental reports.

Table 2 Annual diversions, deliveries and conveyance losses for the Jemalong Irrigation scheme.

Year	Diversions (ML)	Deliveries (ML)	Conveyance losses	
			(ML)	(%)
July 2001-June 2002	85,191	63,788	21,403	25
July 2002-June 2003	31,687	23,498	8,189	26
July 2003-June 2004	3,385	1,259	2,126	63
July 2004-June 2005	3,470	1,212	2,258	65
July 2005-June 2006	**27,786**	**15,055**	**12,731**	**46**
July 2005-June 2006	**22,627**[1]	**15,055**	**7,572**	**33**
July 2006-June 2007	7,180	4,399	2,781	39
July 2007-June 2008	2,183	1,175	1,008	46

[1] *Diversion data from manual water height "dip" measurements.*

Table 3 Monthly diversions (ML) for the Jemalong Irrigation scheme.

Year	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun
						(ML)						
Jul 01-Jun 02			7,704	9,950	9,711	14,910	17,467	5,455	7,747	6,986	5,261	
Jul 02-Jun 03		7,260	5,699	6,846	3,587	4,116			4,179			
Jul 03-Jun 04				3,102				283				
Jul 04-Jun 05			3,470									
Jul 05-Jun 06					**996**	**3,938**	**4,544**	**2,715**	**5,251**	**5,781**	**4,561**	
Jul 06-Jun 07			3,880	1,860	454	224		35		48	679	
Jul 07-Jun 08						100				2,083		

For Tables 2 and 3, apart from that indicated in Table 2 for 2005/06, diversion and delivery volumes were obtained from Annual Environmental Reports, in which reported diversions are an average of 3 measurement methods – AFFRA, State Water meter, and manual water height "dip" measurements. The 2005/06 data is highlighted as this is the year selected for sub-system water balance assessment.

Table 4 Crop water use (ML) for the Jemalong Irrigation scheme.

Crops	July 2001-June 2002	July 2002-June 2003	July 2003-June 2004	July 2004-June 2005	July 2005-June 2006	July 2006-June 2007	July 2007-June 2008
Lucerne	21,610	10,322	267		8,197	1,405	446
Maize	14,285				101		
Pasture	6,834	1,454				213	44
Rice	5,907						
Cereals (Wheat/Barley)	5,633	7,740	162		2,942	2,027	375
Stock & Domestic	4,229	2,578	818	1,212	1,759	423	172
Canola	2,139	870			903	217	138
Other	1,345	218	6		1,108	114	
Sorghum/Millet	1,055	316	6				
Soybeans	751				45		

2.3 Sub-system level water balance

The Jemalong Irrigation scheme has two management divisions, and there are three main supply channels in these two management divisions. A sub-system level water balance of Division 1 and Division 2 was developed to identify and quantify water losses in the off-farm irrigation water supply systems. For each division, the data of monthly diversions and deliveries for all the main and secondary channels during July 2005-June 2006 was used. During the last couple of years, diversions were very low due to recent drought. Appendix 1 presents the spatial maps of rainfall and potential evapotranspiration observed during the July 2005-June 2006 irrigation season in the Jemalong Irrigation.

During the July 2005 - June 2006 irrigation season, with around 18% of general security allocation, 15,055 ML of deliveries were made at the farm gate against the 27,786 ML of diversions. Figure 10 shows the spatial distribution of different crops irrigated during July 2005-June 2006 irrigation season. Figure 11 shows the location of the paddocks where surface supplies were delivered during different months of the July 2005-June 2006 irrigation season. In November 2005, maximum conveyance losses occurred; as deliveries were made to the lowest number of paddocks and those paddocks were located at the downstream of the both divisions. During April and May 2006, when deliveries were made to the maximum number of spatially well distributed paddocks, the lowest percentage of conveyance losses was observed.

While taking into account the diversions and deliveries separately to Division 1 and Division 2, it is estimated that Division 1 has conveyance loss of around 54%, whereas Division 2 has no significant water losses (Figure 12). Then, groundwater table maps were developed for both the divisions to identify the spatial zones where water losses are likely happening in the off-farm irrigation water supply systems.

Figure 13 and Figure 14 present groundwater table maps for January 2002 (in a year with 21,403 ML of conveyance losses) and for January 2006 (in a year with 12,731 ML of conveyance losses).

The groundwater level maps show that in 2006, a year of good water availability, a significant area of shallow groundwater levels occurred within 3 metres of ground surface in the area of the Warroo channel. No such groundwater "mound" occurred in 2006 – a year of low allocation, lower water losses and following several years of drought. This indicates that the mound is driven by water losses, and that the main water losses feeding into shallow groundwater systems are in the Warroo main supply channel of Division 1. This is further supported by the soils map in Figure 4 where it can be seen that the Warroo channel has been constructed mainly on sandy loam soils, whereas much of Division 2 is located on less permeable red clay, red clay loam, red loam and grey clay.

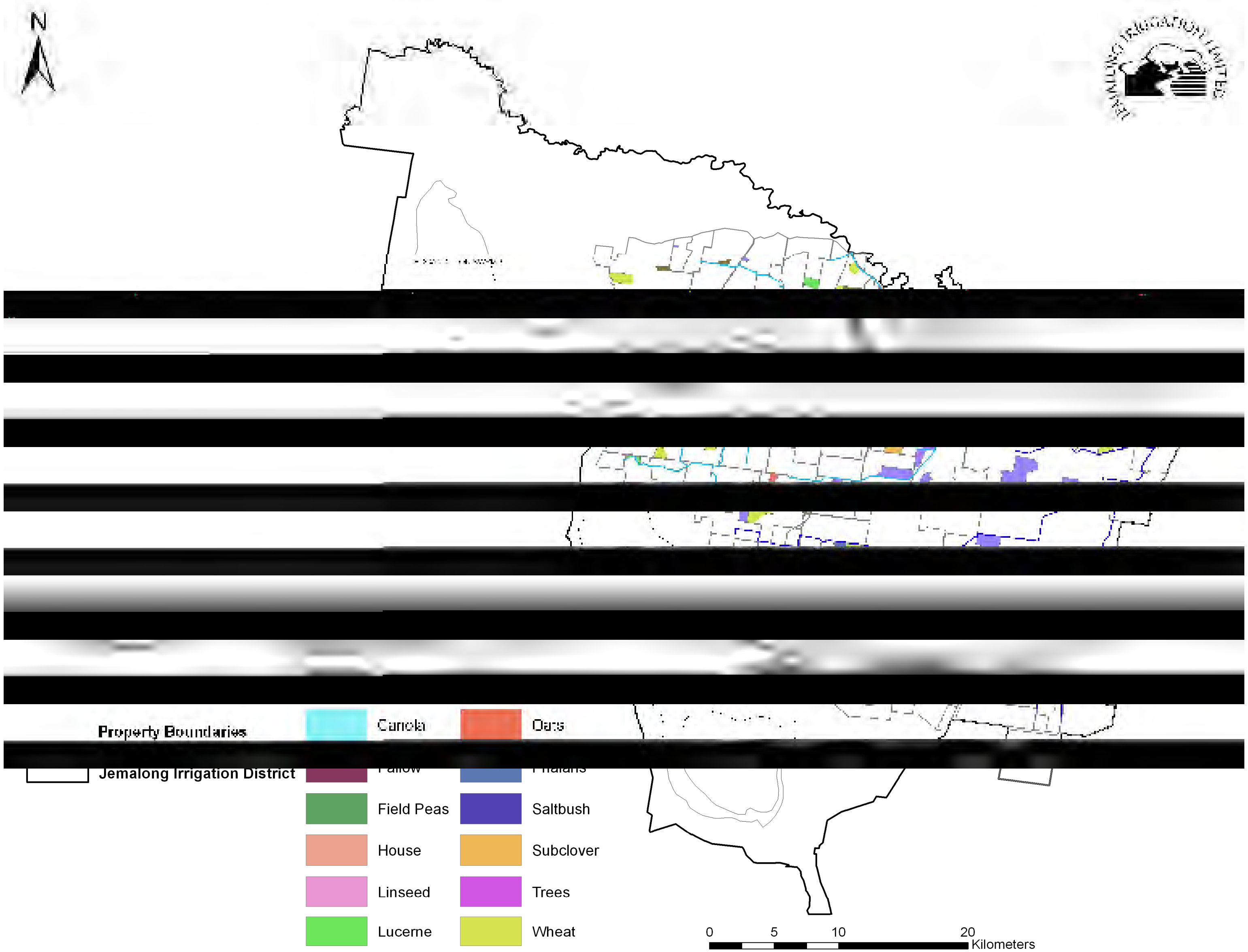


Figure 10 Spatial distribution of different crops irrigated during July 2005-June 2006 irrigation season in the Jemalong Irrigation scheme.

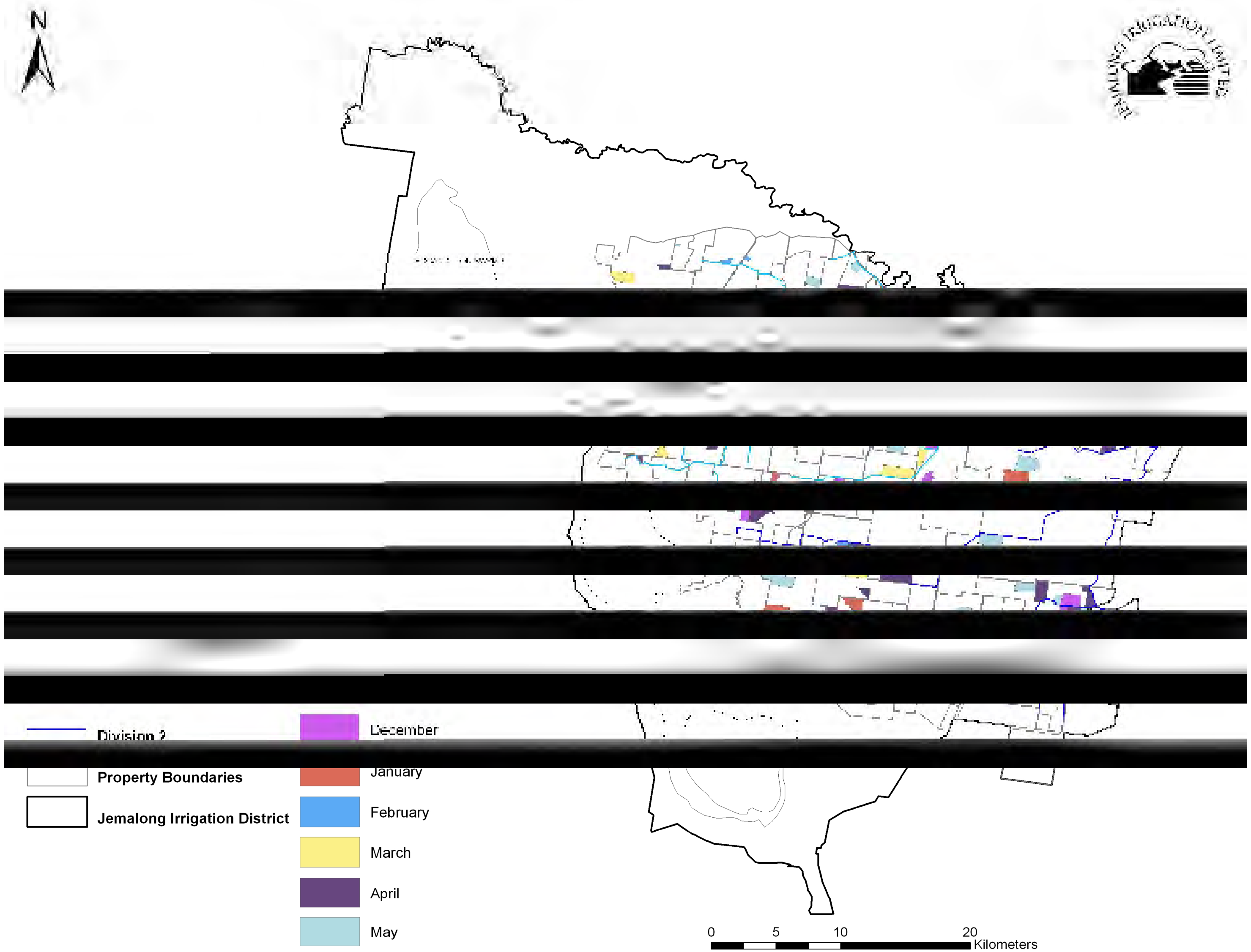
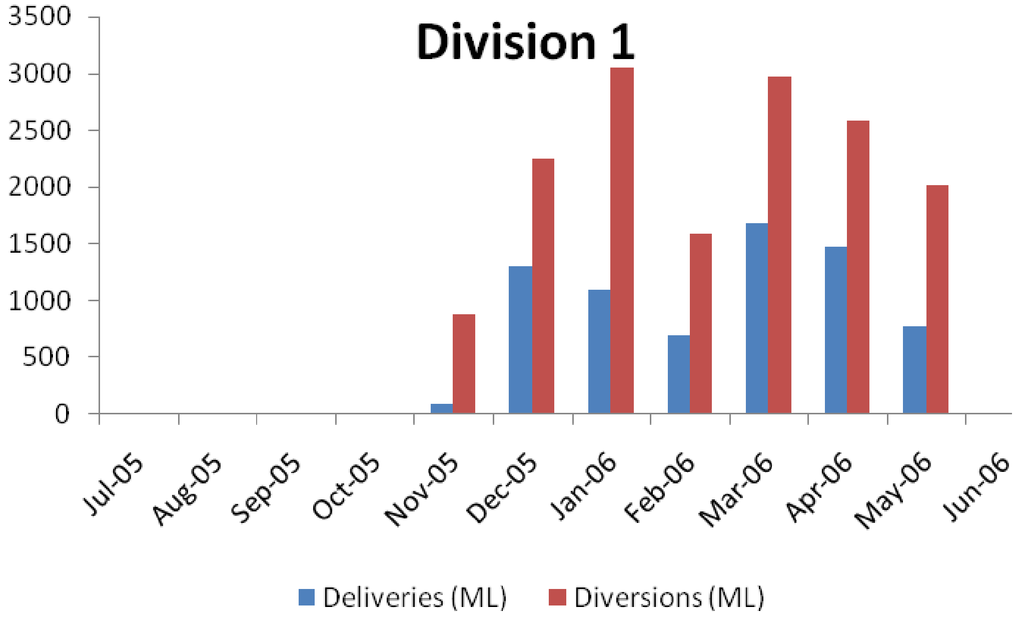


Figure 11 Location of the paddocks where surface supplies were delivered during July 2005-June 2006.



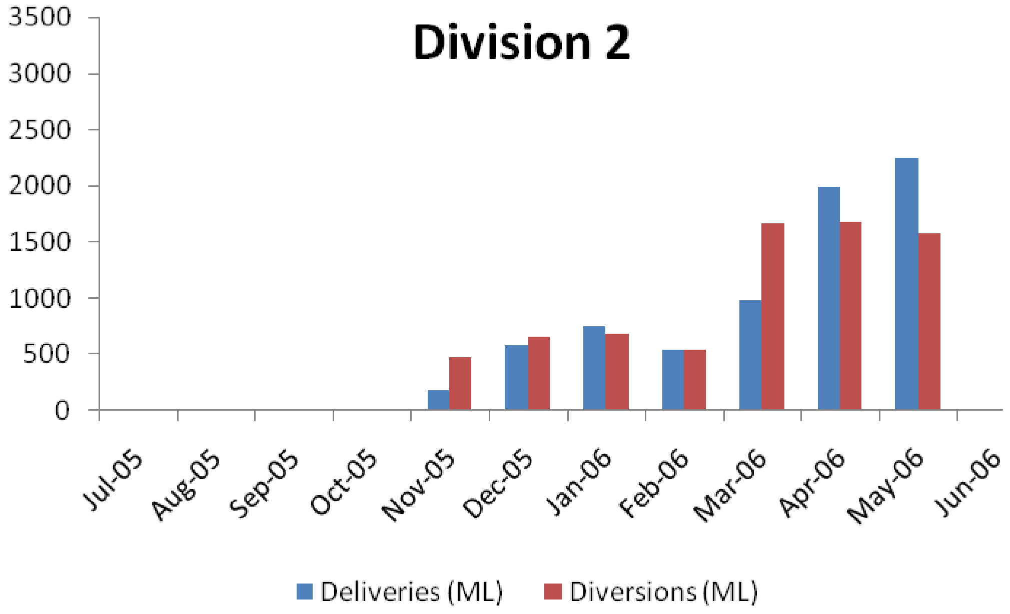


Figure 12 Sub-system level diversions and deliveries during July 2005-June 2006

Note: Diversion data is from manual "dip" measurements of flow height at upstream ends of both Division 1 and Division 2 main channels.

Figure 13 Shallow aquifer groundwater level table map for January 2002. The green shades indicate groundwater levels within 3 metres of ground surface.

[redacted]

Figure 14 Shallow aquifer groundwater levels map for January 2006. The lack of green shades indicates that there are no areas with groundwater levels within 3 metres of ground surface.

2.4 Seepage locations

The Warroo main supply channel runs close to and parallel to a prior stream formation and is known to have high seepage in several locations. This channel has a maximum capacity of about 270 ML/day, and has a length of some 30 kilometres. Several studies in the past have been conducted to identify these seepage locations and as well as to quantify the seepage loses along the Warroo main supply channel (Smith and Rose, 1993; van der Lely, 1993; TES, 1995; DLWC, 1995; LWC, 1998). Anecdotal evidence suggests that there are around 3,000 ML of channel seepage losses. Figure 15 presents the locations of the likely seepage sections in the Jemalong Irrigation scheme.

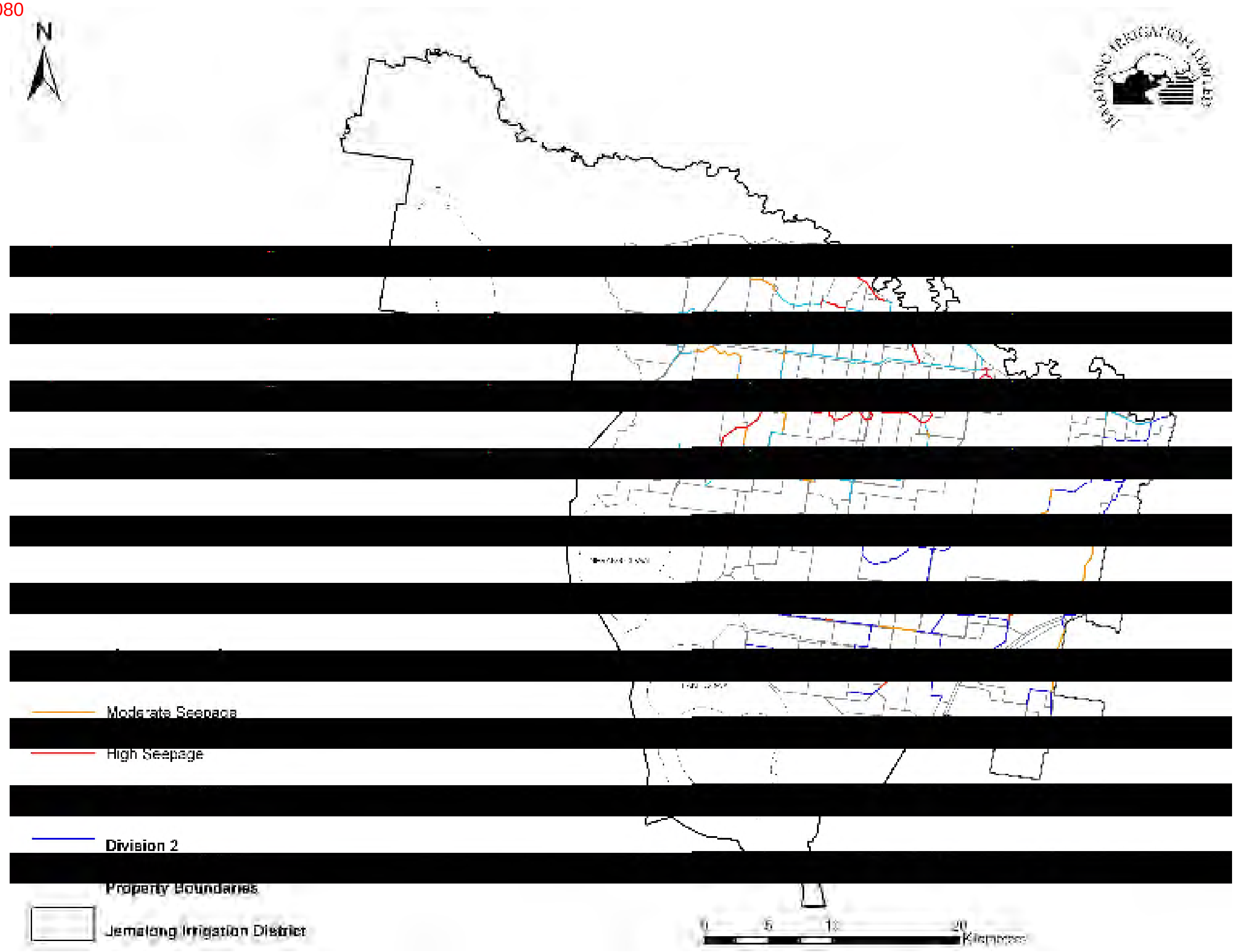


Figure 15 Locations of the likely seepage sections along the main supply channels in the Jemalong Irrigation scheme.

While preparing the Jemalong Land and Water Management Plan in 1998, a soils investigation of eight sites in the Jemalong Irrigation (Figure 16) was undertaken to provide an indication of potentially 'leaky' soils along the main supply channels in the Jemalong Irrigation scheme (LWC, 1998). The sites were located on the upslope side of the main supply channels (within 5 metres of the main supply channels). Soil samples were analysed for various soil physical characteristics including saturated hydraulic conductivity. Of the eight sites examined, six were found to have moderate to highly permeable soils (sites 1,2,3,4,7 and 8) with saturated hydraulic conductivity values ranges from 0.30 to 4.0 m/day) from which considerable water losses through channel seepage can be expected. The remaining two sites had less permeable soils (sites 5 and 6, with saturated hydraulic conductivity values ranges from 0.04 to 0.06 m/day).

During the 1992-93 irrigation season, Smith and Rose (1993) investigated the effects of seepage from the Warroo main supply channel, rainfall and irrigation practices on the groundwater levels. A total of 114 sites, established at 5 locations, were monitored using the neutron moisture metres to measure the changes in volumetric soil water (%) and soil water content (mm). The extent of seepage, which was mainly influenced by soil types, varied from 16 metres to 421 metres along the length of the channel. Actively growing crops, on the areas affected by seepage, reduce the extent of seepage. Operational channel height did not appear to influence the extent of seepage. Also, the extent of seepage did not appear to be any greater where the channel had been de-silted. The degree of seepage was influenced by the soil water content prior to channel fill, and the location of the least permeable zone below the channel bed.

TES (1995) conducted a channel seepage study of the Warroo main supply channel for four adjoining reaches, totalling 6684 metres in length, extending downstream from the Warroo Channel Offtake Regulator (Figure 17). The study was carried out over the period 1552 hours on July 19 to 0935 hours on July 23. Observations of channel water height were taken at two hourly intervals during the day at each end of the reach and at a point midway between two reaches. All structures were monitored to ensure they remained sealed throughout the test period. To estimate the surface water area, width of the water surface was taken after almost every 100 m.

The seepage loss estimated by TES was around 2.58 ML per day for the first 6684 m length of the Warroo main supply channel. These results are comparable with the findings of van der Lely (1993), which estimated seepage loss of around 2.16 ML per day for the same section of the of the Warroo main supply channel.

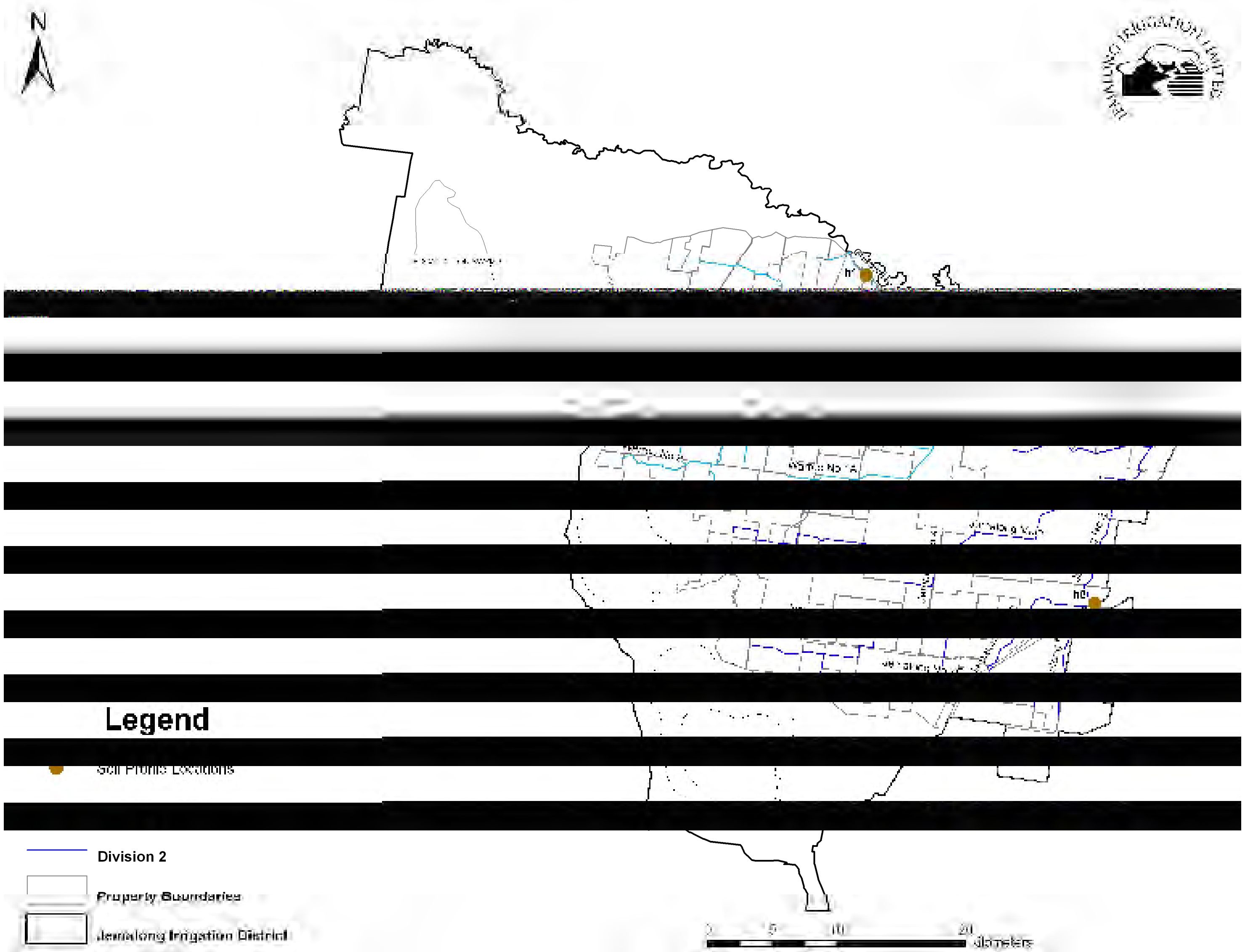


Figure 16 Location of sites investigated to identify potentially 'leaky' soils, along the main supply channels, in the Jemalong Irrigation scheme (LWC, 1998).

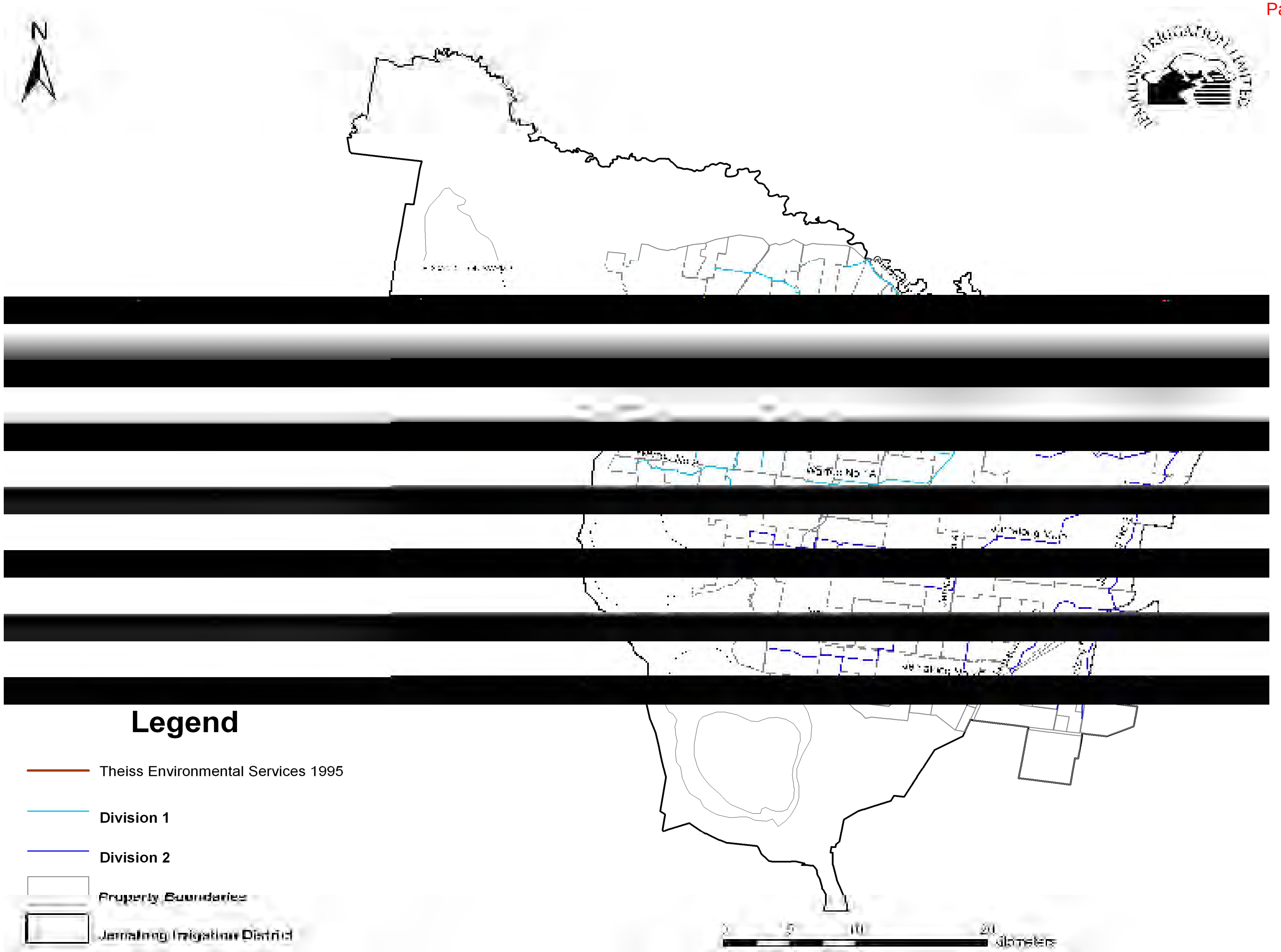


Figure 17 Location of the channel section, starting from the Warroo Channel Offtake Regulator, investigated under the TES (1995) channel seepage study.

Van der Lely (1993) and Smith and Rose (1993) estimated that the seepage loses, from the Warroo main supply channel, were in the range of 1,575 ML per year. These estimates were made during 1992-93 irrigation season, while using the data obtained from: (i) Idaho seepage metre tests, (ii) EM31 survey, (iii) groundwater observation wells, and (iv) the neutron moisture meters. The Idaho seepage metre tests were carried out after every 200 metres or more frequently along the Warroo main supply channel.

Ranking of results, for different channel seepage sections, showed that 50% of total channel seepage may occur over 17% of the total channel length (Figure 18). The next 17% of the total channel length showed 25% of total channel seepage, and the remaining 66% of the total channel length showed the remaining 25% of total channel seepage. The most important factor in seepage rate was considered to be the presence or absence of silt on the beds (bottom and sides) of irrigation channels. Figure 19 shows the locations of seepage zones where 50 percent of the total channel seepage occurs in the Warroo main supply channel (van der Lely, 1993; Smith and Rose, 1993).

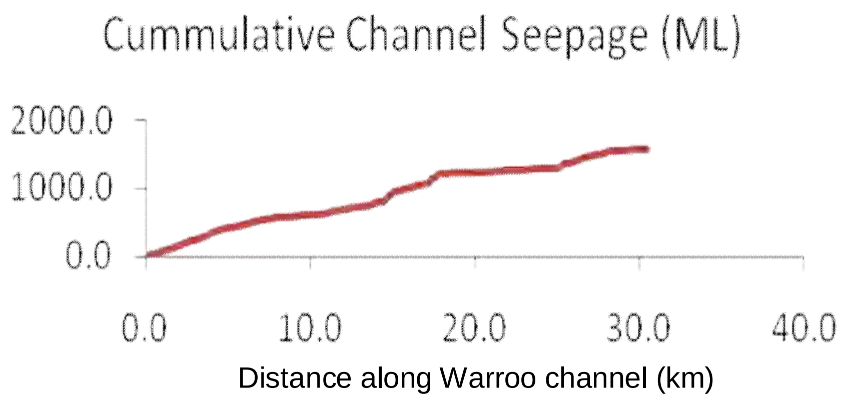


Figure 18 Annual estimates of cumulative channel seepage using Idaho seepage metre test results carried out after every 200 metres or more frequently along the Warroo main supply channel.

Figure 19 Locations of channel sections where 50 percent of the total channel seepage occurs in the Warroo main supply channel (van der Lely, 1993; Smith and Rose, 1993).

2.5 Data Gaps

To conduct a Hotspots Desktop Analysis and Hotspots Assessment Design for the Jemalong Irrigation scheme in line with the Technical Manual for Assessing Hotspots in Channel and Piped Irrigation Systems, the following data gaps have been identified:

Data Required	Issue addressed:
Channel dimensions	- Volume of water used in the filling and draining of channels - Volume of rainfall on, and evaporation from, channel surfaces
Alternative identification of leakage sites	- Verification of priority leakage sites
Metering accuracy	- Diversions at the offtakes of all the main and secondary channels - Deliveries using Dethridge Wheel and HVOs

Dethridge wheels deliver around 5% (high flows) to 18% (low flows) more water than is recorded by the meter (Hydro Environmental, 2008); and the accuracy of the HVOs is still unknown. FlowTracker (refer to Appendix A and Figure 4 in the Technical Manual for Assessing Hotspots in Channel and Piped Irrigation Systems) can be used to check the accuracy of different types of meters installed in the Jemalong irrigation scheme.

3. Hotspots Assessment Design

3.1 Background

A requirement of this project, where it has been determined that the quality or quantity of existing information can be improved by fieldwork, is to develop a Design for an on-ground Hotspots Assessment. The Hotspots Assessment will improve the water loss information needed to quantify the worst losses in the off-farm irrigation water supply systems. The Design must:

- Focus on the worst likely losses in the system that can be addressed through infrastructure modernisation;
- Quantify these losses as accurately as possible within the available time;
- Be for field work that can be completed within 6 weeks, including analysis of results;
- Be structured sequentially so the order and timing of field works is explicit;
- Specifically identify the locations, methodologies, techniques and processes to be employed, using the tests and techniques identified in the Technical Manual for Assessing Hotspots in Channel and Piped Irrigation Systems (CSIRO 2008);
- Demonstrate the need for the tests/technologies and that they will improve confidence in information on the nature, location and amount of critical water losses in the off-farm irrigation supply systems;
- Identify the main quality control points where technical and policy decisions may be required; and
- Identify the prerequisites and constraints that may impact on the ability of the Hotspots Assessment to successfully locate and quantify the worst water

3.2 Discussion

In section 2.2 the total system water balance analysis found that total system water losses are generally about 30% of flows. Sub-system water balances in section 2.3 found that Division 1 has conveyance loss of around 54% of flows, whereas Division 2 has no significant water losses. Maps of shallow groundwater levels also indicate that the main water losses are likely to be occurring in the Warroo main supply channel of Division 1. In Section 2.4, locations were identified where most seepage occurs within the Warroo main supply channel. The total losses identified in the system water balance assessment range from about 1000 to 20,000 ML/yr, depending on the diversion volumes. Van der Lely (1993) and Smith and Rose (1993) estimated that the seepage loses, from the Warroo main supply channel, were in the range of 1,575 ML per year. It is possible that a significant component of this volume could be recovered through appropriate channel works.

Data gaps were identified in section 2.5, and comprise:

- Channel dimensions – required to accurately determine channel volumes, and net evaporative loss
- Alternative identification of leakage sites – required to verify priority leakage sites for treatment
- Metering accuracy – required to further improve on water balance accuracy

Investment in the channel dimensions measurement and metering accuracy investigation will not directly result in decreased water losses, but will provide an improved basis for evaluating scheme performance and assessing water losses in the future.

For alternative identification of leakage sites, an additional area that may be considered for field investigation is that of geo-electrical resistivity surveys of Division 1 channels, and especially the Warroo channel systems, to further evaluate potential leakage sites, and to support prioritisation of sites for treatment to reduce leakage.

3.3 Recommended Design for further Hostpots Assessment

The following recommended actions are considered to be of most value to providing:

- Improved quantification of overall leakage, and
- Improved identification of priority leakage areas and sites within the Warroo channel.

These actions can occur simultaneously, and can be completed within a 6 week period.

Consideration was also given to carrying out pondage tests following the geo-electrical resistivity survey, with sites governed by the geo-electrical resistivity survey results and those of the Idaho seepage meter tests. However, the potential water losses have been reasonably well quantified through the system and sub-system water balance assessments, and given further support with the Warroo channel internal flow assessment and seepage meter analysis. The locations where water losses are most likely to occur have also been reasonably well established through the sub-system water balance, soil and groundwater analysis, TES internal flow assessment and the seepage meter tests. These locations can be rapidly verified and further defined through geo-electrical resistivity survey.

3.3.1 Channel dimensions and net evaporation analysis

Investment in data on channel dimensions is required to determine water surface area to enable an accurate estimation of net evaporation, and to also determine the total amount of water in storage in the channel system.

Net evaporation, once determined, will assist in refining the water loss predictions and better quantify the potential seepage and leakage losses. This will lead to a better understanding of what seepage/leakage mitigation measures can be adopted through actions such as channel lining. The water storage volume will be of value in any further water balance assessments, including those of individual channel sections.

It is recommended that channel dimensions be estimated at:

- the commencement and endpoint of each section of channel, including each branching section of channel, and
- any known anomalies in channel configuration.

This would result in approximately 40 locations for measurement.

The dimensions to be obtained should include:

1. Channel width at a commonly achieved, upper level flow height
2. Channel bed width
3. The height difference between 1 and 2

These measurements could be obtained with the use of a measuring tape and staff gauge, and could be obtained over a period of 2 to 3 days.

This simple approach will allow an approximation of the channel geometry which can be used to assess channel surface areas. With channel surface area adequately determined, average annual net evaporation can be determined with the aid of the spatial maps of rainfall and potential evapotranspiration provided in Appendix A.

3.3.2 Alternative identification of leakage sites

Current knowledge of potential leakage locations is based largely on:

- Soil, groundwater level and sub-system water balance analysis, which have identified the Warroo channel of Division 1 as the priority area in which leakage occurs, and
- Idaho seepage meter tests at 200 metre intervals which have identified priority leakage sections of the Warroo channel; 6 zones of 1 to 2.5 km length have been identified.

It should be noted that the Idaho seepage meter tests do not provide continuous coverage of the channel bed, and that the success of any future channel works could gain significantly from verification using an alternative and continuous method of identifying potential leakage.

To verify the Idaho seepage tests and provide the continuous coverage of the channel bed, it is recommended that an in-channel floating geo-electrical resistivity survey be carried out of the entire length of the Warroo channel. The objective of the resistivity survey is to assess whether the leaks may be low seepage rate seeps through long lengths of channel, or are large leaks through small sections of channel. The resistivity may show either:

- A relatively uniform resistivity structure along the channel length indicating slow seeps through long sections of the channel: or
- Discrete zones of anomalous resistivity possibly indicative of high seepage rates.

For the geo-electrical survey, the following need to be considered:

- The survey will need to be scheduled for when there is water in the channel;
- It may take 2 to 3 days to acquire the data, given the 30 km channel length, 5 km/hr boat speed during acquisition, and possible obstacles/structures that will have to be negotiated; and
- There will be an additional 2-3 weeks required to process and interpret the data and compare against the known soil types, hydrogeological conditions and Idaho seepage tests.

3.3.3 Expected outcomes from further Hotspots assessment

In progressing with the recommendations of the Hotspots Assessment design, the Department will gain an improved understanding of the quantity and location of water losses in the Jemalong Irrigation scheme.

Using the results of these further additional investigations, it is expected that recommendations could be made on the most appropriate intervention to address water losses.

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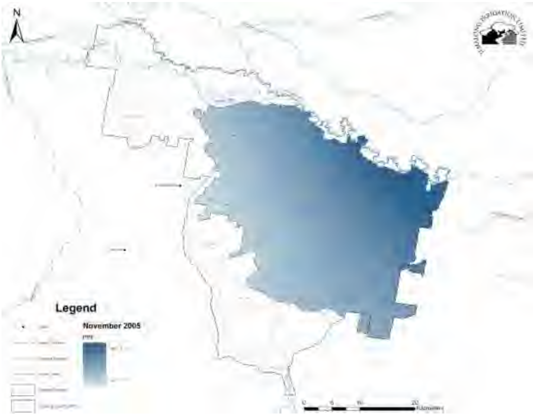
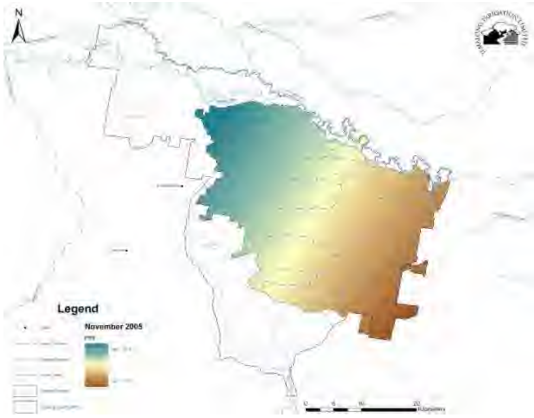
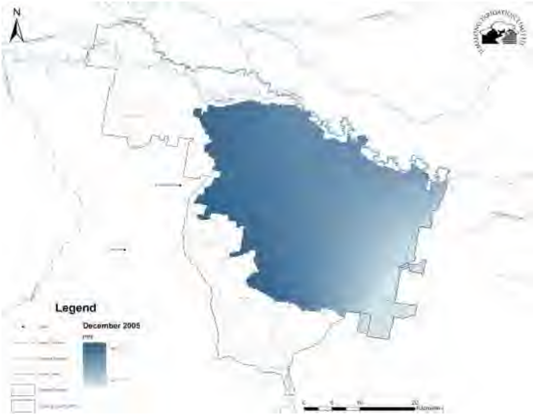
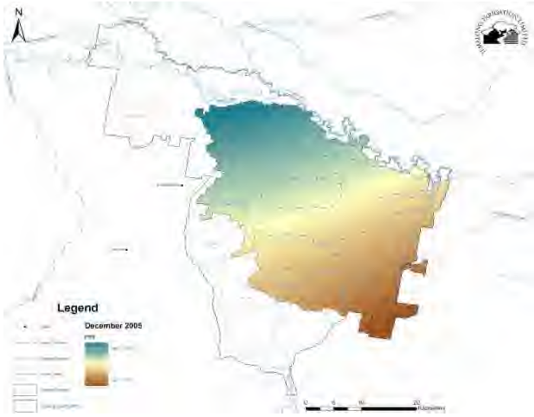
Appendix A
Spatial maps of rainfall and potential evapotranspiration

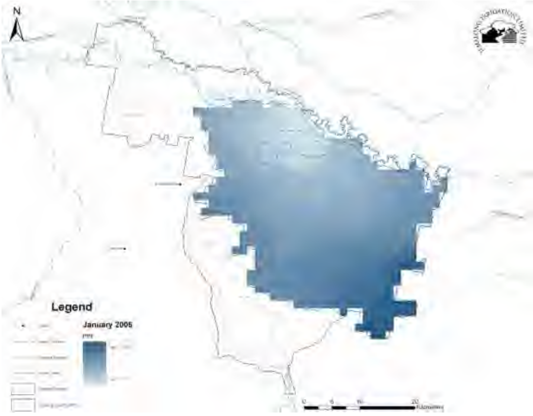
The following Bureau of Meteorology weather stations exist in the areas surrounding the Jemalong Irrigation scheme,: (i) Bogan Gate Post Office, (ii) Burcher Post Office, (iii) Caragabal Post Office, (iv) Condobolin (Borambil Park), (v) Condobolin Agriculture Research Station, (vi) Condobolin Retirement Village, (viii) Condobolin Soil Conservation, (ix) Cookeys Plains, (x) Marsden (Merungle), (xi) Warroo (Geeron) and (xii) Forbes (Camp Street). The following maps of rainfall and potential evapotranspiration for the July 2005-June 2006 irrigation season have been prepared using monthly data for these weather stations downloaded from the SILO website.







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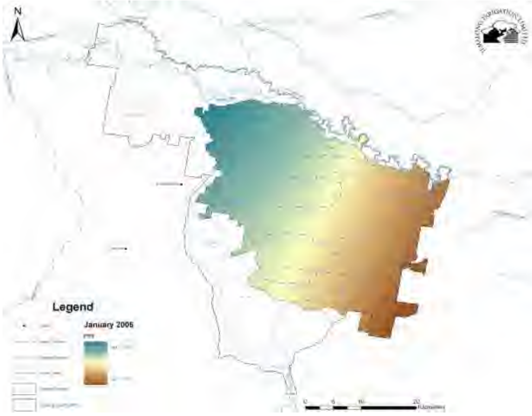
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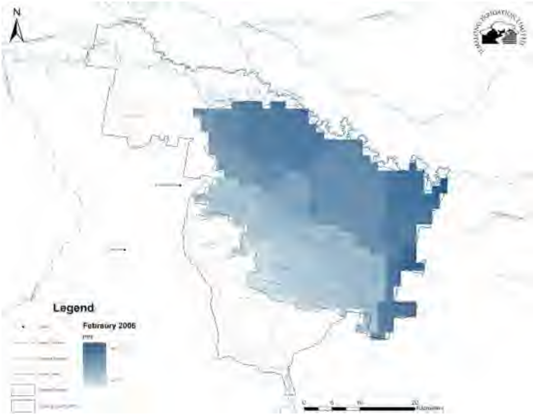
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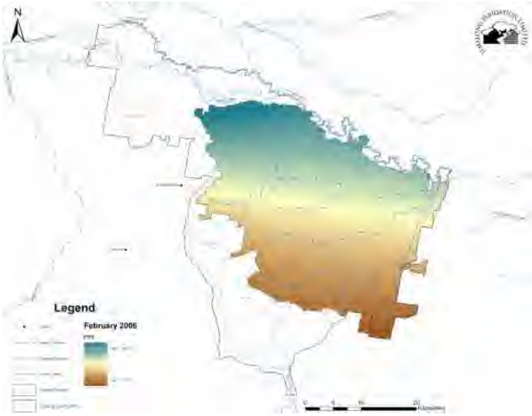
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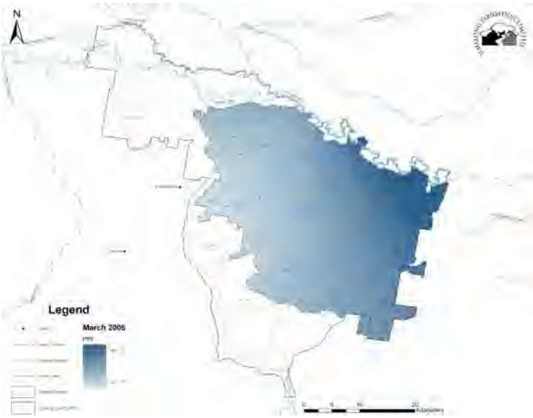
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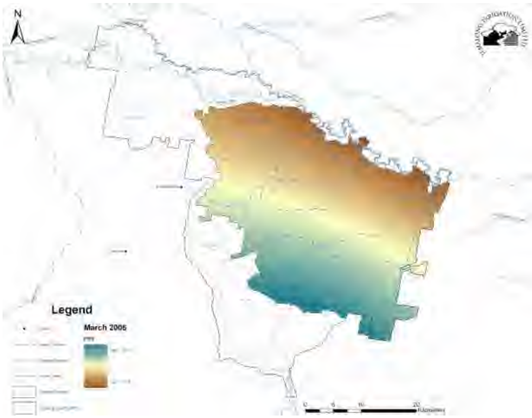
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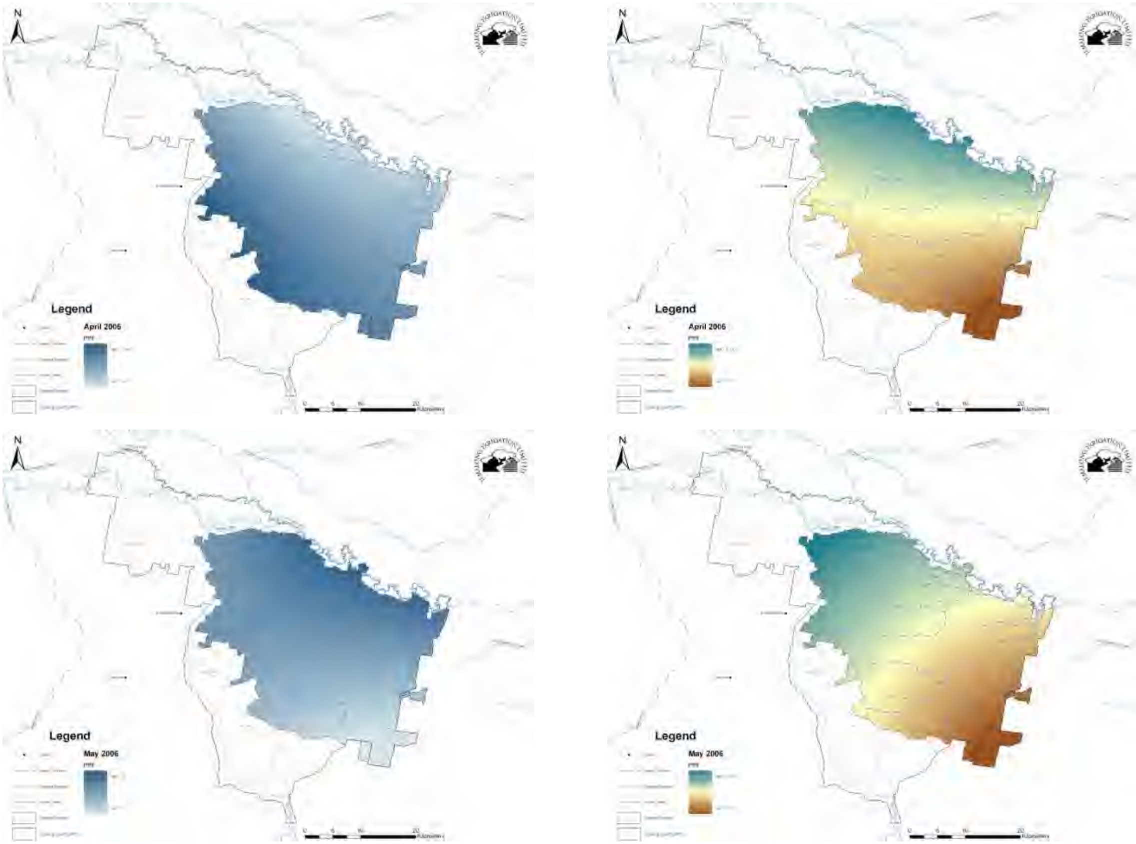
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GHD

Suite 3, Level 1, 161-169 Baylis Street
Wagga Wagga NSW 2650
T: 61 2 6923 7400 F: 61 2 6971 9565 E: wgamail@ghd.com.au

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On-ground Hotspots Assessment

Jemalong Irrigation Limited delivery system

Report Number 22630.38303

Prepared for

Department of Environment, Water, Heritage & the Arts

GPO Box 787
CANBERRA ACT 2601

by

PO Box 411
TOOWOOMBA QLD 4350
Telephone: (07) 4638 7864
Facsimile: (07) 4638 8821
ABN: 67 081 536 281

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This document provides information to address the intent of Project Number 22630 as agreed to by Department of Environment, Water, Heritage & the Arts.

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1. Introduction

This report provides the results of 'on-ground' assessments and data analyses undertaken to satisfy the Department of Environment, Water, Heritage and the Arts (the Department) Service Request 0809-1407.

Service Request 0809-1407 aimed to rectify certain previously documented data 'gaps' in information that might allow the identification and prioritisation of the sites of elevated water loss (*i.e*. 'Hotspots') in the irrigation water delivery system administered by Jemalong Irrigation Limited. The specific data deficiencies that were to be addressed were those identified in an earlier report entitled *Hotspots desktop analysis and design: Jemalong Irrigation* (GHD, 2009).

The services requested can be summarised as follows:

1. 'On-ground' assessments involving:
    a. Fieldwork to determine the as-built geometry and the in-service surface areas of certain irrigation water delivery channels in the Jemalong Irrigation system, with this information to be used in estimating evaporative losses from the subject channels;
    b. A geophysical survey, in the form of an electromagnetic induction (EM) survey, undertaken on those delivery channels; and
2. Analysis of the available data to locate and quantify, as accurately as possible, the worst water losses in the Jemalong Irrigation Systems irrigation delivery system that can be efficiently addressed through infrastructure improvement.

The specific irrigation water delivery channels in the Jemalong distribution system, on which assessments were to take place, were as follows:

- Warroo Main;
- Warroo No 9;
- Cadow Upstream;
- Cadow Downstream;
- Cadow No 2A;
- Cadow No 3;
- Jemalong Main (above Jemalong No 2Up)
- Jemalong No 2Up Channel (above the Jemalong No 2B branch), and
- Jemalong No 2A.

Particular importance was given in the Service Request to the Warroo Main and Warroo No 9 channels, which were identified as the likely sites of the largest system seepage losses in the earlier *Hotspots desktop analysis and design: Jemalong Irrigation* report.

The Service Request also specified that the EM survey was to be undertaken using *'a quad bike* [4-wheel motorbike] *or similar mobile method'*.

Information gathered or generated while undertaking the Service Request was to be provided to the Department to allow for future Departmental use. The datasets supplied were to comply as closely as possible with Departmental standards set out in attachments to the Service Request.

This report is therefore intended to describe the methodologies adopted to undertake the assessments required in the Service Request, provide an analysis and interpretation of the data, and discuss the results and provide recommendations based on conclusions drawn from the assessment. The report also provides some additional background information either not previously considered or considered of increased relevance following the completion of the fieldwork.

2. Background information

2.1 The Jemalong irrigation system

Figure 1 shows the entire water delivery system administered by Jemalong Irrigation Limited. The nine channels identified in the earlier *Hotspots desktop analysis and design: Jemalong Irrigation* report as being likely sites for major seepage losses, and hence the subject of this report (refer Section 1, above), are identified by their designated names. The assessment of the other unnamed channels shown in Figure 1 is not within the scope of this study.

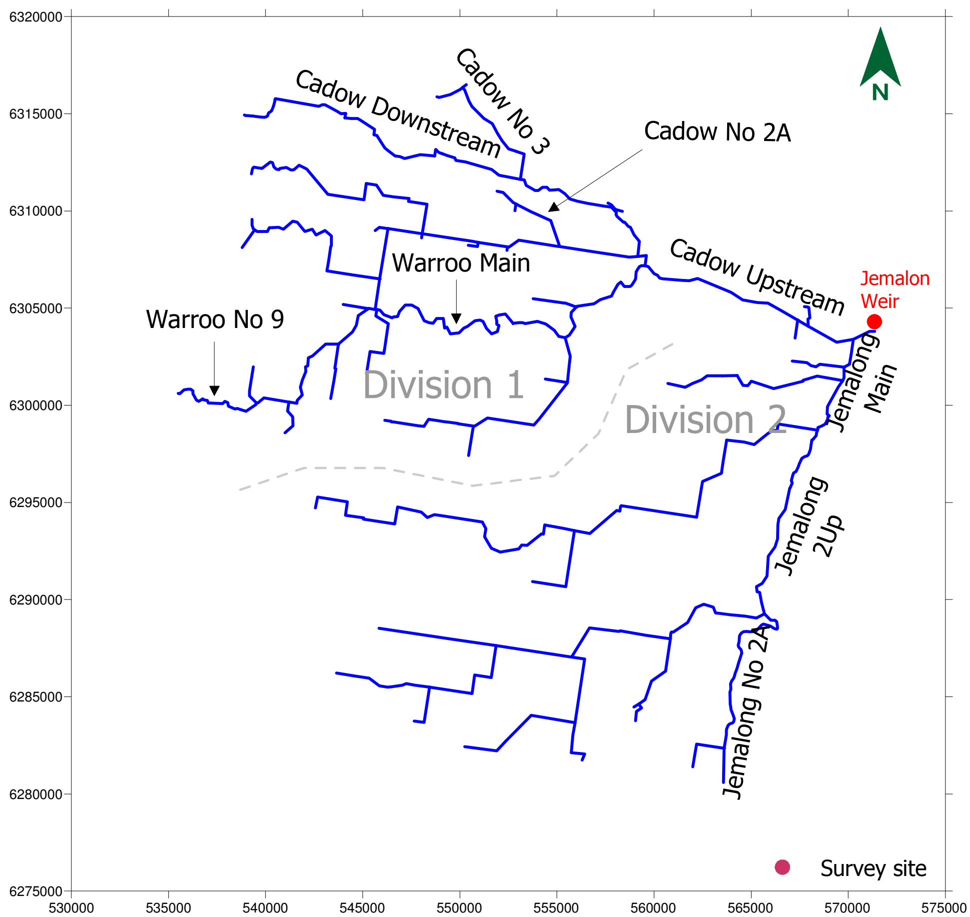


Figure 1: Delivery system administered by Jemalong Irrigation Limited with the subject channels named

Operational details on the distribution system were provided in the *Hotspots desktop analysis and design: Jemalong Irrigation* report, and will not be repeated here.

2.2 Additional published information

2.2.1 Geology

The Jemalong-Wyldes Plain area is within the area covered by the 1:250 000 Forbes geological mapsheet (AGSO, 2000). The relevant part of that mapsheet is reproduced in Figure 2. Overlain on the scanned map are the approximate locations of the distribution channels in the Jemalong system. Also shown are the mapsheet codes applicable to the major geological units in the area. A brief summary of these units, taken from AGSO (2000), is provided in Table 1.

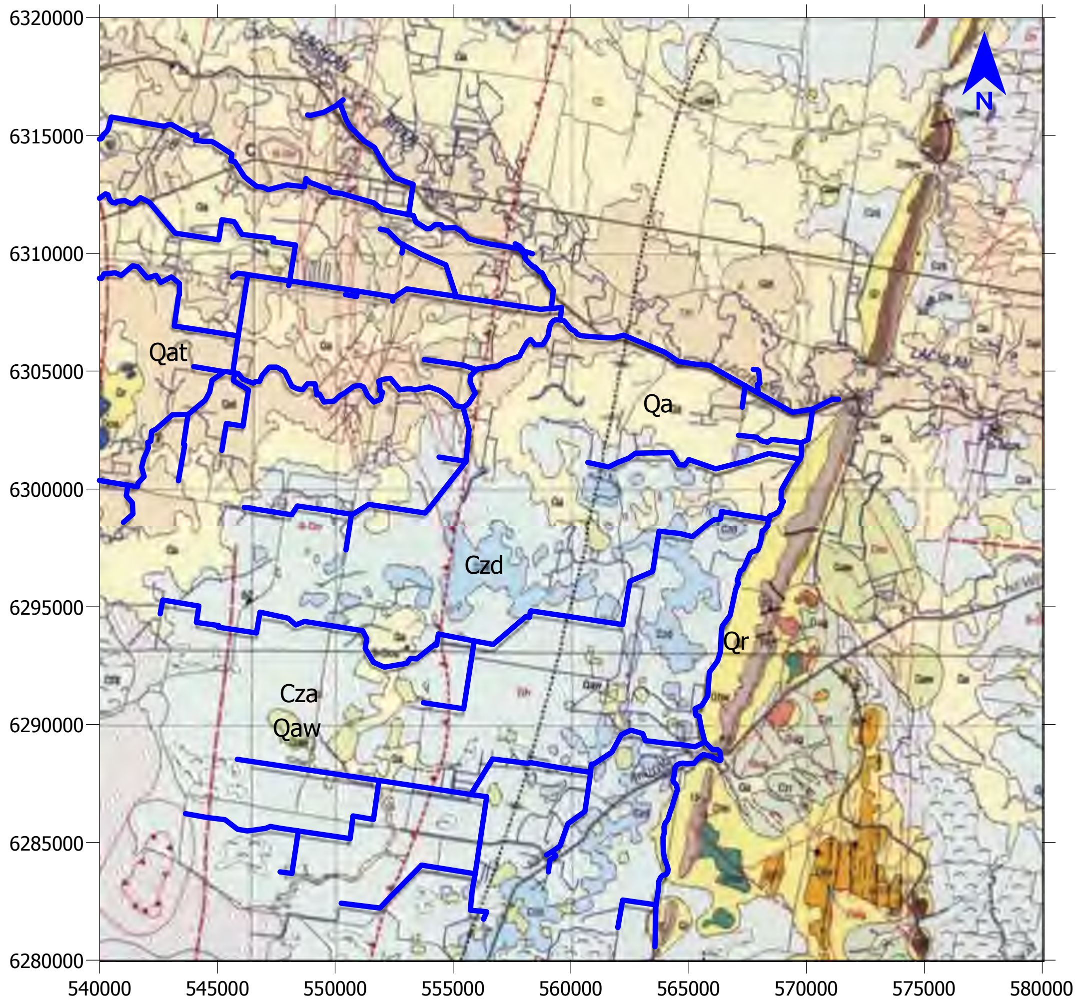


Figure 2: Scanned copy of part of the 1:250 000 Forbes geological mapsheet (AGSO, 2000) annotated to show the approximate location of the Jemalong distribution channels and the codes for the major geological units in the area

Table 1: Legend and descriptions of major geological units identified in Figure 2

Code	Age	Description
Qa	Quaternary	Alluvium, active depositional plains and terraces containing present day drainage
Qat	Quaternary	Low thorium alluvium, predominantly in the modern day flood plain of the Lachlan River
Qaw	Quaternary	Swamp, sump basin
Qr	Quaternary	Colluvial sheet wash and scree slopes; minor aeolian climbing dunes
Cza	Tertiary	Inactive alluvial plains
Czd	Tertiary	Red sand and clay, probably deposited in source bordering dunes

The following are evident from Figure 2:

- The Cadow channels, and the Warroo channels that are the subject of this assessment all overlie extensive tracts of recent Quaternary alluvium, associated with the present-day Lachlan River and its distributary stream channels (units Qa & Qat in Figure 2); and
- For most of their lengths, the Jemalong Main (above No 2Up), Jemalong No 2Up and Jemalong No 2A all run along the western footslopes of the Jemalong Range, close to or at the interface between colluvial sheetwash (Qr in Figure 2), which is derived from the Devonian sedimentary material exposed in the range, and the Quaternary alluvium (Qa & Qat and in Figure 2) and Tertiary alluvium and relict dunes (Cza & Czd in Figure 2), which form the present-day Jemalong-Wyldes Plain.

2.2.2 Soils

The soil landscapes[1] of the 1:250 000 Forbes mapsheet are described by King (1998) and mapped by King (1999). Figure 3 shows part of the 1:250 000 map (not at the original scale), with the approximate location of the Jemalong irrigation distribution channels overlain on it.

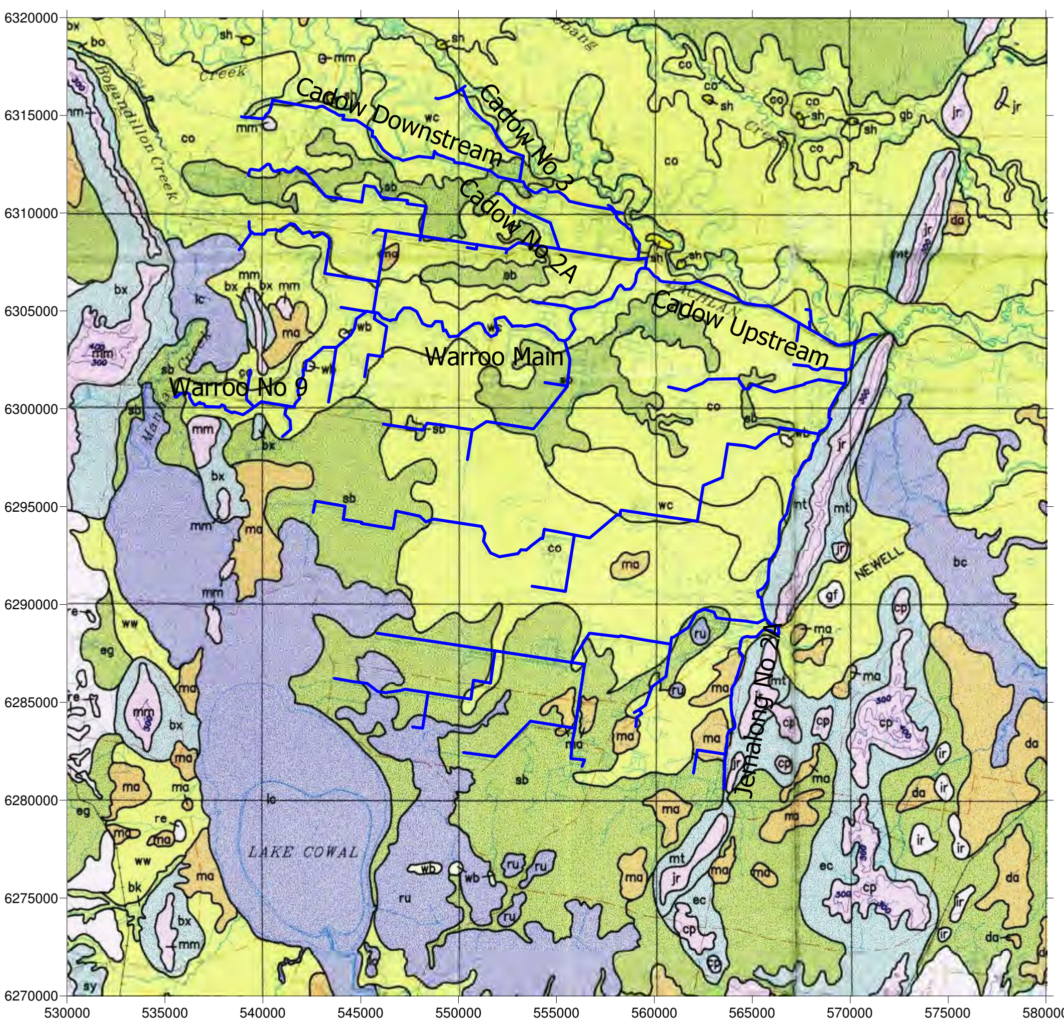


Figure 3: Scanned copy of part of the 1:250 000 Forbes soil landscape map (King, 1999) annotated to show the approximate location of the Jemalong distribution channels

[1] Soil landscapes are mappable areas where similar causal factors have been involved in the formation of the soils and the landscapes. A number of soil types may occur within each soil landscape.

Reference to the geology mapping in Figure 2 (page 3) and the soil landscapes mapping in Figure 3 demonstrates the significant, and not unexpected, influence of geology on the mapped landscape units – a correlation not shared by some other soils mapping of the area.

Table 2 then provides summary details, taken from King 1998, of the three major soil landscape units represented on the Jemalong-Wyldes Plain – the Corinella, Scrubby Plain and Warroo Channel landscape units.

Table 2: Summary details from King (1998) of major soil landscapes identified in Figure 3

Soil landscape	Description
Corinella (co)	**Summary:** Level alluvial plains of the Jemalong-Wyldes Plain district on Quaternary alluvium. Heavier textured (clay loams to sandy clay loams) than the Warroo Channel landscape soils; supporting *Eucalyptus microcarpa*, *Eucalyptus populnea*, occasional *Eucalyptus melliodora* and *Eucalyptus camaldulensis*. Dominant soils are deep (>100 cm), imperfectly drained red brown earths (Dr2.41, Dr2.23, Dr3.13 & Dr2.13; eutrophic & hypocalcic, subnatric red & brown sodosols, sodic & haplic, eutrophic & calcic red & brown chromosols). Other minor soils include deep (>100 cm), poorly drained grey clays (Ug5.28 & Uf6.33; epipedal grey vertosols) and soloths (Db3.22 & Dy5.22; eutrophic subnatric yellow & brown sodosols) along narrow drainage lines. **Limitations:** Alkaline soils with sodic/dispersible subsoils; hard-setting surfaces (localised); high shrink-swell potential (localised) and low fertility. Surface soil K_{sat} = 2.5 mm/hr Subsoil K_{sat} = 1.7 – 12.5 mm/hr
Warroo Channel (wc)	**Summary:** Prior streams and meander scroll fields on level alluvial plains of the Jemalong-Wyldes Plain. Sandy textured surface soils, supporting *Eucalyptus microcarpa*, *Eucalyptus populnea*, *Callitris glaucophylla*, *Allocasuarina luehmanii* and *Casuarina cristata*. Soils are deep (>150 cm), imperfectly drained red brown earths (Dr2.33 & Dr2.23; haplic & sodic calcic red chromosols; calcic subnatric red sodosols) and deep (>150 cm), moderately well drained brown earths (Gn2.43; haplic eutrophic brown kandosols) and brown podzolic soils (Dy4.21; haplic eutrophic grey chromosols) occur on meander scrolls of the Ulgutherie Creek System. **Limitations:** Potential/known recharge area; sodic/dispersible, highly erodible, alkaline soils of low fertility with localised salinity and high permeability. Surface soil K_{sat} = 12.5 mm/hr Subsoil K_{sat} = 1 – 2.5 mm/hr
Scrubby Plain (sb)	**Summary:** Stagnant alluvium forming level plains of the Jemalong-Wyldes Plain district. Grey, brown and red clays supporting *Eucalyptus camaldulensis* along drainage depressions, *Eucalyptus microcarpa*, *Eucalyptus populnea*, *Alectryon oleifolius*, *Acacia*

Soil landscape	Description
	pendula and occasional *Acacia homalophylla*, with understorey of *Muehlenbeckia florulenta* and *Sclerolaena muricata*. Deep (>150 cm), poorly drained grey clays (Ug5.24; haplic & sodic epipedal grey vertosols) and brown clays (Ug.5.34; haplic & sodic brown vertosols) are the dominant soils. Deep (>150 cm), poorly drained red clays (haplic & sodic red vertosols) occur on slightly more elevated plains. **Limitations:** Highly plastic, dispersible soil with low permeability, high shrink-swell potential and localised subsoil salinity. Surface soil K_{sat} = 2.5 mm/hr Subsoil K_{sat} = 1.7 – 12.5 mm/hr

Some significant observations from the information provided in Table 2 include:

- The low to moderate (>10 mm/hr) saturated hydraulic conductivity (K_{sat}) values given for a number of the soils or soil horizons in the three landscape units; and
- The Warroo Channel unit being listed as a potential or known groundwater recharge unit.

Figure 4 represents plots of profile trends in pH, cation exchange capacity (CEC), exchangeable soil percentage (ESP), soil salinity or electrical conductivity ($EC_{1:5}$) and percentage clay values for examples of the Corinella (1), Scrubby Plain (2) and Warroo Channel (1) soils provided in Appendix 7 of King (1998).

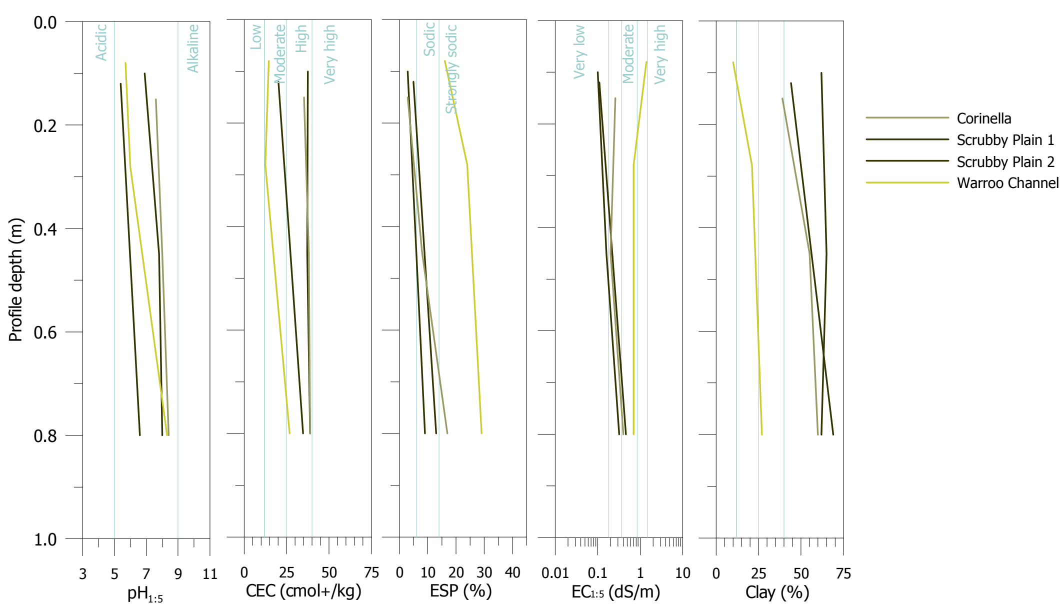


Figure 4: Soil profile trends in values for key analytes in Corinella, Scrubby Plain and Warroo Channel soils

Both the absolute values and the profile trends evident in Figure 4 would suggest that Corinella and Scrubby Plain soils are uniformly and moderately leached (*i.e.* the $EC_{1:5}$ values are in the low range throughout the sampled profile). This would suggest that despite the relatively high clay content of these soils, and the generally sodic nature of their subsoils, they are subject to not insignificant levels of deep drainage (*i.e.* they are somewhat, but not overly 'leaky' soils). This is consistent with the typical K_{sat} values given for these landscape units in Table 2 (above).

Interpretation of the trends in analyte values in the Warroo Channel soil in Figure 4 lack a similarly simple explanation – in particular the generally elevated salinity ($EC_{1:5}$) levels in this soil, and more particularly the very high levels in the surface soil. Given the sandier texture of these soils (*i.e.* the low % clay), it might have been expected that $EC_{1:5}$ levels in these soils would be lower than in the Corinella and Scrubby Plain soils. This apparent aberration might suggest some man-made influence at the sampling site (*e.g*. irrigation induced changes in soil salinity). Nonetheless, the lack of any salt 'bulge' in the sampled profile of the Warroo Channel soil, and the pattern of decreasing values with profile depth, do indicate a relatively free draining soil, lacking any significant impediments to deep drainage.

Modelling deep drainage in the Warroo Channel soil, using the SALF PREDICT model (Carlin *et al.*, 1999), suggests that under irrigation, and in its native state, this soil should provide deep drainage 2 to 3 times greater than that in the Corinella or Scrubby Plain soils, as well as in the long term, moderately lower EC values. These model predictions are consistent with the Warroo Channel soil data provided in King (1998) being from a site that has suffered some form of perturbation.

2.3 Other data

2.3.1 Groundwater

Over the last 30 years or more, a network of over 200 piezometers has been progressively installed in the Jemalong-Wyldes Plain area. Standing water level (SWL) and electrical conductivity – used as a surrogate measure of groundwater salinity – are monitored in these piezometers on a relatively frequent basis (*i.e.* about every 3 to 6 months in recent years).

Figure 5 provides an interpolated plot of the watertable elevations in the monitored piezometers at the most recent monitoring, which was undertaken in July 2009. The elevation of the piezometric surface was obtained from the reported SWL values and the known elevations of the natural surface at each piezometer location[2]. The interpolated surface plot was derived using the default kriging and splining algorithms in the SURFER® surface modelling and mapping software[3]. Flow net vectors, generated by SURFER®, and showing the predicted direction and magnitude of groundwater flows, have been overlain on the isopleth plots.

[2] No elevation datum is provided, but values appear consistent with the AHD values or a very similar datum
[3] SURFER ver. 8.09, Golden Software Inc, Golden, Colorado.

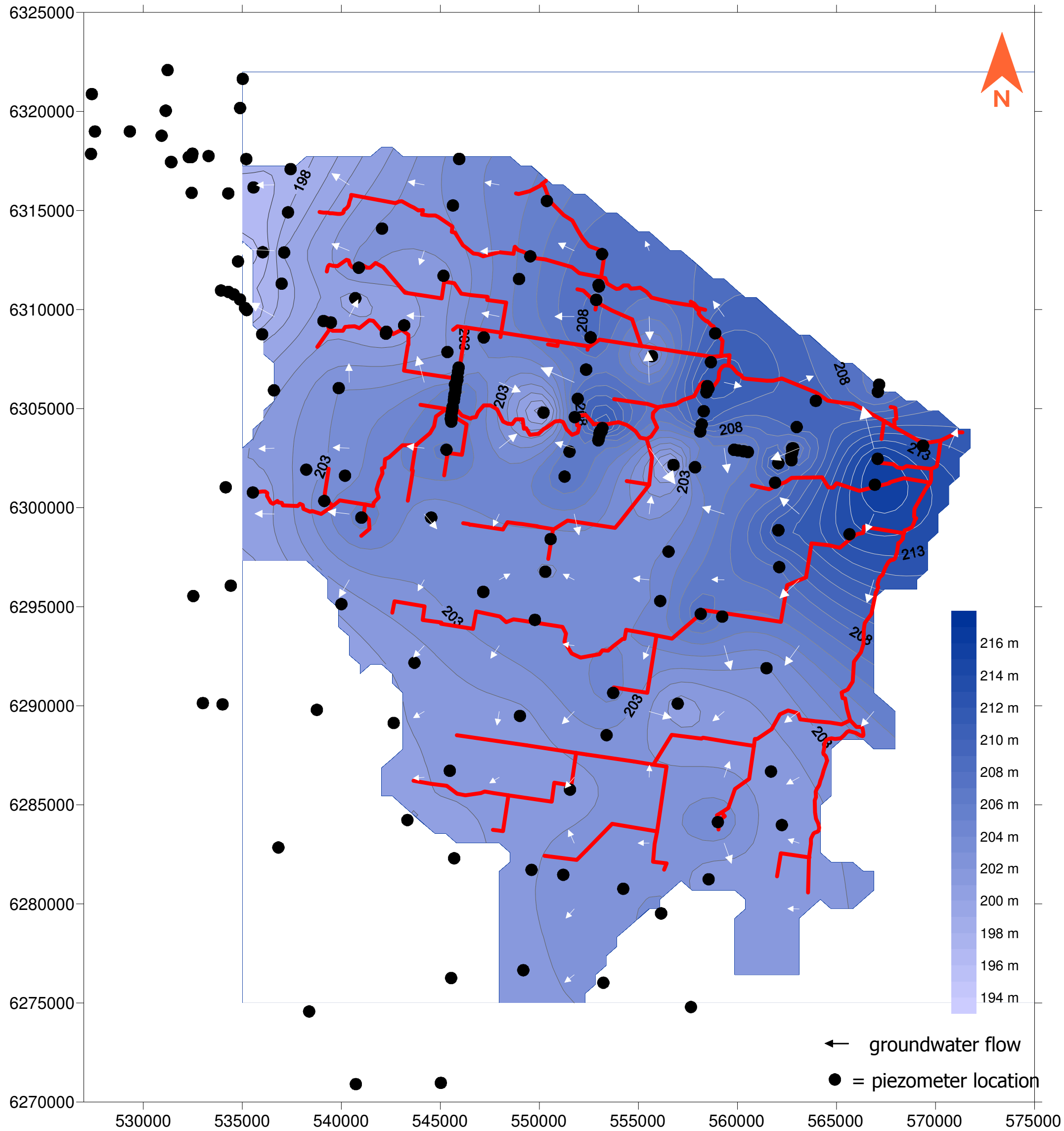


Figure 5: Interpolated plot of the elevation of the piezometric surface based on SWL in piezometers monitored in July 2009

The piezometric surface on the Jemalong-Wyldes Plain dips to the west and south west, generally mimicking the gradient of the plain itself. Nonetheless, some groundwater mounding appeared to be present in the area at this time. The data plotted in Figure 5 suggests that in July 2009, mounding was occurring at the following locations:

- Near the upper reaches of the Jemalong No 1 channel and the terminus of the short and apparently unnamed branch off the Jemalong Main channel, upstream of the Jemalong No 1 channel;
- Along the upper reaches of the Warroo Main channel, immediately downstream of its junction with the Cadow channel;
- At a point on the Warroo Main channel, downstream of its junction with the Waroo No 1A channel, and a about a third of the way between that junction and the junction with the Warroo No 8 channel; and
- Between the lower reaches of the Cadow No 2A channel and a section of the Warroo No 2 channel, directly to the south.

At the time that the latest monitoring round was undertaken, the Lachlan River did not appear to be having substantial influence on groundwater levels in the Jemalong area, with the gradients plotted in Figure 5 being towards rather than away from the river. This would be consistent with reduced flows in the river associated with the very dry conditions prevalent in much of the catchment. It should be noted though that lower density of piezometers in the eastern parts of the area, and particularly near the river itself, mean that the apparent mounding in the upper reaches of the Warroo Main and, to a lesser extent on the Cadow No 2A channels, may still be associated with movement of groundwater coming from the river, along preferential flowpaths, such a palaeochannels, and strings of coarser grained depositional material within the alluvium.

Mounding observed historically along the terminal sections of the Warroo Main channel (Lampayan & Ghassemi, 1999 and GHD, 2009), was not particularly pronounced in July 2009. The reduced mounding in this area may be due to a range of factors including, but not limited to the following:

- Reduced usage of the distribution channels;
- The prevailing dry weather conditions;
- Less on-farm irrigation activity;
- Improvements in on-farm water use efficiency.

Identifying the significance of the above factors is beyond the scope of this report.

An interpolated plot of groundwater electrical conductivity (EC) contours, based on values again obtained in those piezometers sampled for this parameter in July 2009, is presented in Figure 6. The interpolation was also undertaken using the kriging and splining algorithms in SURFER®. Again, groundwater flow vectors generated by SURFER®, and showing the predicted direction and magnitude of groundwater movements based on the isohaline contours, have been overlain on the EC isopleth plots.

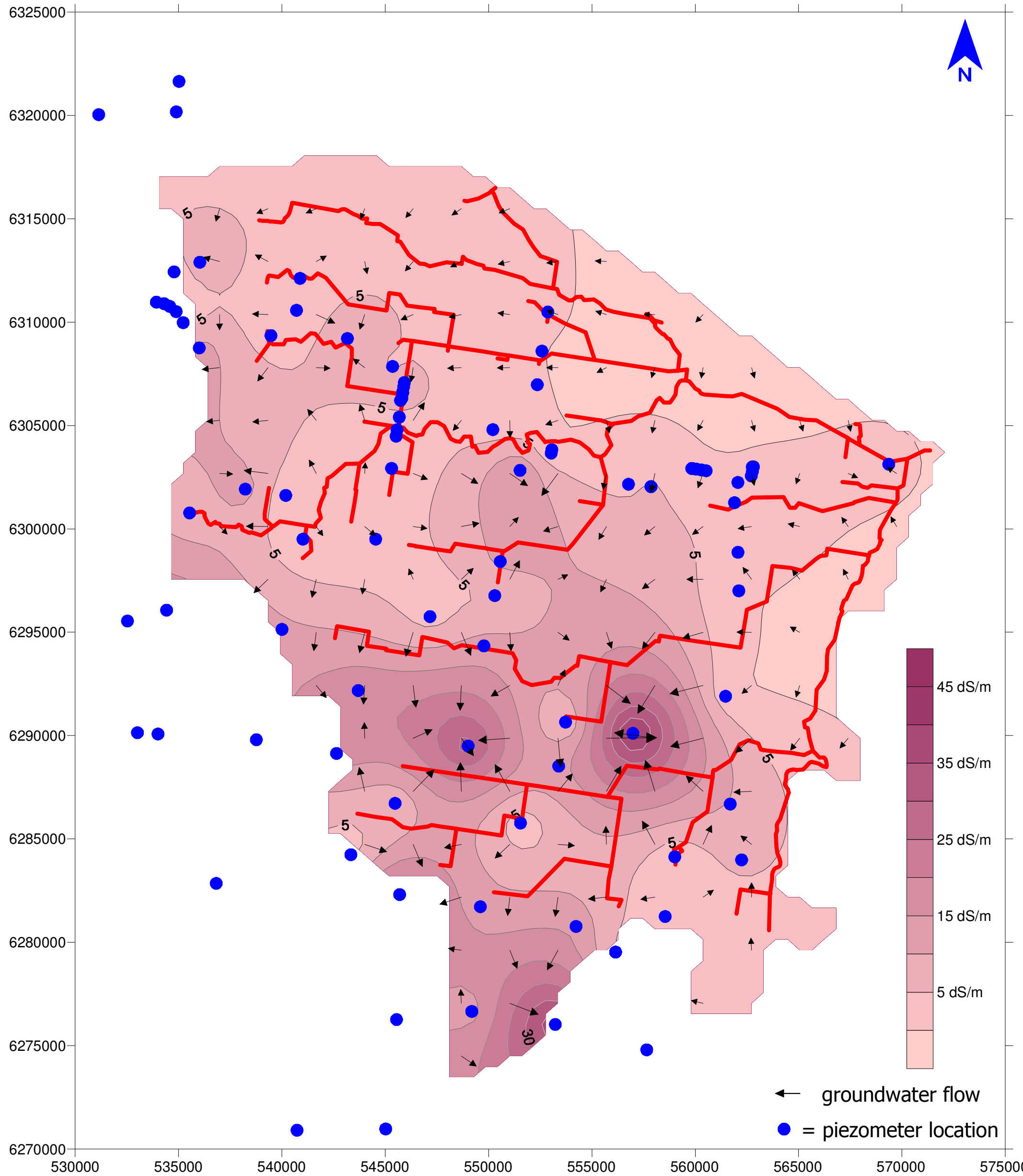


Figure 6: Interpolated plot of groundwater EC values in piezometers monitored for this parameter in July 2009

The plotted isohaline contours in Figure 6 do not appear to be precisely correlated with those for the piezometric surface plotted in Figure 5 (above). Nonetheless, the contours and the associated vectors shown in Figure 6 do appear to suggest accessions of fresher (less saline) water have or are still occurring in the following locations:

- Along the upper reaches of the Jemalong No 2Up channel and lower reaches of the Jemalong Main channel (above the Jemalong No 2Up channel);
- In a broad area from just below the Jemalong Weir, along the river and the Cadow Upstream and Downstream channels, to near the locality of Warroo, and
- In the general area towards the lower end of the Waroo Main channel.

Owing to the lower density of piezometers in which EC values are monitored (compared with those SWLs are monitored in), and the lower density of piezometers in eastern parts of the irrigation area, it is unclear whether the lower EC values between the Jemalong Weir and Waroo are due to accessions directly from the river; from the nearby irrigation water distribution channels; or from other sources. It is also possible groundwater salinity levels do not respond as quickly as SWLs to recent changes in inflows, and the extant EC values might therefore be in part an artefact of past influences (*i.e*. the responses may exhibit a significant lag phase).

2.3.2 Idaho seepage trial data – Warroo Main channel

In an investigation made in 1993 by the then NSW Department of Water Resources, van der Lelij (1993) undertook a series of seepage tests along the Warroo Main channel, using an Idaho seepage meter. The seepages rates observed ranged from the equivalent of 0.25 mm/hr to 64 mm/hr. Figure 7 shows a histogram of the observed seepage rate values, with 10 mm/hr bin intervals applied to the data.

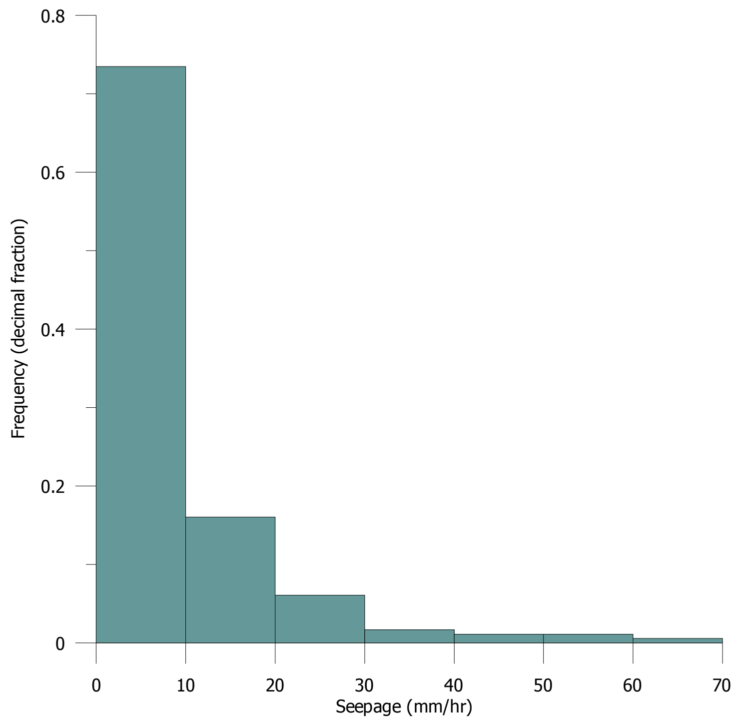


Figure 7: Histogram showing the frequency of various seepage rate ranges in the Idaho seepage meter data for the Warroo Main channel (van der Lelij, 1993)

Figure 7 indicates that the vast majority (>75%) of results were for rates less than 10 mm/hr. However there was small number of sites where the rates observed exceeded 50 mm/hr.

3. Methodology

3.1 Constraints and limitations

3.1.1 Operational channels

The Service Request indicated that the Jemalong irrigation system was not currently operational, and that there were unlikely to be any operation-limited restrictions on the requested fieldwork. However when the assessment was undertaken in October 2009, water was being delivered to the Cowal Gold Mine, by way of the Jemalong Main, Jemalong No 2Up and Jemalong No 2A channels (as well as other channels not the subject of this investigation). This necessitated some changes to the as-proposed methodology. These changes are described in detail below (see Sections 3.2 to 3.4).

3.1.2 Artificial neural network model

The offer made in response to the Service Request was predicated on using the artificial neural network (ANN) model (Kahn *et al.*, 2007), developed at the International Centre of Water for Food Security at Charles Sturt University, to identify seepage 'Hotspots' and determine system losses. This model requires some in-field measurements of seepage loss to calibrate and train the model.

Seepage loss measurements are not possible in dry, non-operational channels. Hence the offer of services included the provision of a small number of ring infiltrometer trials. The data from these trials were to be used for calibration of the ANN model.

Having found that the Jemalong Main and Jemalong No 2Up channels were operational, it was decided to use the Idaho seepage meter to obtain data for calibration of the ANN model. Further, owing to the presence of water in these channels an electrical resistivity survey was conducted in lieu of the electromagnetic induction survey undertaken on the dry channels.

3.1.3 Dry soil conditions

As previously noted in Section 3.1.1, most of the subject channels were not in-service at the time of this assessment, with some sections having not carried water for some considerable time (*i.e.* a number of years). This, together with the prevailing drought conditions and the timing of the assessments in late spring, meant that soil moisture level were particularly low. Such conditions are not conducive to obtaining reliable or precise estimates of hydraulic conductivity with any form of infiltrometer. This is particularly the case in shrink-swell clay soils subject to severe cracking when in a dry condition.

3.2 Channel cross-sectional survey

To estimate the potential evaporative surface area of the in-service channels, cross-sectional surveys were undertaken at 35 sites in the subject distribution channels. These surveys were undertaken at locations identified by Jemalong Irrigation Limited staff as being where major changes occurred in channel dimensions or profiles.

The locations of the survey sites were logged with a handheld Garmin eTrex® H GPS (reported precision ±3 m). These locations are identified in Figure 8.

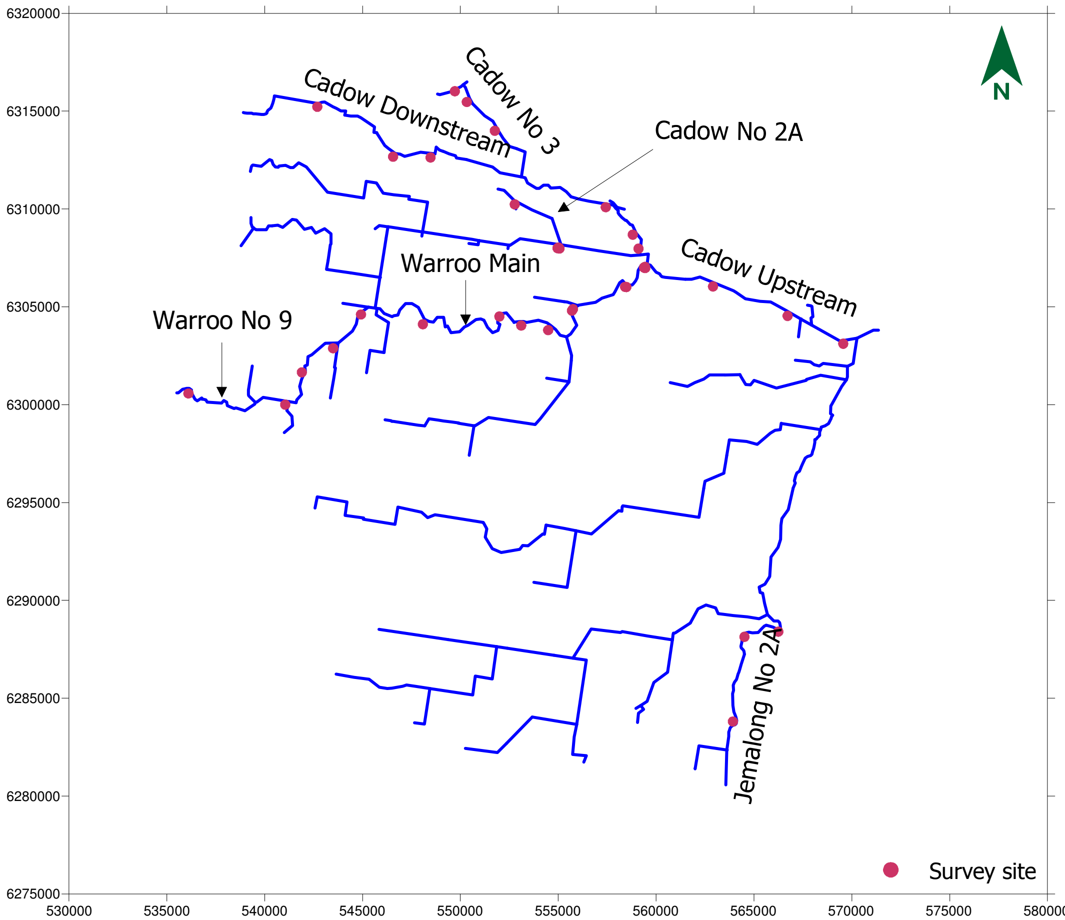


Figure 8: Locations of the 35 cross-sectional survey sites in this assessment

The cross-sectional surveys were undertaken using a dumpy level, telescopic staff and cloth tape. Measurements were taken to allow the following to be ascertained:

- Overall channel width (crest to crest);
- Basal width;
- Side batters; and
- Full supply level.

The measuring points used, and the dimensions to be obtained are represented diagrammatically in Figure 9.

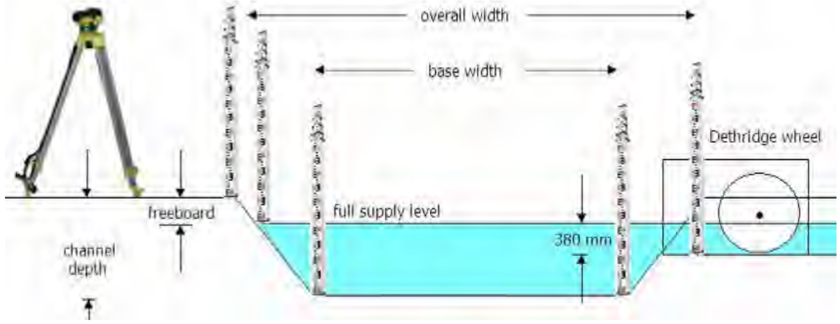


Figure 9: Diagrammatic representation of measurements made in the cross-sectional survey

Ascertaining full supply level in the empty channels was not without some difficulties, and required a number of approaches. Where off-takes fitted with Dethridge wheels were within a sight-able distance of the survey point, the height of the floor of the off-take was measured. The full supply level in that channel reach was then taken to be 380 mm above the bottom of the off-take. Similarly, where there was no off-take present, but weirs, regulators or similar infrastructure were within a sight-able distance, the height of full supply levels marked or evident on these structures was determined. In the absence of either of these indicators, full supply level was taken as being represented by the height of the uppermost flare that had been eroded in the side batter, by water carried in the channel. This later method was obviously the least precise, but its use was nonetheless unavoidable in some instances.

3.3 Electrical conductivity and resistivity surveys

3.3.1 EM31 survey

A Geonics Limited EM31-MK2 ground conductivity meter, which was co-mounted with a Trimble® EZ-Guide™ dGS on a four-wheeled motorbike, was used in the electromagnetic induction survey to measure the apparent conductivity of the substrate underlying some 80 kilometres of distribution channel in the Jemalong Irrigation system. These sections of the system represented the channels that were dry at the time of the assessment.

The EM31 meter was mounted to the side of the 4-wheel motorbike, with the transmitter and receiver 3.66 metres apart, and both some 875 mm above the ground. Figure 10 provides a photograph of the as-installed equipment used in this assessment.

Figure 10: Geonics EM31-MK2 and Trimble® EZ-Guide™ dGPS equipment fitted to the 4-wheel motorbike used in the assessment

Data collection runs were made laterally along the floor of the channels. In wider channels, parallel data collection runs, some 4 metres apart, were undertaken. A maximum of four parallel runs were undertaken in any one reach of the channel system, although in the more distal parts of the distribution system assessed in this study, the generally narrower channel widths often necessitated or allowed only a single pass.

Conductivity measurements were taken at approximately one second intervals during each data collection run, and recorded by the data logger. This logged data was then matched to the time-stamped UTM coordinates recorded by the dGPS equipment. The survey was conducted with the EM31 meter set at the 1 000 mS/m measurement range. The one second data logging interval resulted in measurements being recorded about every 2 or 4 metres along the surveyed channels – the distance interval depending on the extant operating speed of the motorbike.

Along some channel sections, extreme surface roughness, associated with very severe cracking in the very dry shrink-swell clay soils present in the affected areas, limited or physically precluded the passage of the motorbike along the channel. The very limited sections of channel not passable on the motorbike were not assessed in this study. The presence of weirs, regulators, fences and other system infrastructure also prevented conductivity measurements being undertaken in the immediate environs of these structures.

The calibration of the EM31 meter was checked on at least a daily basis at a standard benchmark location. The 'noise' in the response data, associated with the inference produced by the motorbike, was also quantified.

Figure 11 depicts those channel sections surveyed with the EM31 equipment.

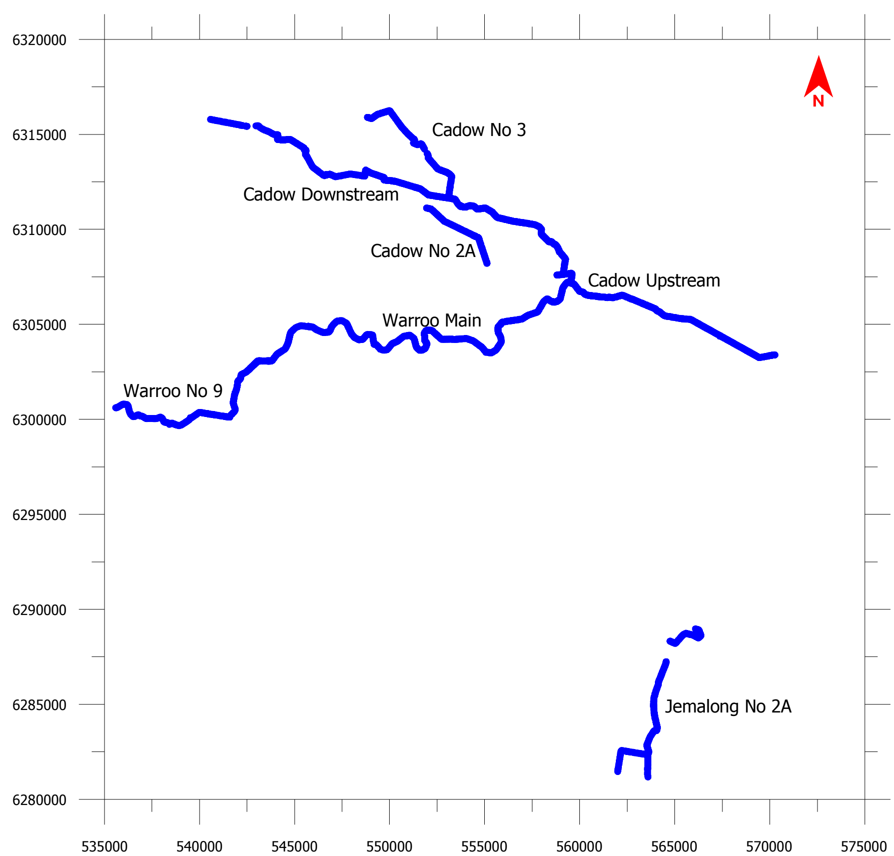


Figure 11: Sites sampled in the EM31 survey

3.3.2 Electrical resistivity survey

Groundwater Imaging Pty Ltd was subcontracted to undertake an electrical resistivity (ER) survey of in-service channels. This survey was undertaken using a geo-electric array drawn behind a boat similar to that shown in Figure 12. Information provided on the subcontractor's Internet website would indicate that the ER survey equipment normally used for these surveys includes an ABEM Terrameter ET200 transmitter and a TerraOhm RIP924b resistivity receiver. Resistivity readings are likewise matched to positional data from a Trimble dGPS located on the boat.

Figure 12: Boat-mounted electrical resistivity survey equipment similar to that used in this assessment (©Groundwater Imaging)

Figure 13 shows the location of the channels sampled in the electrical resistivity survey.

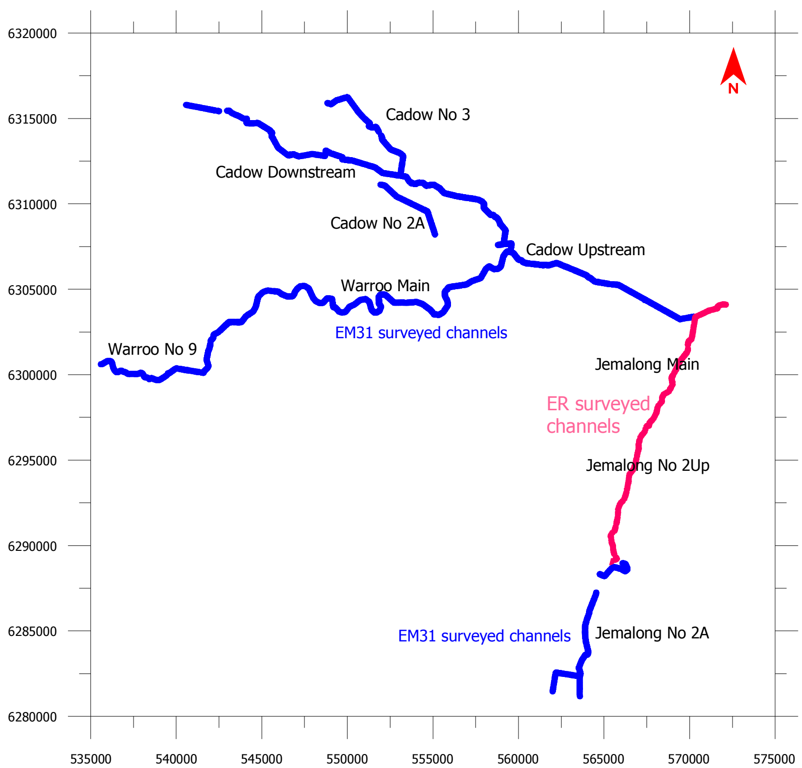


Figure 13: Sites sampled in the ER (●) survey

3.4 Seepage rate estimates

3.4.1 Infiltrometer trials

The original proposal for this assessment allowed for nine infiltration tests, using a ring infiltrometer very like that in Figure 14. The intention was to undertake three tests on three different soil types. The aim of these tests was to provide infiltration data to calibrate and train the ANN model. The data was not intended to be used directly in quantifying any seepage loss estimates.

Figure 14: Ring infiltrometer (ANCID, 2004) similar to the one used in the initial (failed) ring infiltrometer trials in this study

As can be seen from the background of the photograph in Figure 14, that ring infiltrometer is being operated on what appears to be a relatively loose, friable surface, free of any major cracking[4]. Figure 15 provides examples of soil surface conditions encountered in some of the Jemalong system channels during this assessment.

Jemalong No 2A

Warroo Main

Figure 15: Examples of surface conditions in parts of Jemalong channel system

[4] *n.b.* the cracking evident on the side batter in Figure 14 appears to be superficial cracking that is the result of surface crusting, and which does not extend significantly into the soil matrix

The initial trials undertaken in this assessment, using a large (0.25 m²) constant head single ring infiltrometer similar to that in Figure 14, and attempted in soils less severely affected than those in Figure 15, were unsuccessful. These failures were due to the following:

- Difficulties inserting the infiltrometer ring to a suitable depth in the often rough, and generally very dry, very firm and deeply cracked soils;
- Very large losses of ponded water in the deep cracks present in the soil within the ring; and
- Practical difficulties supplying the necessary volumes of water to the ring infiltrometer at rates able to match the relatively high infiltration rates in the sampled soils (*i.e.* it was not possible to maintain a constant head).

To address the above problems, the very simple, falling head well infiltrometer technique[5] was used in the trails undertaken for this assessment. The advantages of using a well infiltrometer included:

- Infiltration from the wells is generally less affected by soil cracking;
- The simplicity and speed of the assessment allowed more sampling to be undertaken;
- The drilling of the auger holes allowed a better assessment of soil characteristics and soil conditions; and
- A substantially smaller volume of water was required for the tests.

Appendix C provides a detailed account of the methodology employed in the infiltrometer trials, as well as some additional discussion of the limitations and constraints of well infiltrometers.

In all, some 25 trials were conducted using the well infiltrometer method (compared to the 9 ring infiltrometer trials originally proposed). Again owing to the less than suitable soil conditions, two of these trails failed to produce useable infiltration data.

An additional noteworthy point is that infiltration data gained from trials undertaken under dry soil conditions pertain only to those soils wetted over the limited duration of the trial – this disadvantage applying to almost any form of infiltrometer used in such conditions, and not just to the well infiltrometer utilised here. As a consequence, the hydraulic characteristics of the superficial soil layers tested in such trials may not be the limiting factor in terms of the actual seepage rates in those channels; with any deeper, less pervious material being the rate-limiting factor in these losses. The influence of this deeper material might only be measured if the soils were saturated or near saturation prior to commencing the trial. Such conditions did not exist at any of the trial sites.

3.4.2 Idaho seepage meter trials

The aforementioned presence of water in the Jemalong Main and Jemalong No 2Up channels precluded 'normal' infiltration trials being conducted in these channels within the timeframe allowed by the Service Request. The associated need to also conduct some form of resistivity or conductance survey of these two channels, and the subsequent incorporation of that data into the water balance calculations, necessitated some form of seepage tests being undertaken in these channels. The Idaho seepage meter was therefore used to undertake these extra-service trials.

The Idaho seepage meter was developed to measure *in situ* seepage flux rates from waterbodies. These flux rates may be positive (losing), or negative (gaining) – the latter occurring where interacting groundwater possess a potential head sufficient to cause it to discharge into the waterbody. Figure 16 shows a photograph of an Idaho seepage meter similar to the one used in these trails.

[5] Also known as the Porchet method or inverse auger infiltrometer

Figure 16: Idaho seepage meter (ANCID, 2004) similar to the meter used in this assessment

In all, some 14 seepage meter trials were conducted along the Jemalong Main and Jemalong 2Up channels. Figure 17 shows the locations of those trials.

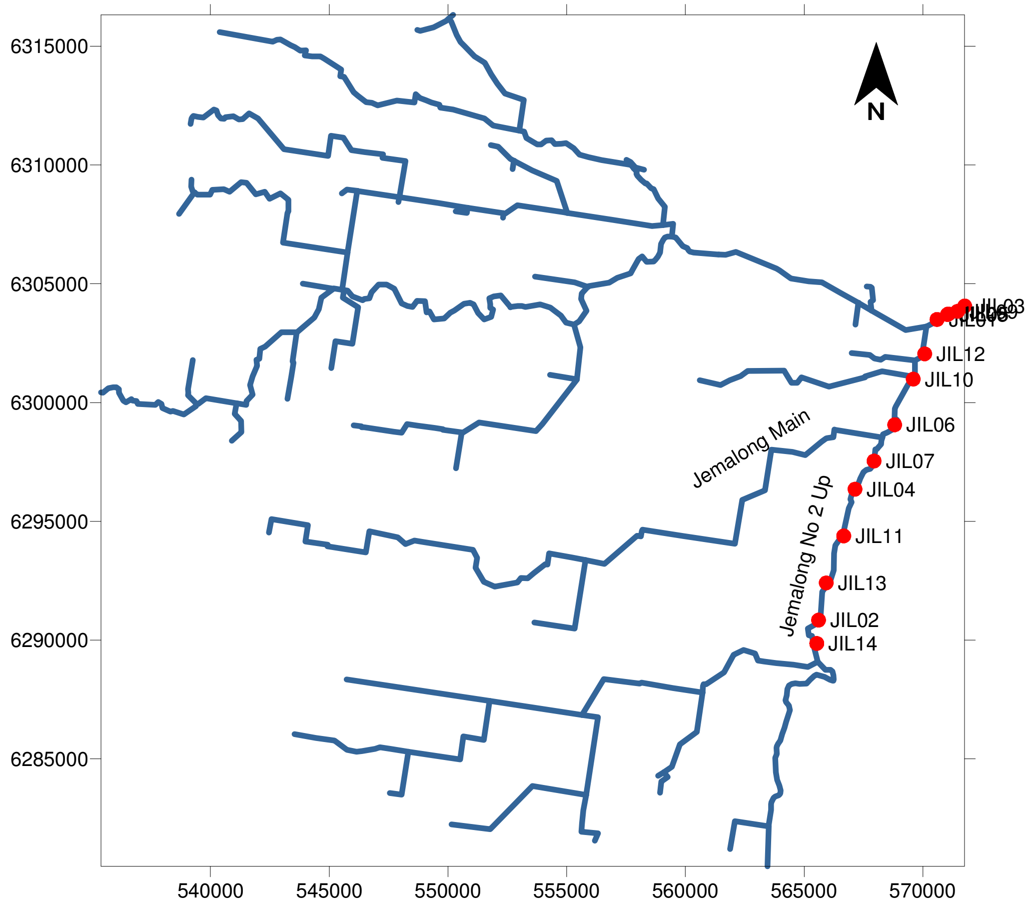


Figure 17: Locations of the 14 Idaho seepage meter trial sites (●)

Appendix D provides a detailed summary of the Idaho seepage meter and its application in this assessment.

3.5 Artificial neural network modelling

The International Centre of Water for Food Security, at Charles Sturt University, were collaborators in this assessment, and used their artificial neural network (ANN) model to provide estimates of losses in the Jemalong distribution system. Details of the model, and its use, are provided in Kahn *et al.* (2007) and Kahn *et al.* (2009). More specific information, relating to the application of the model in this assessment, is given in Appendix E of this report. The EM31, electrical resistivity and groundwater data gathered in this assessment, or presented in this report, as well as data presented in the earlier *Hotspots desktop analysis and design: Jemalong Irrigation* report (GHD, 2009), was to be used to calibrate and train the model.

4. Results

4.1 Channel cross-sectional survey

Channel dimensions obtained from the survey are provided in Appendix A.

4.2 Electrical conductivity and resistivity surveys

4.2.1 EM31 survey

Apparent conductivity (EC_a) values obtained in the survey ranged from 0.5 to 535 mS/m. However some 99.32% of the recorded values were in the range of 20 to 180 mS/m.

Figure 18 shows a spatial plot of the 80 700 data points, with the values sorted into 20 mS/m interval, colour coded groupings.

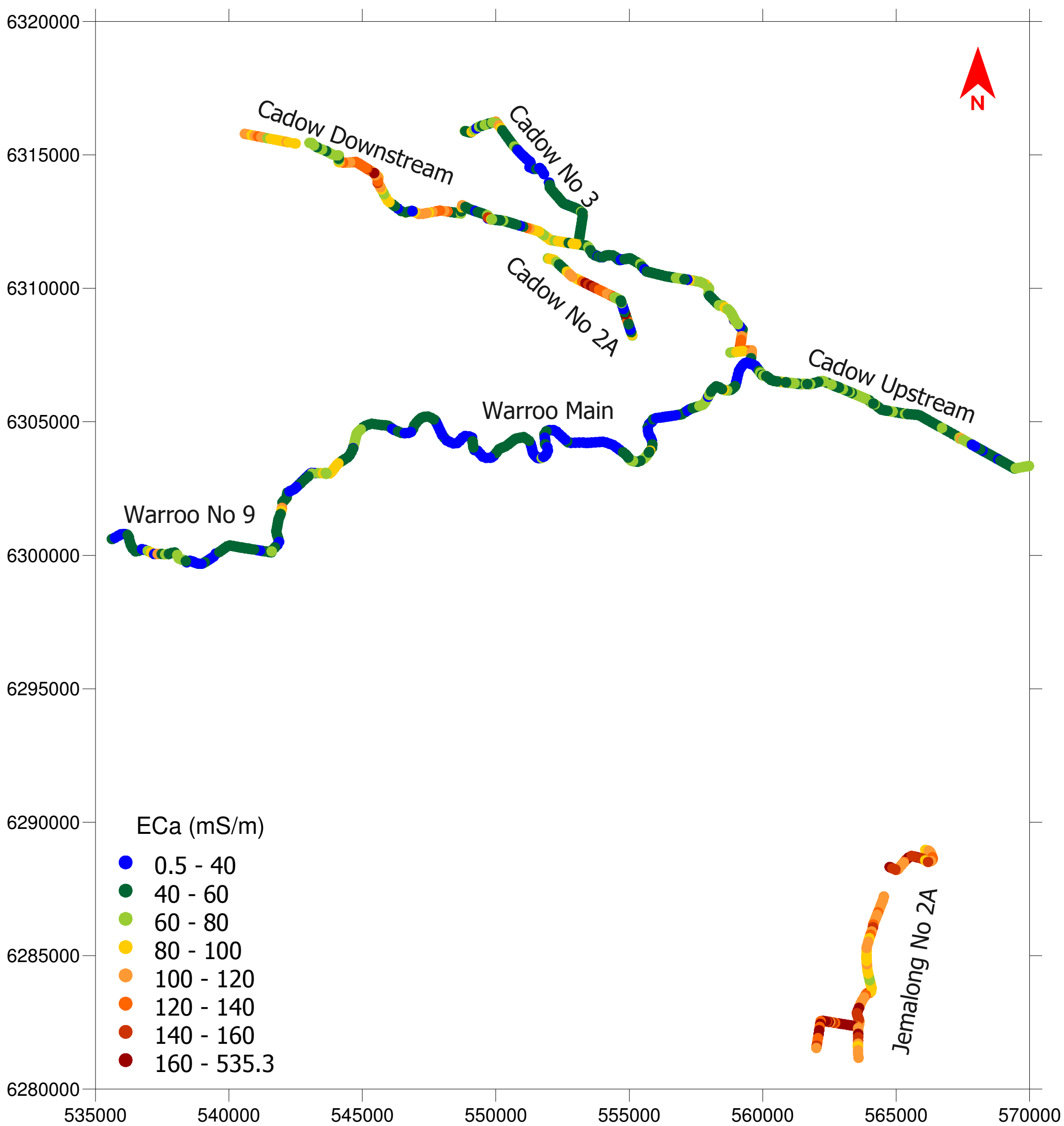


Figure 18: Plot of EC_a values in EM31 surveyed channels

Figure 19 is a frequency histogram of the EC_a values plotted in Figure 18, with the coloured symbols above ear bar corresponding to the colour scale applied in Figure 18.

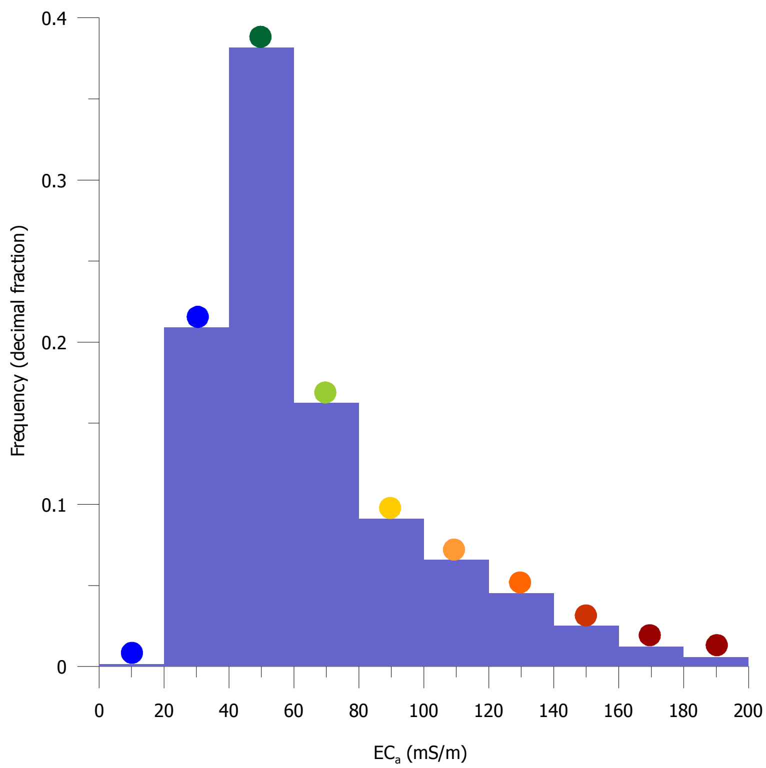


Figure 19: Frequency histogram of EM31 survey data (with symbols showing colour scale applied in Figure 18)

Figure 18 indicates that EC_a values were lowest (<40 ms/m) along significant sections of the following channels:

- Warroo Main;
- Warroo No 9; and
- Cadow No 3.

However, such low values were recorded less frequently, or less extensively, in the other channels – particular along the Jemalong 2A channel.

4.2.2 ER survey

Figure 20 provides a histogram of the electrical resistivity (ER) responses measured during the survey of the Jemalong Main and Jemalong No 2Up channels. The colour scale applied, which has been apportioned on an equal area basis, ranges from red to green to blue; representing resistivity values ranging from 1 to 10 to 100 Ω/m respectively[6].

[6] While conductivity is the converse of resistivity, ER resistivity values are not the direct mathematical inverse of EM31 apparent conductivity values

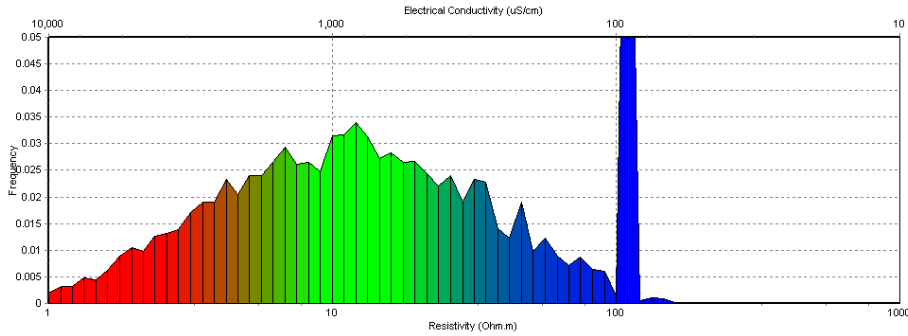


Figure 20: Histogram of ER survey data (Groundwater Imaging, 2009)[7]

Based on the colour scale in Figure 20, sites likely to be associated with large seepage losses might be expected to yield higher resistivity values (*i.e.* denoting the likely presence of 'fresher', less saline groundwater).

A 3-D representation of the ER values recorded along the Jemalong Main and Jemalong No 2Up channels is provided in Figure 21. The plotted ER data, in the form of a series of 'ribbons', has been overlain on an oblique view of the Jemalong-Wyldes Plain area obtained from Google™ Earth. The higher resistivity areas along the ribbons are represented as blue or blue-green areas. The height of the ribbons corresponds to a regolith depth of 32 metres

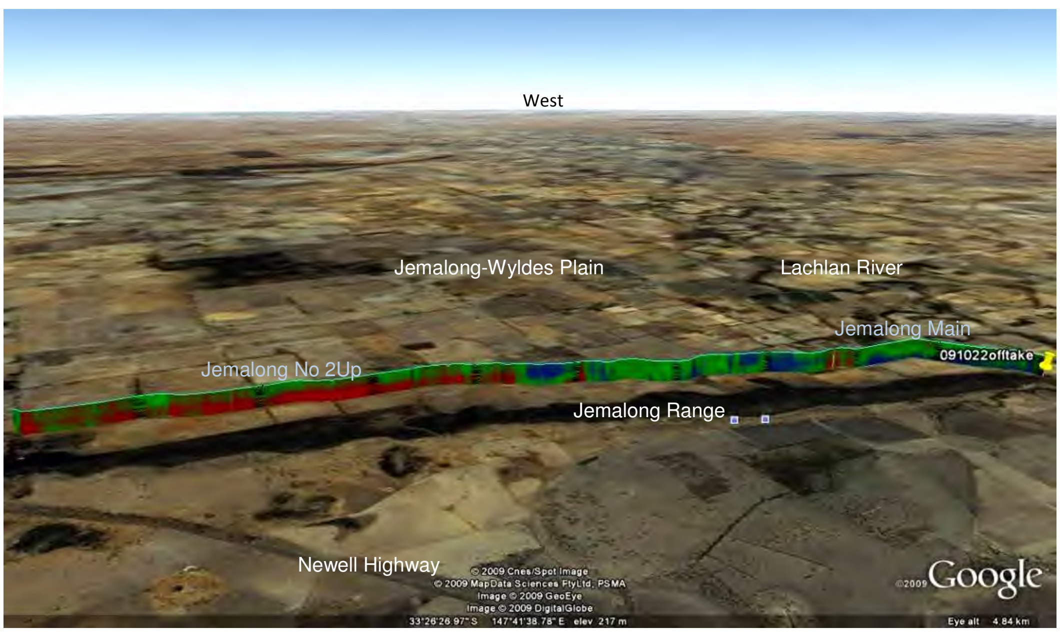


Figure 21: Oblique view of the Jemalong-Wyldes Plain (©Google™ Earth, 2009) overlain with the ER data for the Jemalong No 2Up channel and the upstream Jemalong Main channel (Groundwater Imaging, 2009)

From Figure 21 it can be seen that the two surveyed channels track along the western footslopes of the Jemalong Range[8]. Also evident is that most of the surveyed section of the Jemalong Main channel, and the northernmost section of the Jemalong No 2Up channel, are associated with areas having high resistivity responses (*i.e.* potentially 'leaky' sections).

[7] (a) The blue bar towards the right in the histogram represents the resistivity (and conductivity) values for the actual channel water, and
(b) the x-axis is on a logarithmic and not a linear scale.

[8] Seen as the narrow, dark wooded band in Figure 21

4.3 Seepage assessments

4.3.1 Infiltrometer trials

The infiltration rate time series data obtained for each trial site was fitted to three widely recognised infiltration models (*i.e.* the Philip, Horton and Kostiakov models). Coefficient of determination (r^2) and *t*-test values were computed for each model dataset, to provide an indication of the 'goodness of fit' of the model output with the actual infiltration rate data.

Overall the Horton model tended to provide more consistent agreement between the observed and model values, particularly during the later stages of the infiltration process when hydraulic conductivity is likely to be the dominant factor in the observed intake rates. It is noted though that the Horton model, with one of two exceptions, provided consistently higher K_{fs} values than either the Philip or the Kostiakov model.

The Horton model is based on the following equation:

$$i_t = K_{sat} + (i_0 - K_{sat}) \times e^{\beta t}$$

Where: i_t = infiltration rate (mm/hr) at time t;
K_{sat} = saturated hydraulic conductivity (mm/hr);
i_0 = initial (t = 0) infiltration rate (mm/hr); and
β = an empirical exponent.

The K_{fs} values obtained from the trial data in the middle to lower range of those that might be expected for a natural soil, although still somewhat elevated for a material exposed in the floor or an irrigation channel. The K_{fs} values, together with the corresponding EC_a value for each trial site, are shown in the scatter plot in Figure 22[9].

[9] n.b. The lengths of the axes in Figure 22 are indicative of the typical range of K_{sat} and EC_a values in soils

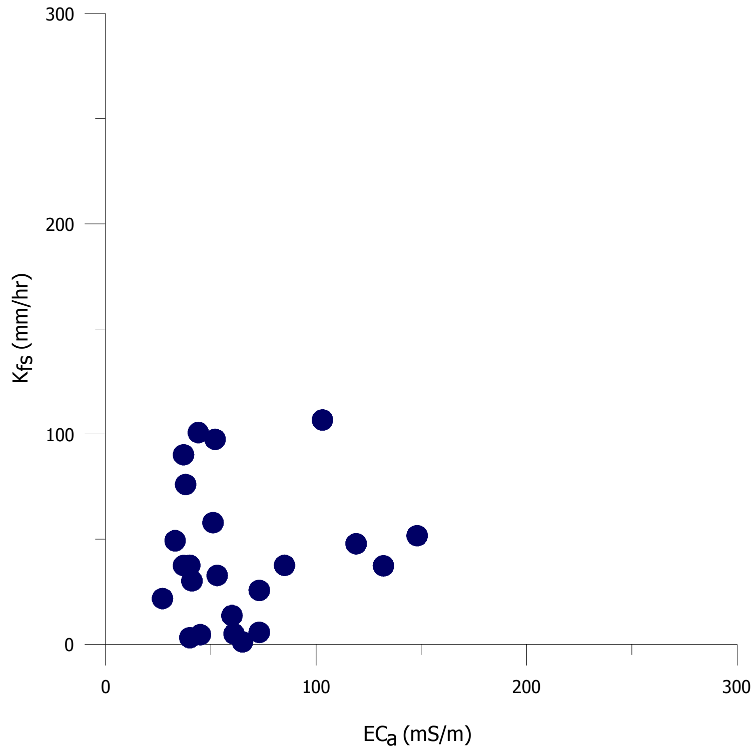


Figure 22: Scatter plot of apparent conductivity (EC_a) and hydraulic conductivity (K_{fs}) values for each trial site

There is no statistically significant trend evident in the plotted values in Figure 22.

Figure 23 shows the locations of the 25 infiltration trial sites, with the corresponding K_{fs} values represented as circular symbols in which the diameter of the symbol is proportional to the K_{fs} value obtained at that site. Trail sites JI02 and JI04 (from which infiltration data was not obtained) are depicted by medium-sized unfilled symbols.

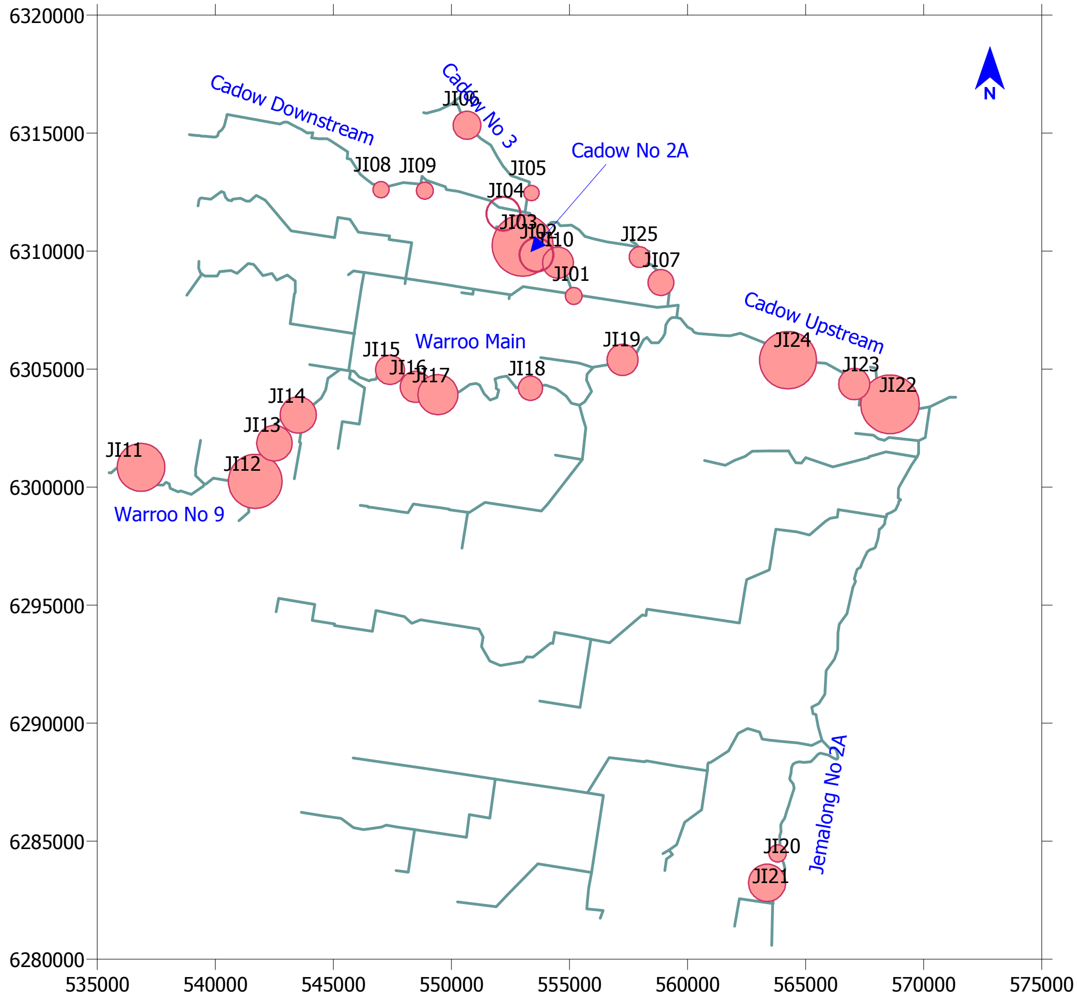


Figure 23: Infiltration trial sites with symbol diameters showing the relative K_{fs} values for each site

Casual observation might suggest that those sites in Figure 23 having higher than average K_{fs} values were at the following locations:

- Along the middle and terminal sections of the Cadow No 2A channel;
- Along the Warroo Channel (in particular the more distal sections); and
- At two locations on the Cadow Upstream channel

More comprehensive details of the above results are provided in the infiltration trial report provided in Appendix C.

4.3.2 Idaho seepage meter trials

The seepage rates obtained with the Idaho seepage meter in the Jemalong Main and Jemalong No 2Up channels were all very low (*i.e.* <0.0001 – 0.013 mm/hr); even when compared to the values obtained by van der Lelij (1993) for the Warroo Main channel (*i.e.* 0.25 – 64 mm/hr). By themselves these results might imply that the two Jemalong channels are not a source of significant seepages losses from the system.

Notwithstanding the above, Figure 24 provides a scatter plot of the seepage rates, and the corresponding electrical resistivity (ER) values at a depth of four meters, at the 14 trail sites (refer Section 4.2.2). With the very low rates observed in the Idaho seepage mater trials, it might be expected that resistivity levels at these sites would be very low (*i.e.* <<5 Ω/m). In fact the near converse is true, with resistivity levels in the mid to high range (represented by green and blue green on the colour scale in Figure 20, page 23).

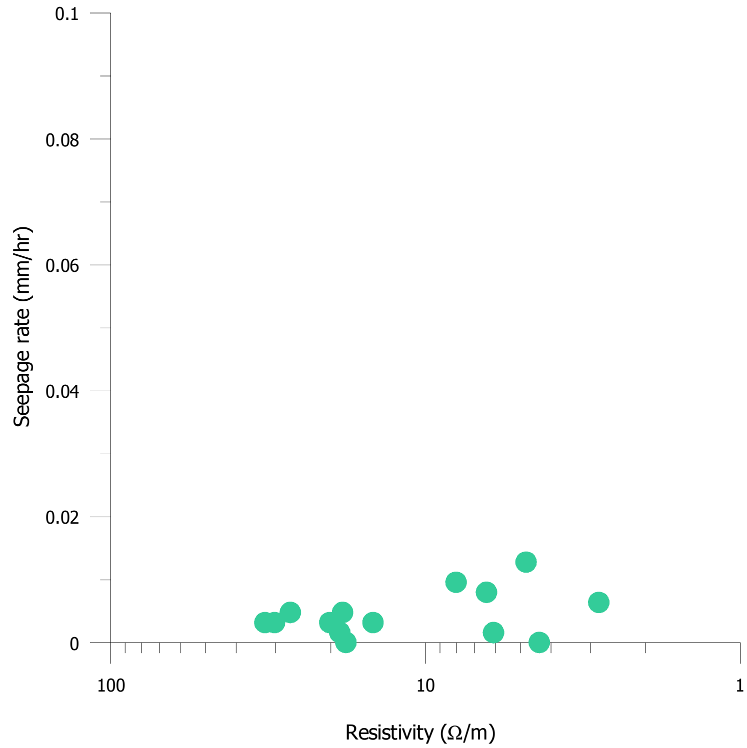


Figure 24: Scatter plot of electrical resistivity and seepage values for each trial site (*n.b.* the x-axis is plotted on a $\log_{10}$ scale and, being resistivity rather than conductivity, in reverse order)

Again there is no statistically significant trend evident in the plotted values in Figure 24.

4.4 ANN model predictions

4.4.1 Model calibration

Appendix E provides details on the calibration of the ANN model.

The modellers were only able to adequately parameterise and train the ANN model for the Warroo Main and Warroo No 9 channels. Attempts to calibrate the model for the Jemalong system proved unsuccessful. This lack of success was reportedly due to the extremely low seepage rates values obtained in the Idaho seepage meter trials undertaken along that channel (refer Section 3.4.2).

The well infiltrometer data proved unusable in the model.

The modellers reportedly found that the following variables provided the best estimators of seepage loss in those channels:

- Water table elevation;
- Standing water level (SWL) in the piezometers;
- EC_a values derived from the EM31 survey; and
- Salinity (EC) values of groundwater in the monitored piezometers.

Figure 25 provides a pie chart depicting the relative contribution of these variables to the seepage rate estimates provided for the Warroo Main and Warroo No 9 channels by the ANN model.

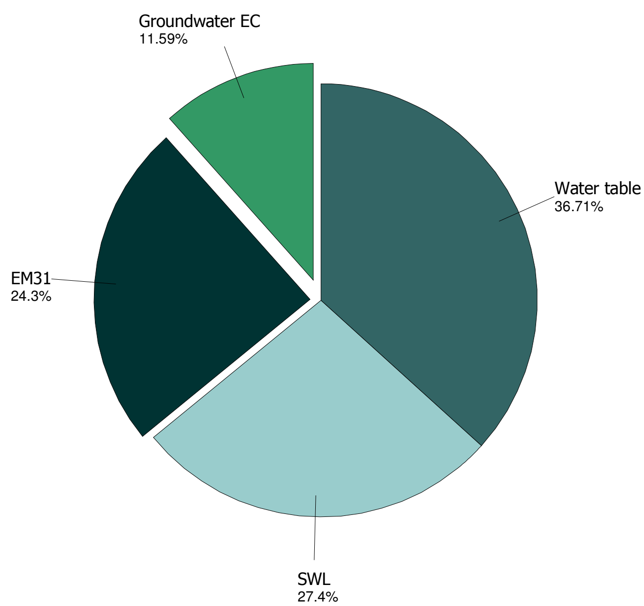


Figure 25: Contribution of input variables to the ANN model when estimating seepage rates in the Warroo Main and Warroo No 9 channels

Further details of the nature of the weighting process applied in the ANN model to the various the data sources are provided in Appendix E.

From Figure 25 it can be seen that the contribution made to the ANN model seepage rate estimates by the EC_a data, was relatively small, being less than 25%. This small contribution might appear surprising considering the importance given to conductivity data (*i.e.* EM31 and EM38) in previous assessments of channel seepage, and in the Service Request.

A significant factor in the minor contribution is undoubtedly the poor relationship between the contemporary EC_a values and the now 16-year old Idaho seepage rate data for the Warroo channel, from van der Lelij (1993), which was used to train the model. This poor relationship is evident in the scatter plot in Figure 26.

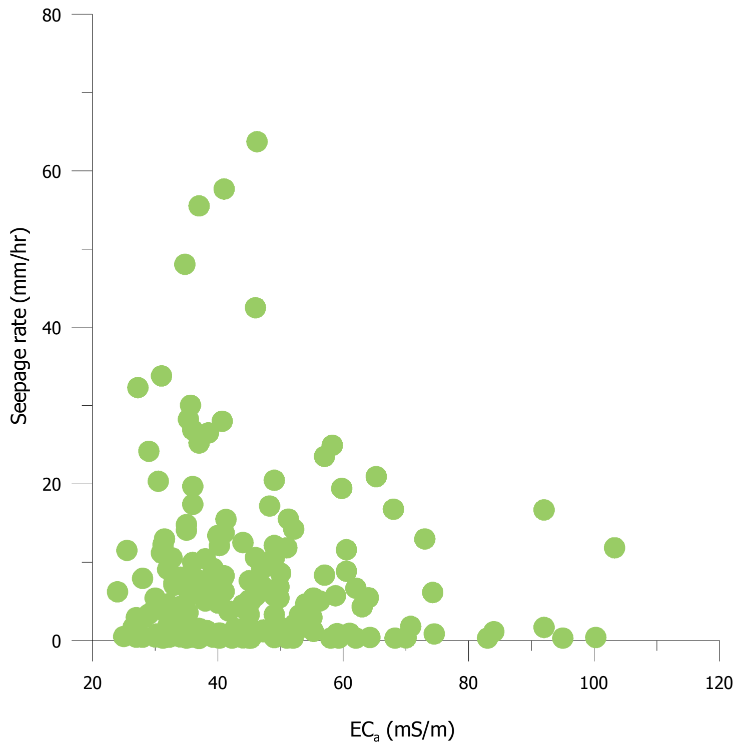


Figure 26: Scatter plot of apparent conductivity (EC_a) and Idaho seepage meter data or van der Lelij (1993)

As might be expected, no statistically significant trend is evident in the plotted values in Figure 26.

It might also be noted that in the very gently sloping, very low relief terrain of the Jemalong-Wyldes Plain, water table elevation and standing water levels are not entirely independent variables, and in a statistical sense are likely to suffer to some degree from collinearity.

4.4.2 Model predictions and validation

Figure 27 provides a scatter plot comparing the Idaho seepage meter data of van der Lelij (1993), with the estimated seepage rates provided by the ANN model, for the sites along the Warroo Main channel where van der Lelij undertook the original tests.

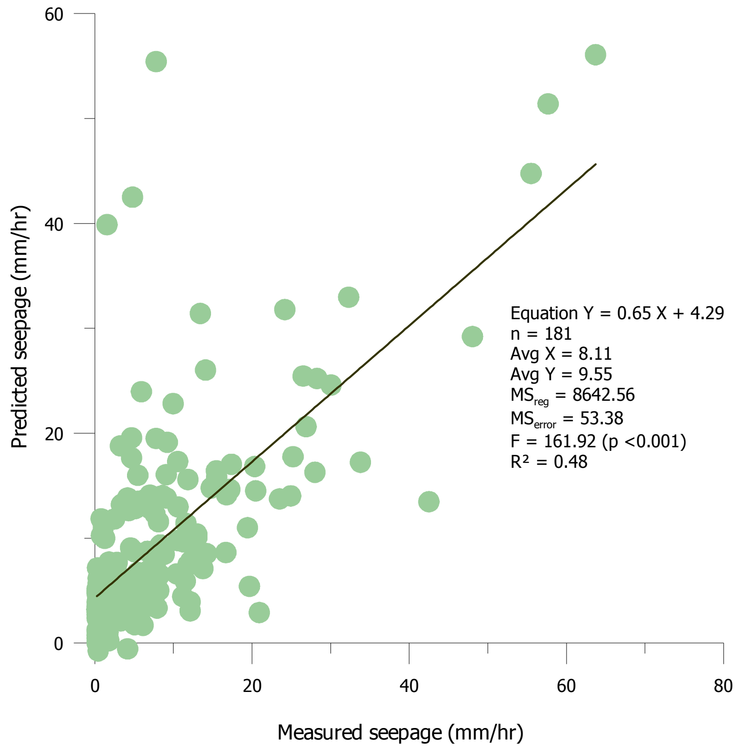


Figure 27: Scatter plot of measured seepage rates (van der Lelij, 1993) and predicted rates

While there is a very strong correlation between the predicted and actual seepage rates in Figure 27, the predicted values are on average 50% greater than the corresponding measured values.

Figure 28 is a colour-coded representation of the ANN model predictions of seepage rates at the various sites on the Warroo Main and Warroo No 9 channels. The plotted values would suggest that seepage rates are generally highest in the middle and upper reaches of the Warroo Main channel.

Figure 28: Predicted seepage rates (m/day) in the Warroo Main and Warroo No 9 channels (source Hafeez *et al*., 2009)

5. Discussion

5.1 ANN model predictions

5.1.1 Hotspots

The ANN model indentified a number of potential seepage Hotspots along the Warroo Main channel. These are shown in Figure 29. Appendix E should be consulted for additional information on the derivation of this map.

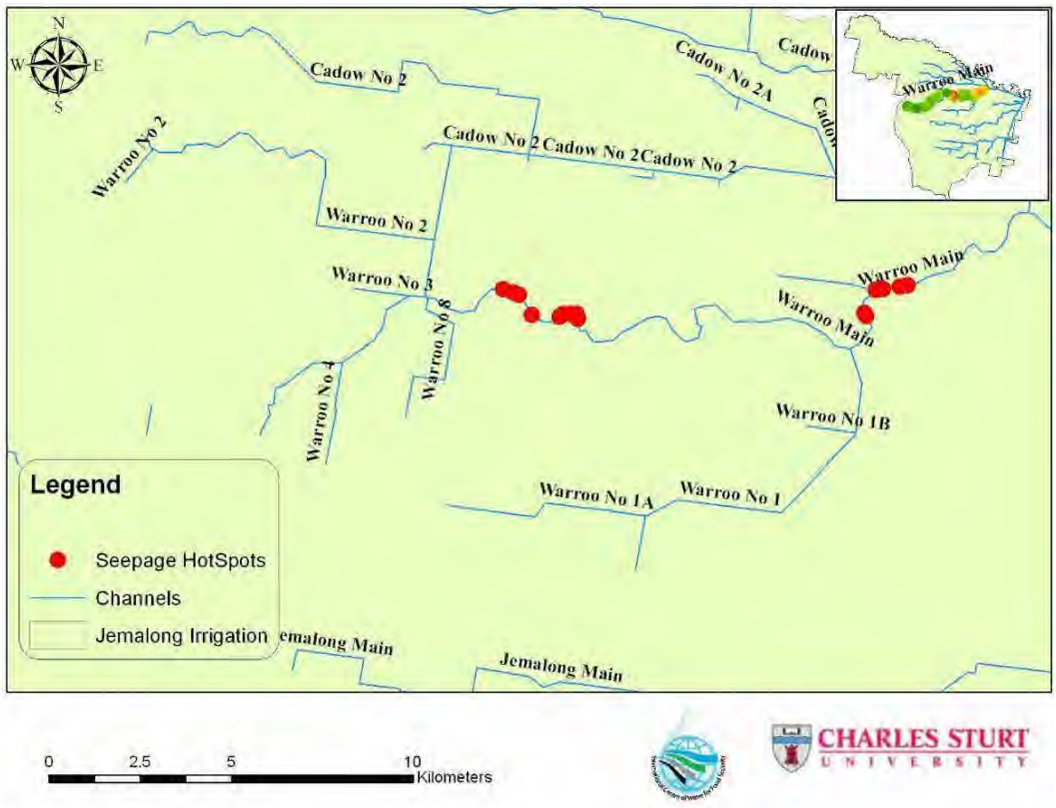


Figure 29: Seepage Hotspots in the Warroo Main channel identified on the basis of the ANN modelling (source Hafeez *et al.*, 2009)

The predicted Hotspots shown in Figure 29 appear to have some merit when compared to other data and information presented in this assessment (*e.g.* groundwater data in Section 2.3.1). However, as with any proprietary 'black box' model it not particularly easy to independently replicate the modelling, and so verify the model output. The priority that might otherwise apply to the identified Hotspots needs to be tempered by the channels that have been mapped in Figure 29 representing only two of the nine channels that were to be assessed in this assessment, and an even smaller proportion of the balance of the Jemalong distribution system.

5.1.2 Water balance

Table 3 shows a monthly water balance for Warroo and Cadow channels in Division 1 of the Jemalong system. The water balance covers the period from November 2005 to May 2006 inclusive. The reasons for the selection of that period, when undertaking the water balance calculations, are given in Appendix E of this report, as are the methods by which these estimates were obtained.

The evaporative losses used in Table 3 are based on FAO-56 ET_0 values[10]. Muirhead *et al.* (1997) provide the rational behind using ET_0 values, rather than pan evaporation data, for small water bodies in irrigation areas in western New South Wales. Loss estimates made using other predictive measures of evaporation are provided in Appendix E. Given the relative magnitude of the evaporative losses in Table 3, when compared to other components of the water balance, the differences between various surrogates for potential evaporation are likely to be relatively minor and can be safely disregarded.

Table 3: Monthly water balance for all the Warroo and Cadow (Division 1) channels for the period Nov 05 – May 06

Month	Diversions (ML)	Deliveries (ML)	Evaporation (ML)	Losses (ML)
Nov 05	882	90	179	613
Dec 05	2 253	1 300	238	715
Jan 06	3 051	1 098	242	1 711
Feb 06	1 592	698	203	691
Mar 06	2 972	1 673	171	1 128
Apr 06	2 581	1 470	107	1 003
May 06	2 014	778	67	1 170

The predicted monthly system losses in Table 3, which include both operational and seepage losses, cover a range between a minimum of 32% of diversions in December 2005, and a maximum of 70% of diversions in November 2005. For the 6-month period in Table 3, these particular losses represented an average of 46% of total diversions. Assuming that (1) the above estimates are accurate; (2) they are replicated across the Jemalong channels in Division 2; and (3) they can be replicated in time; then this water balance suggests that close to 50% of diversions might be being lost from the system in the form of seepage and operational losses. Accordingly any ability to significantly reduce these particular losses may generate significant benefits.

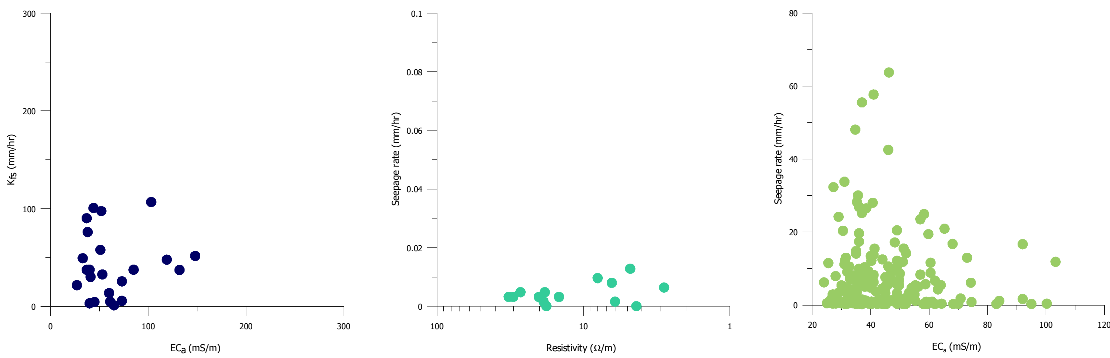
Overall, evaporative losses were predicted to account for only around 8% of diversions into the system. Thus mitigating these losses would appear likely to provide a less beneficial, and likely less productive means of improving the efficiency of the distribution system.

[10] The ET_0 values used are from a SILO DATADRILL dataset, and thus a default wind speed of 2 m/s can be assumed to have applied in deriving these values (DERM, 2009)

5.2 Conductivity and Resistivity data

5.2.1 Relationships with measured hydraulic properties

Figure 30 re-presents the scatter plots previously provided as Figure 22, Figure 26 and Figure 27. These scatter plots compare infiltration and seepage data obtained in this and previous assessments, with the data obtained in the electrical resistivity and conductivity surveys of the subject irrigation channels.



Infiltrometer data *vs* EC_a Idaho seepage meter *vs* ER Idaho seepage meter *vs* ECa

Figure 30: Comparison of the scatter plots of infiltrometer and seepage meter data and conductivity and resistivity data related to this assessment

In none of the plots in Figure 30 was there a statistically significant relationship between the two sets of variables. For example, when logarithmic regression equations are fitted to the data the coefficient of determination (r²) values for the respective datasets are 0.0007, 0.141[11] and 0.003 respectively (*i.e*. left to right in Figure 30). Compare these values and the associated scatter plots with the scatter plot and r² value in Khan *et al.* (2007), as reproduced in Figure 31.

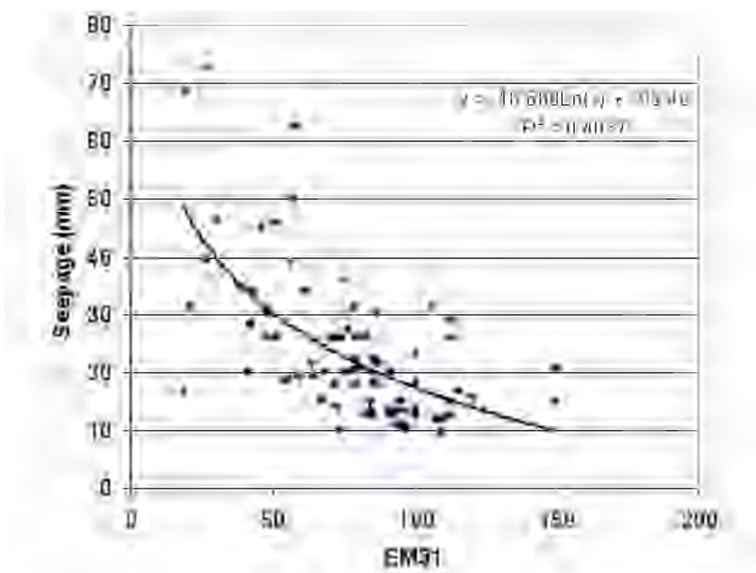


Figure 31: A copy of the scatter plot of apparent conductivity (EC_a) and seepage data in Khan *et al.* (2007)

[11] While the r² value for the ER data is greater than the others, the analysis of variance does not provide a significant F-statistic value, and the logarithmic regression equation fitted to the data slopes the 'wrong' way (*i.e.* lower resistivity values are associated with higher seepage rates)

There are a number of reasons why there might be a lack of any statistically significant relationship between the conductivity or resistivity data and the hydraulic data in Figure 30. Some of the more readily apparent reasons include:

- There might actually be no direct or readily quantifiable relationship;
- The method with which one or more of the variables was measured is deficient; and
- The datasets are too small or cover too small a range of values for a strong relationship to be established (*e.g.* the EC_a are predominantly on the lower end of the normal response range and the ER values at the higher end).

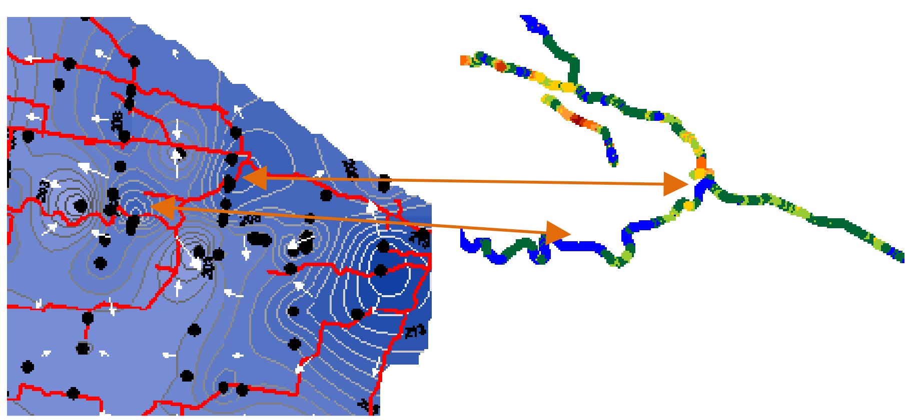
Reference back to matters discussed in Section 3.1.3 (pages 12) would suggest that owing to the characteristics of many of the soils in the Jemalong system, and in particular the soil conditions at the time this assessment was undertaken, it is not entirely unexpected that the infiltrometer trials would fail to produce data that was accurate or precise enough to be of use as a modelling input – such infiltration data being more semi-quantitative in nature, and possibly more useful in evaluating the relative 'leakiness' of soils at different sites, rather than providing precise values suitable as input data in a model.

The remarkably low values obtained in the Idaho seepage meter trails during this assessment have also been previously mentioned (refer Section 4.3.2), and are of some concern.

In respect specifically to the Idaho seepage data of van der Lelij (1993), the age of this data means that any subsequent, and potentially non-uniform changes in soil conditions in the Warroo Channel (*e.g.* siltation, channel cleaning and rehabilitation operations, channel realignment, soil salinisation or sodification, *etc.*), may mean that the extant soil conductivity data will inevitably have a poor or inconsistent relationship with the 16 year old seepage data.

5.2.2 Relationship with groundwater data

Some tentative, but far from consistent relationships between locations of groundwater mounding in Figure 5, and areas of low apparent conductivity Figure 18, are evident in a visual comparisons of representations of these data provided in Figure 32. It may be also noteworthy that neither of the potentially 'leaky' areas highlighted here, correspond with the Hotspots identified by the ANN model in Figure 29 (page 32).

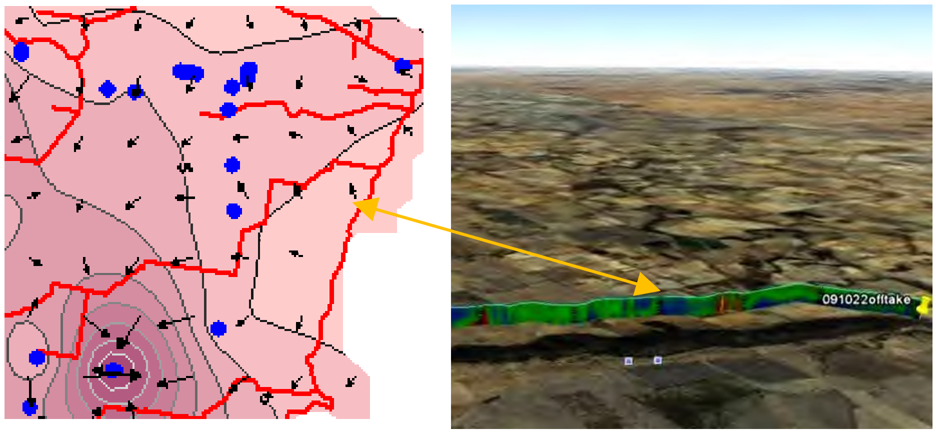


Piezometric surface mapping

EC_a values

Figure 32: Comparison of water table elevation mapping from Figure 5 and EM31 derived EC_a values from Figure 18

Likewise in Figure 33, an area of higher resistivity previously identified along the Jemalong Main and the upper reaches of the Jemalong No 2Up channel in Figure 21, corresponds with an area where there appears to a significant influx of fresher (less saline) groundwater in Figure 6 (page 10).



Groundwater EC mapping ER response ribbon

Figure 33: Comparison of groundwater EC mapping from Figure 6 and ER response data from Figure 21

The casual relationships observed in Figure 32 and Figure 33 might suggest that the resistivity and conductivity data are of more value than the seepage and infiltration estimates obtained in this assessment, or certainly of more value than suggested by the ANN modelling. A fuller investigation of these relationships is however beyond the resources available in this study.

6. Conclusions

Analysis of the data from the infiltration and seepage rate trials undertaken in this Hotspots assessment did not find any statistically significant relationship between that data and the respective EC_a and ER data obtained in the concurrent electrical conductivity and resistivity surveys of the channels in the Jemalong system.

One factor contributing to the lack of any strong relationship may be the imprecision commonly associated with infiltration and seepage rate measurements. Another contributory factor might be that both conductivity and resistivity values are influenced by factors other than soil salinity levels *per se*. McNeill (1980) identified the following as factors that may have a significant influence on conductivity and resistivity responses:

- Soil texture (*i.e.* clay content);
- Clay mineralogy and cation exchange capacity;
- Extant soil moisture contents;
- Ionic species present in the soil solutions;
- Soil temperature; and
- Regolith depth and the geological characteristics of the substrate.

The influence of many of the above factors is likely to differ between geological units and soil types. At least three major soil types, and a similar number of geological units, occur in the areas traversed by the subject channels (refer sections 2.2.1 and 2.2.2). Quantification of some of these variables (*e.g.* quantitative data on particle size distribution data, cation exchange capacity, soil moisture content, *etc.*), might have allowed these to either be identified as extraneous or inconsequential factors, or incorporated as component variables when modelling the seepage losses from the channels.

Despite the above, both the moderate to high infiltration rates and the relatively low EC_a values obtained in this assessment might indicate that the soils are all relatively 'leaky' – unusually so for the soils that appeared to have a substantial clay content. Such a conclusion regarding their leakiness is consistent with hydraulic conductivity estimates for the soils in the Jemalong area provided by King (1998). Similar observations could not be made in respect to the seepage rate and the corresponding ER data – although trends in the ER data did appear consistent with those in the EC_a data.

Casual comparisons of electrical conductivity and resistivity data, and recent groundwater salinity and watertable elevation monitoring data, suggest some potentially strong correlations exist between these datasets. Hence despite the poor relationships observed with infiltration and seepage rate estimates, the conductivity and resistivity data may still be of significant value in respect to identifying potentially 'leaky' sections of the Jemalong channels. However, the conductivity and resistivity data by themselves do not allow any quantification of the losses. A more extensive survey and data analysis, beyond the scope of this study, would be required to properly evaluate any correlation between the conductivity and resistivity data and groundwater monitoring data.

In this assessment, attempts to identify seepage Hotspots and quantify seepage losses using the ANN model were very much constrained by the inability to establish relationships between the conductivity and resistivity data, and the hydraulic conductivity and seepage rate estimates. The resultant reliance on 16-year old seepage rate estimates to calibrate and train the ANN model is thus of some concern. Accordingly, while the ANN modelling did identify some potential Hotspots in the Warroo channel, a high level of confidence cannot be held in respect to the reliability of either this identification, or the associated Division 1 water balance predictions (see Table 3, page 33).

Notwithstanding the problems experienced in using the ANN model in this assessment, it should not be assumed that the model is necessarily critically flawed or unsuitable. Conditions peculiar to the Jemalong system, and in particular many of the channels being out-of-service (*i.e.* ‘dry’) at the time of the assessment, may be outside of those under which the model was originally developed and tested. If that is the case, further refinement of the model might allow it to yield usable predictions for out-of-service channels in the future.

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8. Appendices

Appendix A. Channel cross-sectional survey data

Appendix B. Electrical resistivity assessment

Appendix C. Infiltrometer trials

Appendix D. Idaho seepage meter trials

Appendix E. Artificial Neural Network Modelling

JEMALONG IRRIGATION LIMITED

IRRIGATION MODERNISATION PLAN

Prepared for **Jemalong Irrigation Limited**

With the assistance of **The Australian Government**

Prepared by **Western Land Planning Pty Ltd**

DOCUMENT CONTROL SHEET

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Jemalong Irrigation Limited has relied on independent consultants to provide information and findings in this report.

FOREWARD

It is, with a great sense of responsibility, that I write this foreword to this very important document. The last 7 - 8 years of drought have drastically affected the Forbes Shire, both socially and economically ie. loss of jobs and therefore a drop in population, and also loss of income to the town and shire, normally generated from the irrigation of a wide variety of crops and the fattening of stock.

Having been an irrigation farmer in the Forbes area since 1980, I have been involved in river committees, ie The Lachlan River Advisory Committee; Upper Lachlan Water Users; The Lachlan River Management Committee, which was responsible for producing the Water Sharing Plan for the Lachlan River. I have also served on Forbes Shire Council since September 1990, including 7 years as Mayor, and so have firsthand knowledge of Jemalong Irrigation Ltd and its directors.

The Jemalong Irrigation area is a substantial part of the irrigation in the Forbes Shire, indeed in the Lachlan Valley, consisting of some 90,000 ha of farming land. In the pre drought years an average of 75% of entitlement was used, ie 60,000 ML grossing around $25 million per annum.

The very pro-active Directors of Jemalong Irrigation Ltd have initiated the production of farm plans on all of the members' farms (approximately 100) receiving Jemalong water. Western Land Planning has been commissioned to do this work. This review, already in process, incorporates all water management on farm, ie water reticulation, irrigation methods, suitability of crops on different soil types and generally producing more with less water. The review is funded by Jemalong Irrigation Ltd. Importantly the farm plans will assist in the modernization planning of the Jemalong distribution network.

I applaud the concept of the Irrigation Modernisation Plan by Jemalong Irrigation Ltd; in as much as it studies ways of achieving efficiencies of water delivery; to do more with less water, especially with the ominous climate change issues hanging over us.

It is also important to note that Jemalong Irrigation Ltd supplies water for stock and domestic purposes, some 2750 ML in total. In the case of domestic users there are approximately 150 families involved with relatively no useable ground water in the area, and no other way of sourcing water. It is imperative that the most cost effective and efficient plan is chosen for stock and domestic water. There are two options in the report. It should however be pointed out that, with no water available for cropping over the last seven years, the production of livestock has been the only source of income.

I applaud also the concept of Government Funding to achieve water delivery efficiencies. This is beneficial to both Government and water users alike. In comparison to the Government water buy back scheme, which removes water from communities depleting the earning capacity of a given area with no real plan on how the Government will use the acquired water. This results in job losses and therefore population movement from rural communities to our already overcrowded cities.

The water saving, achievable in the Modernisation Plan, is significant and, as pointed out earlier, the saving will be beneficial to both the environment and producers. To their credit, the Jemalong Irrigation Ltd set up a review committee of irrigators (one from outside JIL) to peruse and advise on the document before it is presented to the Government.

In conclusion, I look forward with anticipation and excitement to the adoption and implementation of this Modernisation Plan, which will undoubtedly be of great benefit not only to Jemalong Irrigation Ltd but also to the whole of the Forbes Shire.

s 22(1)(a)(ii)

Forbes Shire Council

JEMALONG IRRIGATION

ABN 76 067 197 782 ACN 067 197 782
Postal Address PO BOX 520 Forbes NSW 2871
Telephone 02 68574201 Facsimile 02 68574267
Email jil@westserv.net.au

Memorandum from the Chairman Jemalong Irrigation (JIL)

The Board has pleasure in lodging the "Jemalong District Irrigation Scheme Modernisation Plan" for Jemalong Irrigation Ltd. This report has been prepared by Western Lands Planning (WLP), the project manager, and provides an assessment of a full range of possible engineering solutions for the JIL infrastructure.

JIL acknowledges and appreciates this has been largely funded by the Commonwealth Government with JIL also contributing by implementing and financing farm water efficiency plans. It has provided a unique opportunity to assess costings of, and then evaluate options for, a reduction in transmission losses in JIL and thereby a more efficient delivery of water to our customers. The Plan also analyses the on farm losses and proposes solutions. Losses occur all the way from channel to infiltration past the irrigated plant root zone. Assessment of Stock and Domestic options is considered critical to the long term viability of the area. The past seven years has highlighted the need for security of these supplies.

Consultation with our shareholders has been indirectly through the farm planning done by WLP. All farmers in JIL are part of the Modernisation Planning (MP) as future demand by farmers, as indicated in farm plans, reveals likely supply requirements. The appointment of a review committee (mostly JIL irrigators) has provided consultative input. Time (i.e. deadlines to be met) has not allowed for consultation with all the shareholders about the contents on the Modernisation Plan. It is intended to do this at the next stage.

The plan has noted, and JIL strongly believes, that further investigation projects are required by the Federal Governments Hotspots Program. This is needed to identify the trouble spots with the highest leakage in the channel system. This is essential for the assessment of options in the next stage. A range of options from total lining of channels with different materials to piping have been assessed and this can be applied to the results of the Hotspots Program.

s 22(1)(a)(ii)

Chairman

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EXECUTIVE SUMMARY

Background

Water use in the Lachlan Catchment exhibits similar demands as throughout the entire Murray-Darling Basin. The environment, households, stock, the production of food and fibre and mining and manufacture industry each require a proportion of the available surface water each year. The sustainable distribution of water resources between these users is critical to the long-term survival of water ecosystems, and rural and urban communities.

This Irrigation Modernisation Plan has been funded through the *Sustainable Rural Water Use and Infrastructure* program, part of the Australian Government's *Water for the Future* initiative. It presents several options for modernising the water delivery and on-farm irrigation infrastructure in the Jemalong Irrigation District within the Lachlan Catchment. It demonstrates that modernising irrigation in the district has potential to make significant and lasting water savings that may be transferred to the Commonwealth Environment Water Holder for use in the management of the Lachlan Catchment's environmental assets. Irrigation modernisation is also likely to sustain the regional community and national food production.

The Lachlan River rises near Goulburn and flows generally east to west over 1,450km to the Great Cumbung Swamp near Oxley. It is unique in the Murray-Darling Basin in that it is a predominantly terminal system: flows from the Lachlan River reach the Murrumbidgee River only when both rivers are in flood. Wyangala Dam is the largest structure in the catchment, with a capacity of 1,220,000ML. Carcoar Dam, Lake Cargelligo and Lake Brewster are other important water storages, along with numerous weirs. Several effluent (divergent) creeks occur in the lower part of the catchment and there is significant braiding of streams in the central and lower part of the catchment.

This system of multiple channels with interconnections and divergences supports a myriad of environmental assets. There are nine nationally important wetlands listed in *A Directory of Important Wetlands in Australia* and numerous other smaller wetlands that play a key role in connecting the larger sites. An abundance of flora and fauna depend on these wetlands, as well as the riverine ecosystem. Lake Cowal/Wilbertroy Wetlands, the Booligal Wetlands and the Great Cumbung Swamp are three wetlands that have been identified by the Australian Government as priority sites within the Lachlan Catchment.

Agriculture is the dominant industry in the Lachlan Catchment, consisting primarily of dryland and grazing enterprises, and significant irrigation. The most important irrigation activities are cereal crops, and pasture and hay production and the majority of this irrigation occurs on diversified farms that incorporate dryland cropping and grazing. Another major irrigation industry is viticulture, with one-quarter of the farms in the region irrigating wine grapes (ABARE 2008). Horticulture, dairy, feedlots and piggeries are also included in the production mix in the region. Whilst the Lachlan catchment is only 10% of NSW, it is estimated to produce 14% of the States agricultural production (Lachlan CMA, 2009). Mining, tourism, manufacturing, timber production, food processing and fishing are also important industries.

The Jemalong Irrigation District is the only irrigation scheme in the Lachlan Catchment. It commenced operation in 1941 following the construction of Wyangala Dam in 1935 and Jemalong Weir in 1936, from where it draws water from the Lachlan River. Water is distributed to over 90 properties through approximately 300km of open earth channel. A system of check-gates is used to hold the water in each section of the channel and raise it to a level where it can be delivered on to adjacent farms by gravity. The Jemalong Irrigation District may be split into two divisions associated with a split in the main channel system just downstream of the off-take. Division 1 is generally the northern section of the scheme and Division 2 is the southern section.

The scheme is managed by Jemalong Irrigation Limited, an unlisted public company with a board of seven directors elected by the 119 shareholders. Jemalong Irrigation Limited holds all Water Access Licences for the Jemalong Irrigation District, with 78,907 unit shares of general security water, a conveyance licence of 17,911 unit shares and 1,756ML of stock and domestic entitlement. Shareholders' right to have water delivered is separated from their right to a share in water allocations. The number of shares they hold in Jemalong Irrigation Limited is proportional to the water volume they are entitled to.

Jemalong Irrigation Limited also delivers water for stock and domestic purposes to over 19 properties surrounding the Jemalong Irrigation District, termed 'out of district' users, and to Barrick Gold Corporation (Cowal Gold Project).

The *Water Sharing Plan for the Lachlan Regulated River Source* sets out the rules for sharing water on the regulated Lachlan River downstream of Wyangala Dam and various tributaries. On average, surface water availability is 1,139 GL/year and on average about 321 GL/year (or 28%) of this is used (CSIRO, 2008). Under this plan, the average annual available water determination (AWD) that might be anticipated for general security water licences is around 43%. With the effects of climate change taking hold, this figure is likely to reduce to 36% by the year 2030.

However, the Water Sharing Plan has never been enacted as the Lachlan River has been managed according to the Drought Contingency Plan since July 2003 (State Water, 2008). Over the last six years, the average AWD has been just 4%. It is common for Jemalong Irrigation District irrigators to purchase water under temporary transfers from other entitlement holders within the region. Therefore, they generally have water supplies in excess of the AWD, although all general security entitlements on the Lachlan Regulated River are currently restricted to 75% AWD. However, with water availability so low, there has been very little irrigation in the district since 2002. The importance of using what water is available during these times of very low allocation in the most efficient manner becomes paramount for the sustainability of water ecosystems and communities.

Existing Water Losses within the Jemalong Irrigation District

On average, Jemalong Irrigation Limited may currently lose up to 30,136ML or 69% of its water entitlement to infiltration, evaporation and operational losses. Of these losses, 55% occur in scheme channels and 45% occur on farm, highlighting the importance of on-farm infrastructure upgrade. These figures are based on a year with the current estimated average annual AWD of 43%, with irrigation occurring over 7 months of the year. Anecdotal evidence suggests that losses in Division 2 of the scheme channels are lower than those in Division 1.

By the year 2030, with the average annual AWD anticipated to reduce to 36%, the total losses in the scheme could rise to 82%. This is because the losses in the scheme are associated with the water level in scheme channels, which need to be at full supply level to be able to deliver to farms. Therefore, the total volume of losses is anticipated to remain constant over small changes in water availability (larger changes in water availability are required to result in operation change that might alter the duration that channel water levels are at full supply level).

Loss estimates for the Jemalong irrigation District scheme channels have been calculated using extensive modelling that, while technically capable of producing accurate results, relies on large amounts of anecdotal information as input. Loss estimates in this report should therefore be treated with caution. They are considered sufficiently accurate for the purpose of initial Modernisation Option assessment. However, they are not considered appropriate for decision making regarding water transfers or capital investment. It is strongly recommended that detailed assessment of infiltration rates be undertaken throughout all scheme channels prior to further development of upgrade options.

Irrigation Modernisation Options

All potential upgrade techniques and methods that were considered applicable to modernising the Jemalong Irrigation District underwent preliminary assessment. From these, seven Modernisation Options have been determined. These are based primarily on the upgrade of the scheme channels. Upgrade of channel gates and meters, stock and domestic water delivery and on-farm infrastructure are considered to be essential to a modernised scheme and are included in all Modernisation Options. The following table summarises the Modernisation Options for the Jemalong Irrigation District.

Irrigation Modernisation Options for the Jemalong Irrigation District

Option	Division 1 Channels	Division 2 Channels	Scheme gating and metering[a]	On-farm irrigation infrastructure	On-farm channels upgrade and soil moisture monitoring	Stock and domestic delivery
Option 1	Existing	Existing	Existing	Existing	Existing	Existing
Option 2	Stabilised Backfill	Stabilised Backfill	Upgrade scheme gates and meters	As identified in *On-Farm Water Efficiency Plans*	As identified in *On-Farm Water Efficiency Plans*	Upgrade [b]
Option 3	Geofabric Liner	Geofabric Liner	Upgrade scheme gates and meters	As identified in *On-Farm Water Efficiency Plans*	As identified in *On-Farm Water Efficiency Plans*	Upgrade [b]
Option 4	HDPE Liner	HDPE Liner	Upgrade scheme gates and meters	As identified in *On-Farm Water Efficiency Plans*	As identified in *On-Farm Water Efficiency Plans*	Upgrade[b]
Option 5	EPDM Liner	EPDM Liner	Upgrade scheme gates and meters	As identified in *On-Farm Water Efficiency Plans*	As identified in *On-Farm Water Efficiency Plans*	Upgrade[b]
Option 6	HDPE pipe system + line existing Channel	Synthetic Liner	Upgrade scheme gates and meters	As identified in *On-Farm Water Efficiency Plans*	As identified in *On-Farm Water Efficiency Plans*	Upgrade[b]
Option 7	HDPE pipe system	Synthetic Liner	Upgrade scheme gates and meters	As identified in *On-Farm Water Efficiency Plans*	As identified in *On-Farm Water Efficiency Plans*	Upgrade[b]

Notes: [a] Includes upgrading farm off-take meters
[b]The preferred stock and domestic water delivery system will be finalised prior to any application for infrastructure funding.

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Scheme channels

Six options have been considered for upgrading the Jemalong Irrigation District scheme channels. The 'do nothing' case has also been included to provide a comparison for upgrade options. Modernisation Options for scheme channels include:

1. 'Do nothing'
2. Lining channels with a stabilised backfill material. The benefit of this option rests largely on the quality of the backfill material. Material with a 'low' infiltration rate and one with a 'high' infiltration rate have been assessed.
3. Lining channels with a UV protected geomembrane.
4. Lining channels with an ethylene propylene diene monomer (EPDM) rubber material.
5. Lining channels with a high density polyethylene (HDPE) material.
6. Piping Division 1 channels with a pipe large enough to deliver the every day requirement during a 36% AWD year. Lining of the remainder of the channel in Division 1 for times when greater volumes are to be delivered. Lining of Division 2 channels.
7. Piping Division 1 channels with a pipe large enough to deliver the peak capacity of existing channels. Lining of Division 2 channels.

Note that Options 6 and 7 include lining of the channels in Division 2 rather than piping. This is in line with the anecdotal evidence that losses in Division 2 are generally less than those in Division 1. The collection of detailed information on infiltration rates throughout scheme channels will allow refinement of the options.

Scheme channel gates and meters

The upgrading of all check and regulator gates to modern, remote controllable gating technology will allow the Jemalong Irrigation Limited to efficiently deliver and monitor deliveries to all irrigators. Upgrading Dethridge wheels at farm off-takes to Water Management Outlets will increase the accuracy of water measurement and all more water efficient application techniques to be utilised.

Scheme gating and metering upgrade includes replacing current regulator check gates and Dethridge wheels. If pressurised pipe systems are utilised, regulator check gates will not be required.

Stock and domestic water delivery

Four alternatives for stock and domestic water supply have been investigated. Two options follow the route of the existing channel delivery system and have the one off-take at the Jemalong Weir. The other two options follow road reserves as much as possible and have three off-takes along the Lachlan River. All of the alternatives consist of a pressurised pipe network separate to irrigation water delivery.

On-farm irrigation application

Each farm within the Jemalong Irrigation District is having an *On-Farm Water Efficiency Plan* developed. These plans identify on-farm water application inefficiencies based on industry standard figures provided by the NSW Department of Primary Industries. The principal objective of the *On-Farm Water Efficiency Plans* is to develop an on-farm option for future irrigation infrastructure modernisation in conjunction with the farmer. Options are suited to soil type and anticipated future enterprise to substantially increase the efficiency of water use and enhance environmental value.

The proportion of upgrade using sub-surface drip, centre pivot, lateral move and upgraded flood irrigation that has been identified in the *On-Farm Water Efficiency Plans* has been incorporated into each of the Modernisation Options apart from Option 1 – the 'do nothing' case.

Improvements in scheme channel delivery efficiency may result in more water being delivered to the farm gate; however the amount of water that might be traded for scheme channel infrastructure upgrade will not be determined until an application for funding is made. Given this uncertainty, the entitlement of each holding at the farm gate is assumed not to change with upgrade.

On-farm water delivery, storage and moisture metering

The *On-Farm Water Efficiency Plans* identify further inefficiencies through a water balance that considers infiltration and evaporation associated with on-farm storages and conveyance channels.

Losses from farm dams can be lowered by reducing the surface area of water in contact with the atmosphere and soil by sub-dividing, deepening and lining. Reservoirs used to store water for stock purposes may be replaced with a reticulated pipe network incorporating tanks and troughs. Infiltration from farm channels can be reduced by lining with suitable clay or synthetic materials.

Moisture meters optimise water application rates by measuring soil measure at fixed depths. This provides information on how much water should be applied, reducing deep drainage losses.

Upgrade of on-farm water delivery and storage infrastructure, and moisture meters that has been identified in the *On-Farm Water Efficiency Plans* has been incorporated into each of the Modernisation Options apart from Option 1.

Assessment of Modernisation Options

The following table presents a summary of water savings, capital cost and benefits of the Modernisation Options.

Combined Modernisation Option assessment

Option		TOTAL POTENTIAL WATER SAVINGS 75% AWD (assuming in-field upgrade for 36% AWD only) (ML)	Capital cost of infrastructure Scheme and on-farm infrastructure ($M)	Total maintenance cost of scheme channel infrastructure to 2030 ($M)	Potential increase in employment above the 'do nothing' case FTEs	Potential direct economic benefit over 20 years to 2030 compared to 'do nothing' case ($M)	Preliminary cost-benefit ratio. Capital cost to direct benefit only (multiple indirect benefits will also occur but are not factored here)	Rank
1	**Do Nothing**	0	0	23.5	0	0	-	10
2a	**Stabilised Backfill – High Infiltration**	6,880	86.8	23.5	27.3	106	1.24	9
2b	**Stabilised Backfill – Low Infiltration**	16,450	86.8	23.5	27.3	106	1.24	8
3	**Geofabric Liner**	23,680	88.5	34.5	27.3	106	1.22	3
4	**HDPE Liner**	23,680	93.1	31.0	27.3	106	1.16	2
5	**EPDM Liner**	23,680	92.5	30.3	27.3	106	1.17	1
6a	**HDPE Pipe and Geofabric Liner**	24,790	150.7	34.3	27.3	106	0.72	4
6b	**HDPE Pipe and HDPE Liner**	24,790	155.1	30.8	27.3	106	0.70	5
6c	**HDPE Pipe and EPDM Liner**	24,790	154.6	30.2	27.3	106	0.70	6
7	**HDPE Pipe and EPDM Liner**	24,830	258.8	13.5	27.3	106	0.42	7

Notes:

- All employment and economic benefit values are based on a 36% AWD – the average annual water availability anticipated for the year 2030 accounting for climate change
- No score has been provided for carbon emissions and energy use due to complexities in estimation and weighting against environmental benefits. In general, the Options that result in the greatest water savings also result in greatest energy requirements and carbon emissions.
- Co-contributions have not been assessed at this stage.
- On-farm costs account for in-field technology only.

Option 1 represents the 'do nothing' scenario. It does not produce water savings and so does not provide socio-economic or environmental benefit compared to the present. In fact, there are likely to be substantial negative impacts associated with this option including reduced production, employment, and community viability. The reduction in water availability associated with climate change, without additional water for the environment would also have a detrimental effect on the environmental assets of the Lachlan Catchment.

Option 2 would result in water savings of between 6,400ML and 13,840ML in an average year (36% AWD) depending on the infiltration rate of the backfill material used. In a 75% AWD year, water savings may increase to between 6,880ML and 16,450ML. The on-farm infrastructure upgrade would result in an increase of 27.3 full-time equivalent positions over Option 1 and generates $108 million net industry benefit up until 2030. This leads to a comparatively high cost-benefit ratio (calculated as net industry impact divided by capital cost) of 1.24. Maintenance costs are also similar to those for the 'do nothing' case. However, backfill material with a low infiltration rate is likely to be difficult to find within close proximity to the scheme. Importing material from further away would increase costs. If material with a low infiltration rate cannot be sourced, the relatively low average annual water savings would provide minimal environmental benefit, even if all savings were to be transferred to the Commonwealth.

Options 3, 4 and 5 would result in annual water savings of 23,680ML in a 75% AWD year and 19,470ML in a 36% AWD year. These water savings provide potential for significant environmental benefit. Synthetic lining eliminates infiltration and while evaporation still occurs, it is by far the smaller component of losses. Maintenance costs, particularly for the geofabric (Option 3), are higher than the 'do nothing' case and Option 2. However, these may be funded with the additional production possible with modernisation. Furthermore, the capital cost of the lining options is not significantly greater than for Option 2 and water savings may be up to three times greater. The primary risk of the lining options is that some of them have not been used for irrigation channels and are unproven. Again, this is particularly true for the geofabric (Option 3). Again, the on-farm infrastructure upgrade would result in an increase of 27.3 full-time equivalent positions over Option 1. The $108 million net industry benefit results in cost-benefit ratios of 1.16 for the HDPE liner to 1.22 for the geofabric liner.

Option 6 would result in annual water savings of 24,790ML in a 75% AWD year and 20,360ML in a 36% AWD year, with similar potential for considerable environmental benefit as the lining options. The pipe in this option conveys the every day requirement during a 36% AWD year. Lining of the remainder of the channel in Division 1 is still required for times when greater volumes are to be delivered. The capital cost of Option 6 is therefore much greater than for the lining options, and maintenance costs are similar. However, there are operational benefits in utilising a pipe, and the pipe is likely to last well beyond 2030. If viewed over the lifespan of the pipe, the cost-benefit ratio is likely to increase from 0.7 for the 20 years to 2030 to be well above 1. The increase in full-time equivalent employment levels would also be sustained over a longer timeframe if a larger initial capital outlay is injected into the scheme.

Option 7 would result in annual water savings of 24,830ML in a 75% AWD year and 20,420ML in a 36% AWD year. Again, it would have similar advantages as Option 6 in terms of environmental and social benefits. Maintenance costs would be lower than Option 6 and there is less liner to replace than for Option 6, so the longevity of Option 7 is better again than Option 6. However, the capital cost is much higher than any of the other options.

A potential benefit of upgrading Jemalong Irrigation District scheme channels would be the ability to deliver targeted environmental water efficiently to Lake Cowal/Wilbertroy Wetlands, a priority system in the Lachlan Catchment. Water currently cannot be delivered to Lake Cowal/Wilbertroy Wetlands directly from Wyangala Dam as the lake is on a tributary of the Lachlan River. The most direct delivery mechanism is through the Jemalong Irrigation District. If the members of the Jemalong Irrigation District continue to temporary transfer water onto the scheme, upgrading scheme channels would result in not only the most efficient use of water for production in the region, but the most efficient means of maximising environmental benefit.

The socio-economic benefits associated with all options that provide significant water savings include:

- Stable farm enterprises
- Increased income for farming families, particularly during times of low allocation

- Greater flexibility in farm management and diversification in crop selection throughout the scheme as well as encouraging more productive use of the irrigated land
- The retention of expertise including agricultural specialists, banking and professional services and social support such as health and education resources
- Increased stability of small businesses, services and communities
- Increased likelihood of value adding enterprises increasing within the region following stable production
- Increased quality of life, ability to provide children with a higher level of education and a reduction in rural mental health issues and suicide
- Long term sustainability of farming and national food production
- Promotion of amenity value and community identity
- Increased social well-being – attachment to place, access to social networks – increased 'social capital'
- An increased rate base for local government and decreased reliance on social support

Any of the four secure stock and domestic water delivery systems may be incorporated into the Modernisation Options. This would provide further benefits including stock health, psychological benefits and water savings.

Irrigation modernisation of the Jemalong Irrigation District has very few identified disadvantages. There are some risks though, primarily that, despite the capital investment in infrastructure the drought may continue and the forecast benefits may not be derived for some time.

The Modernisation Options presented in this Irrigation Modernisation Plan provide valuable information on the potential water savings that might be made if various upgrade technologies were to be implemented across the entire scheme, and the cost of these technologies. Prior to development of an application for infrastructure funding, should Jemalong Irrigation Limited wish to make one, rationalisation, the outcome of the Hotspots desktop review, and refinement and optimisation of technologies for each channel reach should be considered. It is also strongly recommended that scientific information on infiltration rates throughout the scheme be collected to enable a more accurate portrayal of losses and to better target areas of higher losses.

Modernisation of the Jemalong Irrigation District is well aligned with the aims of the *Sustainable Rural Water Use and Infrastructure* program. There is great potential to deliver substantial and lasting returns of water to the environment through permanent transfer of a portion of up to 24,830ML to the Commonwealth Environment Water Holder. Modernisation will secure a long-term future for the Jemalong Irrigation District and the regional community by injecting approximately $5.4 million into the regional economy annually and supporting over 29 full-time equivalent positions. Finally, the preliminary benefit-cost ratio for the Modernisation Options presented in this report show that modernisation has the potential to provide substantial benefit over and above the capital cost of upgrade infrastructure, particularly if the social and environmental benefits are considered.

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1 INTRODUCTION

1.1 Background

This report presents the case for modernising irrigation infrastructure and associated stock and domestic water reticulation within the Jemalong Irrigation District. Irrigation modernisation within this section of the Lachlan Valley aims to produce sustainable water savings for the environment and to ensure the future sustainability of the associated communities by underpinning their future with technology that ensures the viability of the local irrigation farm enterprises.

The Lachlan River Basin consists of 9.1 million ha including 8.3 million ha used for agricultural production. Irrigated agricultural area is about 10% of agricultural production, with the remaining 90% of agricultural production encompassing dryland agricultural production of cropping and grazing enterprises (Australian Government, 2007).

Irrigation development on the Lachlan River was initiated following the construction of Wyangala Dam in 1935 and the Jemalong Weir in 1936. The primary function of Jemalong Weir was to provide for the reticulation of stock and domestic water supplies with the additional benefits of providing for irrigation supplies. The Jemalong Wyldes Plains Irrigation District commenced operation in 1941. In 1995 it became the Jemalong Irrigation District, managed by an unlisted public company called Jemalong Irrigation Limited.

The Jemalong Irrigation District is the only irrigation scheme on the Lachlan River, with 90,000ha of farming land, including Jemalong Station and over 90 other commercial farms. Most of these enterprises are underpinned by some irrigation capacity, with an approximate total of 23,000ha of irrigation development throughout the district (WLP 2009).

The Jemalong Irrigation District has a direct relationship with its surrounding rural community. Irrigation is a fundamental component supporting all facets of primary production typical to Central West New South Wales including mining, urban and rural domestic living and all of the associated industries and frameworks that constitute a productive regional economy. The social fabric of small rural communities is also closely aligned with their economic well being. The contemporary trend in rural to urban migration is directly influenced by declining industry and the resulting reduction in the foundations on which rural economies are built. Stock and domestic water delivery through scheme channels is also vital to the district.

Climate change is imposing a new perspective of water use and water availability in the region. The recent reduction in water availability has refocussed the attention on water use and mechanisms to achieve water security for the environment, food production, and sustainable rural and urban communities. With long range forecasts and climate change modelling predicting a general transition toward a warmer and drier climate, the implications for agriculture include the need to examine options for, and adjustment to, more efficient use of available water and resources.

Adapting for climate change will involve the development of supply systems, farming practices and management techniques that are both flexible and responsive to greater fluctuations in water availability. The options for maintaining viable irrigated farming will encompass a range of management

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techniques across all aspects of irrigation: the scheme conveyance system, storage, reticulation and application of irrigation water. Additional on-farm changes include the production of less water intensive crops whilst maintaining return per megalitre, changing farm rotations for seasonal water fluctuations, sowing crops on soils which contain a sufficient moisture profile and securing on-farm water supplies to finish crops and support livestock and domestic dwellings.

The average annual general security available water determination for the purpose of this report has been estimated as 43% for the short term and 36% at the year 2030. It must be noted that prolonged drought conditions have reduced available water determinations for the previous six years to an average of 4%.

Therefore, the emphasis of this report is a focus on modernisation options for the enhancement of water security for effective water use in low to medium allocation years. This is essential to ensuring a consistent level of production is maintained for the benefit of the region.

1.2 Irrigation Modernisation Planning

The *Sustainable Rural Water Use and Infrastructure* program, under which this report is funded, is part of the Australian Government's $12.9 billion *Water for the Future* long-term framework to secure the water supply of all Australians. Initiatives under the program will also assist irrigation communities to make adjustments in anticipation of new Murray-Darling Basin management arrangements and Basin Plan incorporating the effects of climate change. The *Sustainable Rural Water Use and Infrastructure* program aims to fund projects that will provide for:

- The delivery substantial and lasting returns of water for the environment;
- The long-term security of irrigation communities; and
- The delivery of value for money outcomes in the context of the first two tests.

In the development of modernisation options for the Jemalong Irrigation District that meet these criteria, this Irrigation Modernisation Plan addresses the following key components:

- An assessment of water efficiency issues on farm
- Assessment of land capability issues on farm
- Evaluation of existing scheme operations and associated water use
- Determination of water losses in scheme channels and on farm
- Identification of water saving technologies for scheme channels and on farm and their applicability
- Consultation with key stakeholders
- Assessment of the socio-economic factors that will be influenced by modernisation of irrigation infrastructure in the region
- Assessment of the environmental factors associated with water use in the Lachlan River Valley and the impact of irrigation modernisation
- Assessment and determination of the legal implications associated with modernisation, particularly with regard to water transfers

1.3 On-Farm Water Efficiency Plans

The *On-Farm Water Efficiency Plans* project is being undertaken by Western Land Planning Pty Ltd (WLP) in conjunction with this irrigation modernisation plan. Jemalong Irrigation Limited has facilitated the resources required for the *On-Farm Water Efficiency Plan* development and has made considerable investment in the co-ordination and management of this project. The principal objective of the *On-Farm Water Efficiency Plans* is to develop an on-farm option for future irrigation infrastructure modernisation of each farm in the Jemalong Irrigation District, in conjunction with the farmer. Options suited to soil type and anticipated future enterprise, which will substantially increase the efficiency of water use and enhance environmental value.

The plans identify on-farm water infrastructure inefficiencies and potential infrastructure upgrades to improve efficiencies on a farm-by-farm basis. Estimates validating the size and scale of on-farm irrigation inefficiencies consider evaporation and infiltration from reservoir storage, infiltration rates from conveyance channels and inefficiencies in crop water application. Typical on-farm options include:

- Upgrade of crop application techniques (e.g. from flood to upgraded flood, spray or drip irrigation) for high priority irrigation fields with suitable soil types. The total area of proposed upgrades relates to anticipated future average water availability.
- Piping stock and domestic water deliveries directly to tanks and troughs. Significant water savings can be made with enclosed stock and domestic systems instead of using earth farm dams. Water in these systems can be managed by a digital telemetry network.
- Reduction of water reservoir plan area. Such reservoirs are required to guard against crop failure resulting from water delivery scheduling or temperature fluctuations. However, infiltration and evaporation can be reduced by making storages deeper, lining and reducing their plan area.
- Improvement of the alignment and structural integrity of supply channels and head ditches, tail-water disposal and water recycling networks, particularly in areas with soil types prone to comparatively high infiltration rates.
- Sections of the property/s are identified for the establishment and/or conservation of native vegetation and wetland areas. These areas are proposed to be fenced for livestock management for the duration of and following development.
- Sections of the property/s with established border windbreaks will be further developed to provide additional top soil protection and soil moisture retention and connecting wildlife corridors.
- Identification of, and remediation options for areas of soil degradation and promotion of sustainable farming practices.

1.4 Environmental Assets that might benefit from Modernisation of the Jemalong Irrigation District

There are significant environmental assets within the Lachlan River catchment that would benefit from additional water that might be made available through modernising irrigation, including wetlands and floodplains of national importance. There is evidence that the growing use and demand on water for agriculture, industry and domestic needs, is contributing to environmental stress within the river and in particular, important these wetland areas.

Wetlands listed in *A Directory of Important Wetlands in Australia* within the Lachlan Catchment include the following:

- Booligal Wetlands
- Cuba Dam
- Great Cumbung Swamp
- Lachlan Swamp (Part of the mid-Lachlan Wetlands)
- Lake Brewster
- Lake Cowal/Wilbertroy Wetlands
- Lake Merrimajeel/ Murrumbidgil Swamp
- Merrowie Creek (Cuba Dam to Chillichil Swamp)

There are also many smaller wetlands that have become disconnected from the river due to changed flood regimes associated with regulation. These sites plan an important role in linking together the main wetlands.

River health is another critical environmental asset that stands to benefit greatly from any additional water that might be made available through modernising irrigation infrastructure.

These water ecosystems provide habitat for several vulnerable and endangered species.

Figure 1.1 A section of the Great Cumbung Swamp

Source: Google Earth

WESTERN LAND PLANNING

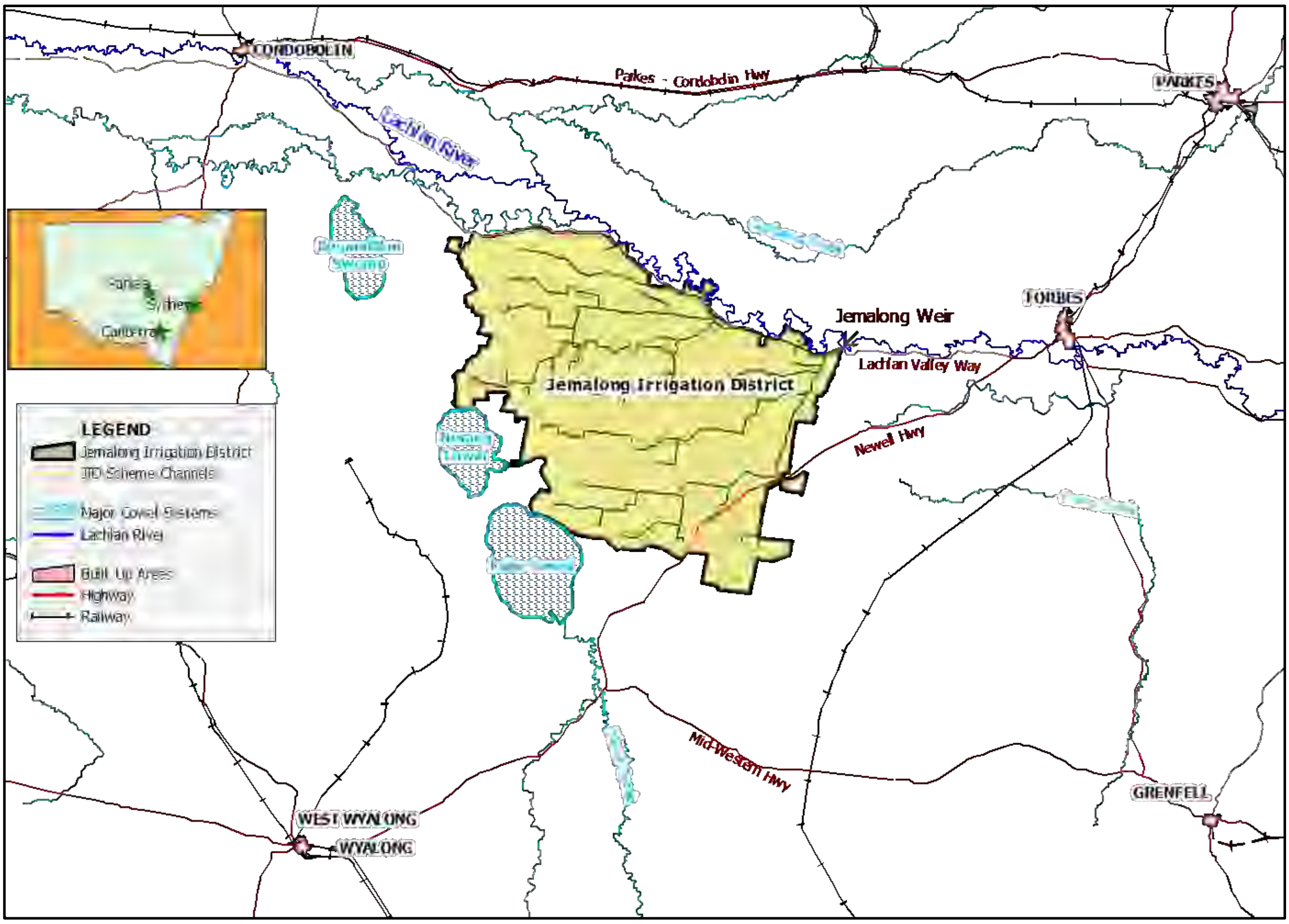
2 BASELINE CONDITIONS IN THE MID-LACHLAN CATCHMENT

2.1 Geographical Location

The Jemalong Irrigation District lies within the Lachlan Catchment in the central west of New South Wales. The Lachlan Catchment comprises 8% of the Murray-Darling Basin. It is bounded to the east by the Great Dividing Range, the Macquarie and Bogan catchments to the north, the Darling to the west and the Murrumbidgee to the south.

The Jemalong Irrigation District is approximately 25km south-west of Forbes, which is approximately 370km west from Sydney. The scheme lies within (147.36°E, 33.29°S) to the north-west and (147.77°E, 33.66°S) to the south-east. The scheme's off-take from the Lachlan River is at the north-eastern corner at (147.78°E, 33.4°S). Figure 2.1 shows the location of the Jemalong Irrigation District.

Figure 2.1 Location of the Jemalong Irrigation District



The Mid-Lachlan Catchment is defined for this report as the area bounded by Forbes to the east and Lake Cargelligo to the west. The Mid-Lachlan Catchment area has a narrow north-south axis with an approximate distance of 150km at its widest and most easterly point.

The town of Forbes provides the bulk of the facilities required for the Jemalong Irrigation District's operation. Forbes is located on the Newell Highway, the primary inland transport link between

Melbourne and Brisbane. The town's location also provides commercial and industry links with other rural service centres such as Parkes, Condobolin and West Wyalong and convenient road access to the ports of Adelaide and Newcastle.

2.2 Environment and Ecology in Focus

2.2.1 Topography

The topography of the Lachlan Catchment may be broadly divided into three zones – the upper, mid- and lower catchment (CSIRO 2008). The upper catchment is characterised by elevated undulating country of the western slopes of the Great Dividing Range. The mid-catchment is characterised by undulating landscape and fertile alluvial floodplains adjacent to the watercourses and includes the section of river between Wyangala Dam and Lake Brewster. The lower catchment includes the area west of Lake Brewster and includes the broad alluvial floodplain (CSIRO, 2008).

The Lachlan River is unique within the Murray-Darling Basin in that it is the only major river that is classified as terminal. The relatively level topography of the alluvial plains of the downstream sections of the Lachlan River allows it to form a series of anabranches and floodplains that terminate in the Great Cumbung Swamp, 100km north east of Mildura. During large flood events, flow may spill through the swamp into the Murrumbidgee River.

Jemalong Irrigation District is positioned approximately half way along the course of the Lachlan River within the mid-catchment. The gently sloping topography of the district is mainly comprised of floodplains, backplains and the meander plains of intermittent and previous water courses.

There are two significant landforms that influence the direction of the Lachlan River as it moves through the district. The Jemalong Ridge is a narrow elevated landform with a north east to south west axis and the Manna Range to the west. The most dominant feature of the Jemalong Irrigation District and corresponding land units is the extensive prior stream floodplain formation of the Warroo Prior Stream.

2.2.2 Geology and soils

The underlying geology of a landscape has a strong influence on the landform, soils and the resulting suitability of the landscape for agricultural use. The eastern fringes of the Murray-Darling Basin have been shaped by a continual process of erosion and deposition from the volcanic and sedimentary uplifts of the eastern escarpment. Sedimentary material transported by rivers such as the Lachlan River has been deposited in large, level formations across the western slopes and plains, creating areas of deep, fertile soils.

The Jemalong Irrigation District is supported by a geological structure that provides the landform and soils capable of sustaining intensive agricultural production. The area consists of three significant geological formations that have resulted from movements in the Lachlan fold belt approximately 400 - 500 million years ago.

The Jemalong Range is a significant feature of the region. The Jemalong Range is oriented along a general north-south axis and is responsible for channelling the Lachlan River in a westerly direction through a narrow split in the geological structure. The Jemalong Range consists of uplifted sandstone sediments from the Devonian period 400 million years ago.

Figure 2.2 Jeamlong Range with the Lachlan River cutting through

Source: Google Earth

The Manna Range forms the south-western boundary of the Jemalong Irrigation District, running from south-east to north-west. It has similar geological characteristics to the Jemalong Range. Together these ranges have a notable influence on the landscape and soils of the district.

The Jemalong-Wyldes Plains formation is nested between the Jemalong and Manna Ranges. The plains formation is derived from consolidated and unconsolidated alluvial material deposited within the confines of the ranges including Aeolian sand and alluvial deposits. The Jemalong-Wyldes Plains formation supports most of the Jemalong Districts agricultural activity.

Soil types of the Jemalong Irrigation District are the result of alluvial deposits left by the action of wind and water over many years. These soil types vary between Grey-Brown Vertosols (clays), Red-Brown Chromosols (clay loams), Red-Brown Kandosols (loams), and Red-Brown Tenosols (sandy loams). The general landform is shaped mainly as relatively flat alluvial plains with smaller areas comprised of elevated, eroded ridges and resistant rock outcrops. Sodicity and saline characteristics can occur naturally, particularly amongst the red earths. Vertosols may carry a degree of self-mulching with shrink-swell characteristics which can form Gilgai surfacing, leaving depressions and channel formations. Sandy loam surfaces are common adjacent to prior stream beds and meander plains. They may also constitute low rises and foothills. The alluvial landscapes generally consist of clay loam surfaces grading to medium clay at depth. These soil profiles provide for effective water holding capacity and reduction of water movement through the soil profile, making them highly suitable to agricultural production.

2.2.3 Climate, rainfall and runoff

The climate affecting the Mid-Lachlan Catchment is temperate with hot summers and cool winters, as described by the Köppen classification. On average, monthly rainfall totals are distributed evenly throughout the year, but rainfall occurs on more days throughout the winter.

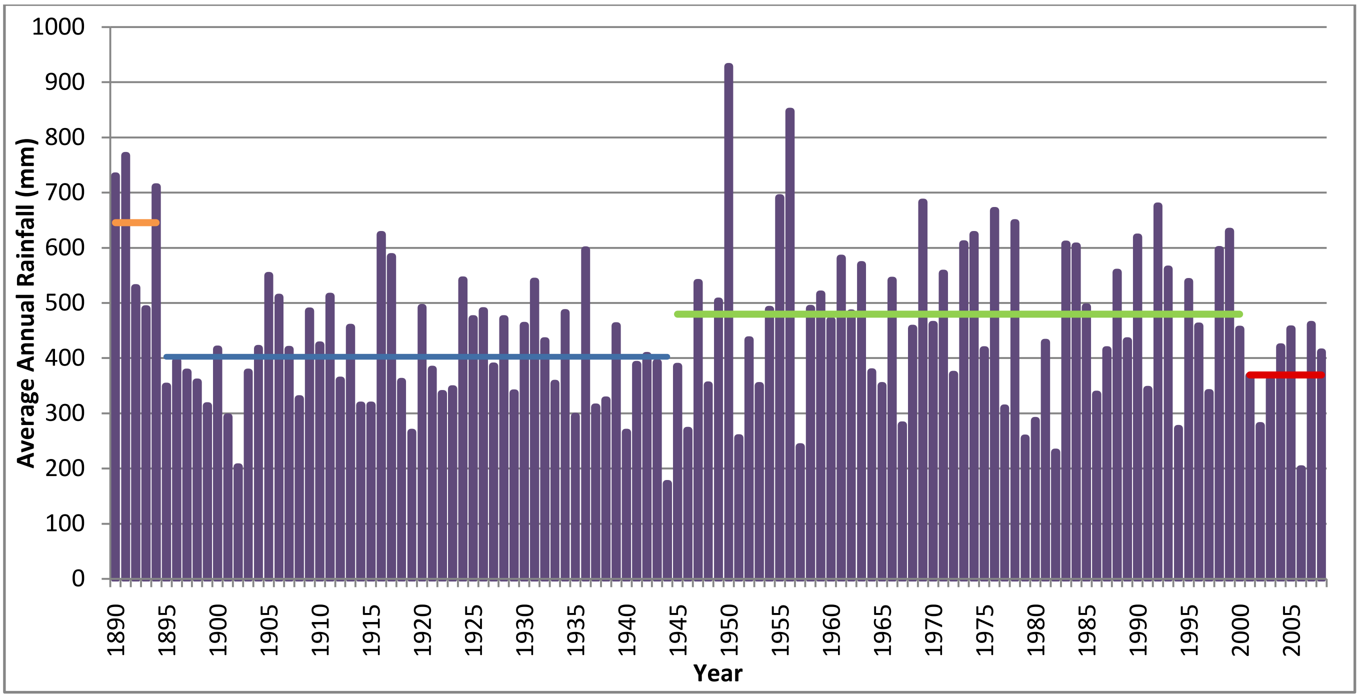
Average temperatures in all seasons are sightly cooler in the east and warm gradually toward the west. Temperatures for the region range from an average minimum of 18˚C to an average maximum of 33˚C in summer, and an average minimum of 2˚C to an average maximum of 14°C in winter. Similarly, rainfall averages are slightly higher towards the east with Forbes averaging 526mm (recorded 1875 – 1998), and decrease gradually towards the west, averaging 429mm at Lake Cargelligo (recorded 1881-2009).

There is a moderate to high degree of variability from the average or expected conditions, with seasonal conditions being subject to extremes. Maximum temperatures can be expected to exceed 35°C on 33 occasions each year, while winter temperatures will, on average, fall below 0°C on 15 occasions each year.

Sustained periods of below average rainfall are a reasonably common feature and are a limiting factor for the region's water availability.

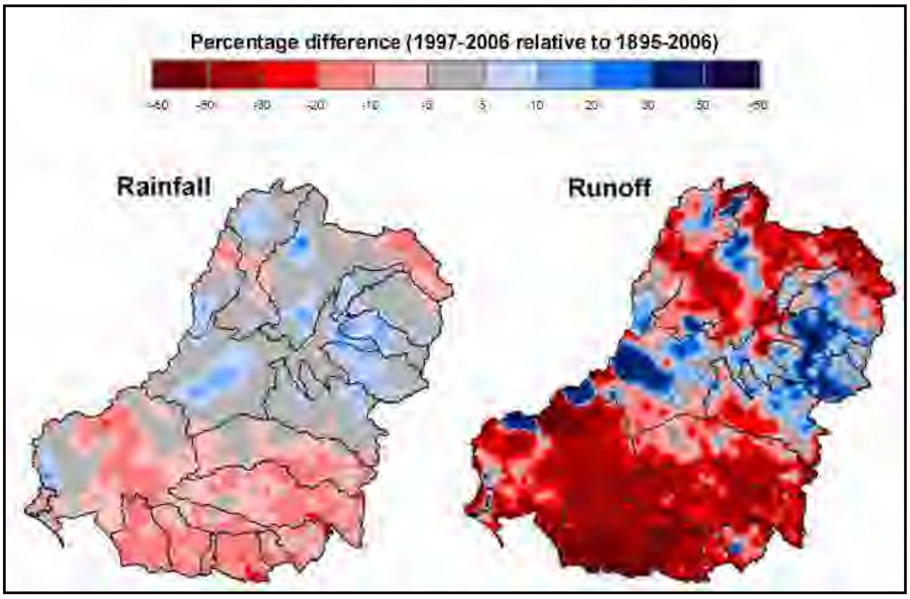
However, the occurrence of below average rainfall in the Mid-Lachlan Catchment since 2001 has been longer than usual and is consistent with the general trend across south eastern Australia in recent years. Meteorological records at Forbes Airport which have been recorded since 1995 show a decrease of 51mm or 10% when compared to the data recorded for Forbes since 1876 and 1999. In the past 10 years the annual rainfall recorded in Forbes has been as low as 159mm (in 2006) to as high as 687mm (in 1999) (Bureau of Meteorology, 2009). Rainfall records at the Condobolin Agricultural Research Station show an 81mm reduction in average rainfall from 1995 to 2008 compared to the long-term average since 1955 (Bureau of Meteorology, 2009). This represents an 18% reduction. Figure 2.3 illustrates a marked decline in annual rainfall as averaged across several gauging stations within close proximity to the Jemalong Irrigation District, particularly when comparisons are made with the period 1950-2000.

Figure 2.3 Historical rainfall data surrounding the Jemalong Irrigation District



The prevalence of drought conditions throughout the region at present has been reflected in a decrease in run-off across the Mid-Lachlan Catchment. The lack of available run off to replenish the region's dams and storages has meant that full irrigation entitlements have not been available since the 1998-1999 cropping season. Additionally, a report by the CSIRO concerning water availability in the Lachlan (CSIRO 2008) demonstrates the critical balance between rainfall and run-off, where an 8% decrease in average annual rainfall coupled with higher than average temperatures has resulted in a 24% decrease in run-off for the period 1997-2006. The CSIRO report states that this difference is not statistically significant due to high inter-annual variability. However, the sustained period over which this reduction in runoff has occurred has had significant impact on local communities and the environment. A reduction in cash-flow through a community over several years can lead to closures of services and businesses. Similarly, the reduction in breeding events over several years can have devastating impacts on waterbirds.

Figure 2.4 Difference between 1997-2006 and 1895-2006 rainfall and runoff in the Murray-Darling Basin



Source: http://www.clw.csiro.au/conferences/GICC/chiew.pdf

2.2.4 Surface water and water ecology

Catchment areas may also be described as drainage basins. In broad terms this means that any water falling within a catchment area will either infiltrate into the soil, be captured in surface storages or form part of the surface water flow. Once water becomes part of the surface flow it will flow toward the lowest point within the catchment area, generally as a river.

The Lachlan River represents the outlet for surface flow within the Lachlan Catchment. At 84,700 km^2 in area, the Mid-Lachlan Catchment is a drainage basin of considerable size. Within this area there are a number of creeks and tributaries that join the Lachlan River.

Lachlan River

The Lachlan River catchment headwaters are located on the western slopes of the Great Dividing Range. The Upper Lachlan River catchment forms a drainage basin covering an area between Blayney and Gunning at an altitude of approximately 900m AHD.

It flows over 150km north-north-west before it is impounded by Wyangala Dam, 30km south-east from Cowra. Wyangala Dam is the only major dam regulating the flow of the Lachlan River, supplying irrigation, urban, rural stock and domestic and mining water requirements.

The Lachlan falls through a relatively steep, north-westerly descent for a short distance before reaching the level alluvial plains of the Mid-Lachlan Catchment area to the west of Cowra.

The Mid-Lachlan Catchment is notable for providing the natural resources for a productive agricultural industry. The Mid-Lachlan Catchment is the only area where off-river irrigation occurs. Flowing west of Forbes through the Jemalong Range, water is diverted from the Lachlan River at the Jemalong Weir, 23 kilometres west of Forbes supplying the irrigation water for the Jemalong Irrigation District.

From the Jemalong Range, the Lachlan River flows north-west to Condobolin and west a further 45km before turning south-west. It passes Lake Cargelligo and Lake Brewster. These are two off-line storages systems which can be used to re-regulate water in the Lachlan River. Lake Cargelligo represents the western margin of the Mid-Lachlan Catchment area.

The Lachlan River is forced slightly north around the Lachlan Range, then follows a south westerly direction, through Hillston and towards Balranald in southern New South Wales. The flat topography between Lake Cargelligo and the Hay Plain causes the Lachlan River to form a series of braided channels that provide water for the Booligal Wetlands and later the Great Cumbung Swamp near Oxley. The Lachlan River discharges its waters into this extensive wetland system at an average rate of 3,456ML per day (CSIRO Sustainable yields, 2008).

The Lachlan River is only intermittently connected to the Murrumbidgee River when both rivers are in flood. The Lachlan River serves as a connecting corridor for the wetland environments which together provide essential habitat for many of the Murray-Darling Basin's endangered plant and animal species.

Tributary Rivers and Creeks

There are two main tributaries that join the Lachlan River in the upper catchment area. The Abercrombie River is a primary tributary, converging with the Lachlan immediately upstream of Wyangala Dam. The Belabula River joins the Lachlan River downstream of Wyangala Dam near the town of Cowra. The upper reaches of the Belubula River flow into the Carcoar Dam, which provides 36,400ML of storage for downstream users on the Belabula River system.

Other tributary creeks of the Lachlan River include: Bland, Mandagery, Goobang, Gunningbland, Humbug and Booberoi.

Distributary Rivers and Creeks

There is significant braiding of the Lachlan River and distributaries surrounding Condobolin. Bumbuggan Creek, Wallamundry Creek and Wallaroi Creek are all intermeshed throughout this area.

Downstream of Lake Cargelligo Willandra Creek, Middle Creek, Merrowie Creek, Box Creek, Merrimajeel Creek and Muggabah Creek branch off from the Lachlan River.

Wetlands of National Significance

Along with the Lachlan River, these tributaries and distributaries offer the physical environment necessary for wetland systems to occur. Wetlands of national significance in the Lachlan Catchment include:

- Booligal Wetlands

- Cuba Dam
- Great Cumbung Swamp
- Lachlan Swamp (Part of the mid-Lachlan Wetlands)
- Lake Brewster
- Lake Cowal/Wilbertroy Wetlands
- Lake Merrimajeel/ Murrumbidgil Swamp
- Merrowie Creek (Cuba Dam to Chillichil Swamp)

These wetlands provides habitat for a number of vulnerable and endangered species including;

- Australasian Bittern *Botaurus Poiciloptilus. The Australasian Bittern finds habitat and refuge in dense wetland vegetation. The Australasian Bittern is listed by NSW DECC as vulnerable, with the reduction in the size and condition of wetland habitat providing the main threat to the species survival.*
- Black necked stork *Ephippiorhynchus Asiaticus. The Black Necked Stork is Australia's only stork species. Inland freshwater wetlands are essential to the breeding cycle of the Black Necked Stork, providing the shelter and building material required for nests of up to two metres in width. The decline and degradation of wetlands are the main threats to the species, currently assessed by NSW DECC as endangered*
- Blue Billed Duck *Oxyura Australis. The Blue Billed Duck is one of only two native Australian diving ducks. The Blue Billed Duck is completely aquatic and requires wetlands with dense aquatic vegetation for habitat and breeding.*
- Macquarie Perch *Macquaria Australasica. A species of fish once widespread throughout the Murray-Darling Basin. Alteration of riparian environments has reduced its habitat to large pools of water which are relatively free of suspended sediment. The Macquarie Perch is listed as vulnerable in NSW under the Threatened Species Act, 1995.*
- Austral Pillwort *Pilularia Novae-Hollandiae - A semi aquatic, grass like species of fern listed by DECC as endangered. Lake Cowal supports the only known extant population in NSW.*

Lake Cowal/Wilbertroy Wetland

Lake Cowal is situated 50 km south west of Forbes and is recognised as the state's largest natural inland lake. The wetland Lake Cowal is home to a variety of vulnerable and endangered plant and animal species.

The Wilbertroy Wetland System is an ephemeral wetland that connects the Lachlan River to Lake Cowal. The ecology of the wetland is adapted to regular periods of drying.

The Lake Cowal/Wilbertroy Wetland System is part of the Bland Creek catchment that drains surface water from the area in and around the Jemalong Irrigation District. It provides drought refuge both in area, diversity of habitat types and availability of resources. As an ephemeral wetland, the system will on average contain water for seven out of every ten years, providing a fairly reliable source of water for migratory birds. The lake is on the Register of the National Estate and in the Directory of Important Wetlands, and it is listed as a Landscape Conservation Area by the National Heritage Trust.

Booligal Wetlands

The Booligal Wetlands cover approximately 5,000ha in the Lower Lachlan region near the township of Booligal, north of Hay (CSIRO, 2008). The wetlands consist of sections of the braided channel formation of Merrimajeel, Merrowie and Muggabah Creeks, which are distributaries branching from the Lachlan River. The importance of the Booligal Wetlands is recognised by its inclusion in the National Directory of Important Wetlands.

The natural cycle of the wetlands involves infrequent floods from the water supplied by the Lachlan River. These wetlands are significant for the large numbers of waterbirds that congregate to breed and forage in the area during flood years, attracted by an array of aquatic macrophytes that colonise the creeks and swamps following inundation (DEWHA Australian Wetlands Database, 2009). The area is considered to be one of the top five breeding sites for the Straw-necked (*Threskiornis spinicollis)*, White (*T. mollucca*) and Glossy Ibis (*Plegadis falcinellus*), with several state vulnerable species also recorded at the site, including Freckled Duck (*Stictonetta naevosa*) and Blue-billed Duck (*Oxyura australis*) (CSIRO, 2008).

The Booligal Wetlands remain in a relatively natural condition and provide a representative example of inland floodplain wetlands.

Lake Cargelligo

Lake Cargelligo is a significant water resource for the Mid-Lachlan Catchment. The lake is situated on a natural depression adjacent to an anabranch of the Lachlan River. Lake Cargelligo is a regulated water body in that water can be delivered to this storage from the Lachlan anabranch. Lake Cargelligo offers tourism and recreation facilities as well as a reliable water supply to the surrounding area.

Great Cumbung Swamp

The Great Cumbung Swamp represents the terminus of the Lachlan River and is adjacent to the Murrumbidgee River. This extensive wetland system is more than 500km in length and covers a combined area of 16,000ha (Australian Wetlands Database, 2009). The Great Cumbung Swamp is a permanent freshwater "Reed Wetland", although the area of the swamp varies with water availability. Its name is a derivative of the aquatic plant species cumbungi *typha angustifolia* that occurs along the more frequently flooded stream lines. Common Reed (Phragmites australis), river red gum (Eucalyptus camaldulensis) and Black Box (E. argiflorens) woodland also cover large areas of the swamp. The wetland provides sheltered habitat and refuge for the breeding sites of waterbirds including Freckled Duck (*Stictonetta naevosa*) and Blue-billed Duck (*Oxyura australis*). The complex ecology of this wetland environment is sustained by a flood flows from the Lachlan River.

Lake Brewster

Lake Brewster is situated on the Lachlan River floodplain between Lake Cargelligo and Hillston. The lake occurs naturally as a shallow wetland but has been modified, with the inflow and outflow of water regulated by a weir. Lake Brewster has large patches of Cumbungi and is significant for providing refuge, habitat and breeding requirements for water birds.

Cuba Dam

Cuba Dam refers to the constructed wall designed to regulate the flow of Merrowie Creek, a distributary of the Lachlan River. The purpose of the dam is to store water for stock and domestic purposes; however the construction of Cuba Dam and numerous other examples situated within this floodplain area have created a persistent wetland corridor. The combined wetland area is nationally significant for attracting many water birds including an exceptional number of Ibis.

Lachlan Swamp

The Lachlan Swamp is part of the Mid-Lachlan Wetlands, an extensive wetland system located on the floodplains of the Lachlan River north of Hay. This wetland system comprises of a series of smaller lakes including Lake Waljeers, Peppermint Swamp, Lake Bullogal and Ryans Lake. The waters from each lake combine with the flow of the Lachlan River during flood events. The Lachlan Swamp supports extensive remnant ecological communities of River Red Gum and Black Box vegetation that rely on the flooding and drying cycles of this shallow wetland.

2.2.5 Ground water, salinity and water table management

Groundwater aquifers in rural Australia are an important resource for irrigation, stock and domestic, industrial and urban water requirements. Surface water and groundwater resources are highly integrated, the intrinsic link coming through groundwater recharge or discharge.

The Jemalong Irrigation District is perched on the Lachlan and Cowra groundwater formations. Both formations are responsible for the movement and drainage of water from the soil profile.

The Lachlan formation lies approximately 100m below the surface. Groundwater in the Lachlan formation flows in a northward through to a westward direction, similar to surface water. The Cowra formation is a more shallow formation and therefore lies between the Lachlan formation and the surface. Groundwater in the Cowra formation drains predominately toward the west to north-west.

The CSIRO Sustainable Yields report *Water Availability in the Lachlan* (2008) indicates a moderately high level of development of the Mid-Lachlan Regions available groundwater resources. Groundwater in the region services household, livestock, industrial mining, recreation, and some irrigation requirements. The report outlines groundwater supply and extraction rates from the more highly permeable Lachlan formation.

The quality of groundwater in the Jemalong Irrigation District is largely well within the acceptable standards required for stock and domestic use. A source of good quality groundwater is essential in securing household and livestock water resources, particularly where irrigation and stock and domestic water supply is mutually dependent. Groundwater resources are however not infinite, and a sustainable yield index is critical for the management and continued availability of groundwater resources.

Fluctuations in, and modifications to, surface water flow can affect the rate of recharge in groundwater systems. A major contributor to groundwater accession in the Jemalong Irrigation District is recharge by floodwater. Another contributor is seepage below irrigation channels and fields.

Rising groundwater tables have previously become evident throughout the Jemalong Irrigation District with the associated surface problems of water-logging and salinisation apparent. A groundwater mound developed in the shallow alluvial groundwater system of the Cowra formation. Rising groundwater tables forced the reversal of the natural groundwater flow direction in some areas. During more recent times, with management by Jemalong Irrigation Limited and reduced rainfall and flooding producing less recharge, water table levels have fallen. The 2007-08 Jemalong Irrigation Annual Report shows that the water table under the majority of the scheme was more than 6 metres below surface level. The volume of saturated soil for the whole Jemalong Irrigation District was below levels experienced in 1969.

Water accumulates salts as it moves through the soil. When a rising groundwater table is close to the surface, water is drawn to the surface by surface tension force and evaporated. This induces the accumulation of dissolved salts in the soil profile.

In areas where rising groundwater tables occur, the presence of concentrated salt and mineral particles can adversely affect plant growth and lead to a reduction in the fertility and productive capacity of the land. In agricultural areas, seed germination and plant growth is retarded, affecting crop yields and ground mass for livestock grazing. In vegetation communities plant regeneration is inhibited, leading to a decline in the structural composition of the plant community.

The management of groundwater in the Jemalong Irrigation District was identified as a critical issue in *The Jemalong Land and Water Management Plan* and resulted in large scale monitoring and management procedures. To help reduce the impact of irrigation on water tables, the *On-Farm Water Efficiency Plan* project is assessing the drainage capacity of the land where irrigation occurs.

The recommended model for efficient irrigation includes direct sensing and responsive management of soil water content in the upper soil profile. This model aims to alleviate rising groundwater levels by eliminating over-watering and reducing deep drainage as a result of irrigation. Where rising water tables are evident, plant regeneration programs will assist in enhancing on-farm sustainable management practices by removing excess water from the soil profile.

Modernisation planning for the proposed development of scheme infrastructure will have a profound influence on groundwater management. Options for scheme modernisation will enable improvements in water delivery infrastructure to substantially minimise or eliminate current rates of water accession into groundwater aquifers.

2.2.6 Vegetation, habitat and fauna

Vegetation communities throughout the Jemalong Irrigation District are described using the Broad Vegetation Types (BVTs) provided by the NSW Department of Environment and Conservation (DEC, 2006).

The composition and species assemblage of the Jemalong Irrigation District ecological communities are indicative of an Open Grassy Woodland ecosystem. Dominant communities identified are recorded with reference to listed ecological communities on the DEC database. These include:

- BVT 15 - Cyprus Woodland
- BVT 20 – Grey Box-White Cyprus Pine-Poplar Box-Smooth Barked Coolibah on red earths (co-dominant throughout area)

- BVT 30 – River Red Gum riparian woodland/forest on floodplains
- BVT 31 – Black Box woodland/forest on floodplains
- BVT 58 – Myall Open Woodland (co-dominant throughout area)
- BVT 71 – Poplar Box Woodland
- BVT 72 – Belah Open Shrubland

These vegetation communities are widely distributed across the Jemalong Irrigation District. They support the habitat requirements for many animals endemic to the area as well as providing significant nesting areas for migratory birds.

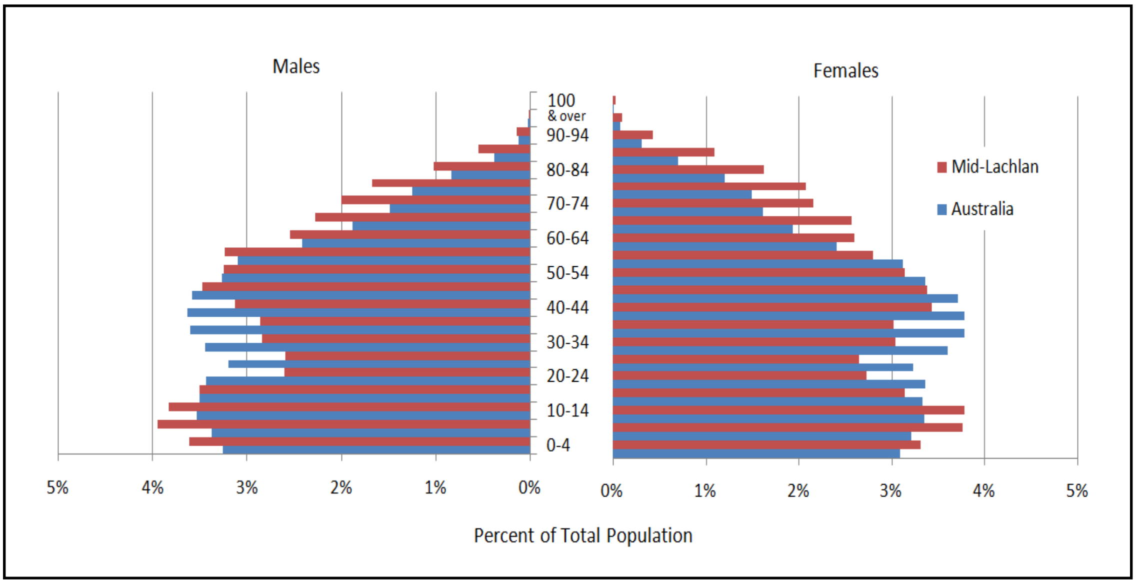
The ongoing conservation of these environments has been given a strong emphasis in the planning objectives of the Jemalong Irrigation District. Vegetation management strategies outlined in *The Jemalong Land and Water Management Plan* and *On-Farm Water Efficiency Plans* have been widely embraced by farmers in the Jemalong Irrigation District with funding opportunities available under the Department of Environment and Climate Change's Grassy Box Woodland conservation program. Farmers have recognised the value of planting of new vegetation for windbreaks, shade and shelter and on-farm biodiversity resources.

2.3 Socio-Economics and Culture in Focus

2.3.1 Population and demographic

There are 27,420 people living in the Mid-Lachlan region as defined in this report. An analysis of the age of this population reveals that there are fewer people in the 20-35 age bracket in the Mid-Lachlan compared to Australia as a whole. Figure 2.5 illustrates that 16% of people in the Mid-Lachlan region are between the ages of 20 and 35, compared to 20% for Australia as a whole. These figures are consistent with known issues associated with rural demographics: there are fewer employment, education and social opportunities for younger people as a whole in rural areas.

Figure 2.5 Age by sex for the Mid-Lachlan compared to the whole of Australia



Source: 2006 ABS Census of Population and Housing

The lower proportion of people ages 20-35 results in a greater proportion of people aged below 15 and over 65. This imbalance can place further strain on social and welfare structures.

The indigenous population of the Mid-Lachlan, at 8.4%, is more than double the average for NSW at 4% and nearly four times the national average of 2.3%. This fact has implications on the importance of employment within the region as long-term stable employment is especially essential for the indigenous population.

The population of the Mid-Lachlan region has decreased slightly in recent years from 28,236 people in 2001 to 27,420 people in 2006. ABS data from 2005 indicates that economic considerations were the most significant reasons why people left the outer regions and remote areas of Australia within the study period. Much of this may be attributed to decreasing employment opportunities within the agricultural sector associated with reduced water availability and flow on effects because of this.

2.3.2 Education and employment

There is a high level of education within the ABS Collection District that best represents the Jemalong Irrigation District. Table 2.1 shows that the Jemalong Irrigation District has a higher proportion of people that have completed Bachelor Degrees compared to Australia as a whole. A high proportion of people in the district have also completed an Advance Diploma or Diploma level compared to the national average. In addition, there are generally fewer people in rural areas that have attained postgraduate degrees compared to the whole of Australia; however the proportion of this level of education within the Collection District that best represents the Jemalong Irrigation District is similar to the national average.

Table 2.1 Level of Education above High School

Education Level	Jemalong Irrigation District	Australia
Postgraduate Degree Level	6%	6%
Graduate Diploma and Graduate Certificate Level	0%	4%
Bachelor Degree Level	36%	28%
Advanced Diploma and Diploma Level	24%	17%
Certificate Level	34%	41%

Source: 2006 ABS Census of Population and Housing

In addition to educational qualifications beyond high school, the Jemalong Irrigation District has a similar level of people completing Year 12 and Year 10 compared to Australia as a whole.

This high level of education within the Jemalong Irrigation District indicates that farming and farm business management practices in the region are likely to be of a high standard.

Agriculture is the largest industry of employment within the Mid-Lachlan Region, with 15% of persons employed working in this industry. The other main industries of employment are shown in Table 2.2.

Table 2.2 Major industries of employment within the Mid-Lachlan Region

Industry of Employment	Percent Employed
Agriculture, Forestry and Fishing	15%
Retail Trade	13%
Health Care and Social Assistance	10%
Education and Training	8%
Accommodation and Food Services	7%
Public Administration and Safety	7%
Manufacturing	6%
Construction	6%
Mining	4%
Wholesale Trade	4%
Professional, Scientific and Technical Services	3%

These figures demonstrate the importance of agriculture to the regional economy and community sustainability. The next three largest employment industries: Retail trade; health care and social assistance; and education and training are also likely to be highly impacted by the number of positions available within agriculture.

2.3.3 Household income, annual household expenditure

The median weekly income for the ABS Collection District that best represents the Jemalong Irrigation District in 2006 was $400-599, which was the same as the average for Australia in that year. Jemalong Irrigation Limited delivered 18% of the general security entitlement to shareholders in this year after transmission losses were accounted for. This demonstrates that the Jemalong Irrigation District is able to provide substantial financial support to the surrounding community if it's able to have water delivered.

This is particularly important if the median weekly income for the broader Mid-Lachlan region of $250-399 is considered. Irrigation within the region is vital to the financial sustainability of surrounding communities.

3 BASELINE WATER AVAILABILITY AND MANAGEMENT

3.1 Regulated Lachlan River management and operation

3.1.1 History of Water Development

The construction of the Wyangala Dam in 1935 marked the commencement of water regulation in the Lachlan River. Since this time, off-river lakes Lake Brewster and Lake Cargelligo have been regulated with inflow and outflow management structures. Various other weirs and diversion structures have also been constructed on the River, including the Jemalong Weir. These structures have altered the pattern and volume of the flows in the Lachlan River considerably (DIPNR 2004).

In 1997 the Lachlan River Management Committee was established to provide advice for the creation of environmental flow rules. The Committee was made up from representatives from a wide range of stakeholder groups that included the irrigation industry, indigenous communities, local government and state government agencies such as the Fisheries and National Parks and Wildlife Service (DIPNR 2004).

In 2001 the Minister for Land and Water Conservation asked the committee to make recommendations on water sharing rules for the Lachlan and as a result a draft Water Sharing Plan was prepared. In 2004 the statutory *Water Sharing Plan for the Lachlan Regulated River Water Source 2003* took effect. However, the Lachlan was in drought prior to this time and continues in this state. The rules under the Water Sharing Plan have therefore never been enacted. The Lachlan Regulated River Source is managed under the relevant Drought Contingency Plan.

Currently, the average surface water availability is 1,139GL/year, and about 321GL/year (28%) of this is used. This is a moderately high level of development and includes surface water diversions that total 292GL/year and eventual stream flow loss that is induced by current groundwater use. Groundwater use is about 236GL/year or 45% of total water use (CSIRO 2008). Flows in the Lachlan River are highly regulated, with Wyangala Dam regulating 68% of all inflows. General Security water in the system is highly utilised at approximately 71% (CSIRO 2008).

3.1.2 Institutional Arrangements

State Water is the rural bulk water delivery corporation for New South Wales. State Water manages and operates the dams and weirs on the Lachlan River, monitors usage, manages customer accounts, bills and collects bulk water charges.

Available Water Determinations (AWDs) are the responsibility of the NSW Department of Water and Energy (DWE), supported by State Water, as discussed in greater detail in Section 3.1.4.

Ownership and maintenance of licensed extraction meters currently rests with the water supply work approval holder, with meter readings taken by State Water. A $90 million dollar program announced in July 2008 is aimed at replacing all privately owned extraction meters with patent approved extraction meters that that will be owned, maintained and managed by State Water.

Water pricing is set by the Independent Pricing and Regulatory Tribunal (IPART).

3.1.3 Lachlan Regulated River Water Entitlements

The Water Sharing Plan lists the following access license categories and share components for the Lachlan Regulated River Source. The Water Sharing Plan notes that these values are estimates of what was considered likely at the time of commencement of Part 2 of Chapter 3 of the Water Management Act 2000. Details of the actual licensed share components held by State Water are provided in Table 3.2

Table 3.1 Access licence share components detailed in the Water Sharing Plan

Share type	Priority	Entitlement ML/yr
Basic rights		
Stock & Domestic		None
Native Title		None
Extraction		
Total Licensed Long Term Extraction		305000
Local Water Utilities	High	15539
High Security Access	High	26472 (shares)
Conveyance	High	999.4
	General	16911.6
Stock & Domestic	High	13100
General Security Access	Medium	592847 (shares)
Environmental Provisions		
Total Environmental share		907000*
Environmental Allocation	High	350000** (shares)

*By limiting long-term average annual extractions to an estimated 305,000 ML/y this plan ensures that approximately 75% of the long-term average annual flow in this water source (estimated to be 1,212,000 ML/y) will be preserved and will contribute to the maintenance of basic ecosystem health.

** An allowance for replenishment flows to be provided for the environment and unregulated river access licences if required, of up to 12,000 ML/y to Willandra Creek; 9,000 ML/y to Marrowie Creek; 9,000 ML/y to Torriganny/Muggabah/Merrimajeel Creeks; and 12,500 ML/y to Booberoi Creek.

Source: (DIPNR 2004)

Table 3.2 Access licence entitlements according to the State Water Lachlan Valley Business Plan

Access Licence Category	Number of Licences	Licence Entitlement (ML)
General Security	779	581,710
High Security	91	26,685
Conveyance	1	17,911
Domestic and Stock	307	12,286
Domestic and Stock (Domestic)	60	172
Domestic and Stock (Stock)	178	1,639
Town Water Supply	9	15,545
TOTAL	1425	655,948

Source: State Water Lachlan Valley Business Plan

The Water Sharing Plan includes an annual allowance of 10,000ML for the management of an environmental contingency allowance held in Wyangala Dam (the WECA) and 10,000ML for the management of an environmental contingency allowance held in Lake Brewster (the LBECA).

Additional notes regarding water entitlements of the Lachlan catchment area include:

- Floodplain harvesting of water is not covered in the Water Sharing Plan or allocation procedures. There are three Rural Floodplain Management Plans underway or finalised for the Lachlan Catchment:
    - Lachlan River: Gooloogong to Jemalong;
    - Lachlan River: Jemalong to Condobolin and
    - Lachlan River: Lake Brewster Weir to Whealbah (Hillston).
- The unregulated section of the Lachlan River comes under the Lachlan River – Unregulated Surface Water Management Area (SWMA) and comprises 59,891km^2. This SWMA has a set of high level performance indicators for water management separate to the operations of the regulated section of the river.

3.1.4 Water Allocation Methodology

The allocation 'Water Year' commences on 1 July of each year and runs to 30 June. High security Available Water Determinations (AWDs) are reset to zero on 1 July. Unused General Security AWDs and environmental water allowances up to 100% of the allocation may be carried over from one year to the next. All AWDs are increased or decreased throughout the water year as dam levels allow.

The NSW Department of Water and Energy website states that one of its roles is to "determine the volume of water available for extraction for the various categories and subcategories of access licences in relation to those water sources covered by water sharing plans". In reality, this role is supported by State Water, which carries out resource assessment as part of its operations planning. The resource assessment, with recommendations, is passed on to the Department of Water and Energy (DWE) which makes an Available Water Determination (AWD – previously referred to as announced allocation).

The *Water Sharing Plan for the Lachlan Regulated River Source* states that "the water supply system shall be managed so that available water determinations for domestic and stock access licences of 100% of share components can be maintained through a repeat of the worst period of low inflows to this water source represented in flow information held by the Department". Similarly, the water supply system shall be managed to that "available water determinations for local water utility access licences of 100% of share components" and "available water determinations for regulated river (high security) access licences of 1 megalitre per unit share can be maintained through a repeat of the worst period of low inflows to this water source represented in flow information held by the Department."

These allocations are generally made before any general security AWD is made. A proportion of Jemalong Irrigation Limited's conveyance licence is included in these high security determinations.

The available water determination for regulated river (general security) access licences are then made and based on the volume available after making provision for:

(a) the environmental water provisions established by the Water Sharing Plan,
(b) requirements for domestic and stock rights,

(c) requirements for native title rights
(d) requirements for domestic and stock access licences
(e) requirements for local water utility access licences
(f) requirements for regulated river (high security) access licences
(g) requirements for regulated river (conveyance) access licences
(h) allocations remaining in access licence water allocation accounts from previous available water determinations
(i) water losses associated with the holding and delivery of water to meet the requirements identified in subclauses (a) to (g)
(j) an appropriate volume to meet water losses associated with the holding and delivery of water resulting from the available water determination and
(k) any other relevant matters

Available water determinations for regulated river (conveyance) access licences are made at the commencement of each water year and as required, during the water year. The rules governing the volume allocated to the regulated river (conveyance) access licences are based on the amount of general security access licence AWD and are set out in the Water Sharing Plan.

If, at the start of a water year, the AWD is less than 100%, the AWD is reviewed monthly until the end of the water year. If sufficient rainfall occurs during any one month, the AWD will be increased. General security AWDs not used in one water year may be 'carried over' to subsequent years until it is used, traded or forfeited to water accounting rules (e.g. evaporation losses). Evaporation reductions apply to carryover water in account balances at the end of each quarter, based on the net evaporation on the extra surface area generated by the carryover account water (DIPNR, 2004).

3.1.5 Water Delivery and Billing

Water Access Licence Holders place a Water Order with State Water stating the date and amount of water in megalitres for each licence type that is required and nominating the water supply works through which the water is to be extracted. Sufficient time should be allowed to account for transmission from the dam to the extraction site.

An access licence holder's water account is debited as: "the volume of water taken by the approved water supply works nominated by the access licence, or the greater of (i) the volume of water extracted by the approved water supply works nominated by the access licence, or (ii) the volume of water ordered for extraction by the approved water supply works nominated by the access licence, where the Minister has applied such a discretionary condition to the access licence" (*Water Sharing Plan for the Lachlan Regulated Rives Water Source*, 2003).

Transmission losses from Wyangala Dam to each Lachlan River extraction location have been estimated by State Water and are released in addition to the Water Order amount to ensure sufficient water reaches the extraction site. Should the amount extracted by an access licence holder be less than their water order, State Water have the ability to re-regulate the water using any of the structures further downstream. State Water works closely with the water users to get the water orders to closely match the water extraction in order to minimise operational surpluses and shortfalls.

3.2 Average annual general security available water determination

The Average Annual General Security Available Water Determination (AWD, previously known as allocation) has been calculated using information sourced from the Water Sharing Plan for the Lachlan Regulated River Water Source 2003 - REG 31, (NSW and Government 2004).

An estimate of the Long-term Average Annual Extraction Limit within the Lachlan Regulated River Water Source has been made under conditions specified in subclause (1) (a) of the Water Sharing Plan for the Lachlan Regulated River Water Source 2003 Plan (NSW and Government 2004).The Long Term Average Annual Extraction Limit estimate made using the Lachlan IQQM computer model under the conditions as specified in the Water Sharing Plan indicated a long-term average annual extraction volume of approximately 305,000 ML/year. The Maximum Average Long Term Extraction Limit set using the Lachlan IQQM computer using baseline conditions established under the Murray-Darling Basin Agreement, indicate a Maximum Long-Term Average Annual Extraction volume of approximately 315,000 ML (DIPNR 2004). The Water Sharing Plan establishes that the long-term extraction limit for the Lachlan Regulated River water source is the lesser of these two scenarios.

By limiting long-term average extractions to an estimated 305,000 ML/year the Water Sharing Plan ensures that approximately 75% of the long-term average annual flow in the Lachlan River (estimated to be 1,212,000 ML/year) will be preserved and will contribute to the maintenance of basic ecosystem health (DIPNR 2004). This 305,000 ML/year is to be shared between the 655,948ML or unit shares of extraction licences.

To calculate the average water availability or the Average Water Determination (AWD) for the Lachlan Regulated River Water Source, all access share components other than the General Security component are subtracted from the Total Licensed Average Long Term Extraction Volume. The result is then divided by the number of general security unit shares to determine the Average Annual General Security Available Water Determination.

For the purpose of this estimate and with input from State Water Operations Manager we assume that the utilisation of high security licenses is currently 100%. Current utilisation of Local Water Utility access licences & Stock & Domestic access licences has been advised as 70%-80%. 75% has been assumed as the average figure. Conveyance water for Jemalong Irrigation Limited currently has a pseudo high security component. When general security allocation is zero, 999.4ML of conveyance water is allocated. The remaining 16911.6ML portion of Jemalong Irrigation Limited’s conveyance volume is regarded as general security.

Using the access entitlement figures presented in the Water Sharing Plan the Average Annual General Security Available Water Determination is calculated as 43%.

Using the access entitlement figures presented in the Lachlan Valley Business Plan (State Water 2006), the Average Annual General Security Available Water Determination is also calculated as 43%.

Adopted 2009 Average Annual General Security Available Water Determination

43%

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4 THE JEMALONG IRRIGATION DISTRICT

4.1 General Scheme Description

The Jemalong Irrigation District (JID) is managed by Jemalong Irrigation Limited (JIL). Water distribution is the company's core business and is budgeted to operate on a financial break-even basis.

The Jemalong Irrigation District includes approximately 300km of open channel delivery system, which when at full working capacity are able to divert and deliver a volume of up to 700ML of water per day. The system is comprised of an off-take adjacent to Jemalong Weir on the Lachlan River and a network of supply channels.

Water is ponded upstream of the Jemalong Weir above the lip level of the Jemalong Irrigation District off-take. Water is transferred from the Lachlan River to Jemalong Irrigation District channels through gravity when the off-take gates are opened.

Figure 4.1 Jemalong Weir

Source: Boyden & Partners

Flows and water levels throughout the system are regulated by check-gates. Shareholders/members receive their allocation when water in the scheme channel adjacent to their property is high enough and gates at their off-take are opened. The scheme is therefore operated by gravity throughout, with no pumps required. Volumes are measured by Dethridge wheel meters or water management outlets.

4.2 Legal and Water Entitlement Structure

Jemalong Irrigation Limited is an unlisted public company that was formed in 1995. There are 119 shareholders in the company, with the number of shares held proportional to the water volume that shareholders are entitled to.

Jemalong Irrigation Limited is governed by a Board of Directors that are made up of irrigation farmers within the district. All members of the board are elected by shareholders and hold a term of four years.

Jemalong Irrigation Limited is the holder of all Water Access Licences for the Jemalong Irrigation District, shown in Table 4.1. Shareholders/members may have a water access/delivery entitlement and/or a separate water volume entitlement. That is, the right to physical water is separate to the right to have that water delivered.

Table 4.1 Water access licences of Jemalong Irrigation Limited

Water Access Licence	Entitlement Category	Share
Water Access Licence No. 13739	General Security	0 units
Water Access Licence No. 15132	General Security	78907 units
Water Access Licence No. 7708	Conveyance	17911 units
Water Access Licence No. 7709	High Security	200 units
Water Access Licence No. 7711	Stock and Domestic	1756 ML per year

Note: The unit shares in this table represent the number of megalitres that would be allocated if a 100% AWD was made,

4.3 Water Users

There are 175 holdings for general security irrigation water and stock and domestic water within Jemalong Irrigation Limited. The members of the Jemalong Irrigation District also consistently undertake temporary transfer water in to the District from other entitlement holders. Therefore, they frequently have water volumes in excess of the AWD with which they are able to produce more than they would otherwise.

In addition to holdings within the Jemalong Irrigation District, Jemalong Irrigation Limited also delivers general security water that is utilised for stock and domestic purposes to 19 farms and their families outside the Jemalong Irrigation District. This group is called the 'out of district users'.

Barrick Gold Corporation (Cowal Gold Project) utilises the Jemalong Irrigation Limited infrastructure to deliver water to their extraction point located in the "2C" channel on Division 2 of the Jemalong Irrigation Limited system. Barrick Gold purchase water from Jemalong Irrigation Limited and from the river and pay service fees to Jemalong Irrigation Limited for delivery.

4.4 Organisational Structure, Staff and Experience

An elected Board of Directors represent Jemalong Irrigation Limited in decision-making and management. A board of seven members serve a four year term with half of the board elected every two years. The Board positions are made up of the Chairperson and Deputy Chairperson and five Directors. Jemalong Irrigation Limited outsources the Board Secretary role.

The Board is responsible for five paid positions employed by Jemalong Irrigation Limited. These are scheme General Manager, Senior Irrigation Officer, two Irrigation Officers and the Land and Water

Management Project Manager. The responsibilities of the paid staff are presented in Table 4.2 and Board members and their experience are listed in Table 4.3.

Table 4.2 Jemalong Irrigation Limited staff roles and responsibilities

Jemalong Irrigation Limited Position		
General Manager	**Irrigation Officer**	**LWMP Manager**
Responsibilities:		
• Undertake the role of Company Secretary	• Record keeping of water orders placed and water usage	• Prepare annual environmental and compliance reports
• Ensure the company's share register is properly maintained	• Liaison with both irrigators and State Water regarding timing and delivery	• Process applications for incentive funding
• Ensure that all compliance obligations are met	• Operation of a variety of plant and equipment	• Update GIS and excel files with information from shareholders e.g. cropping details, land forming, irrigation, new tree plantings etc
• Accounts and billing	• Carry out of a variety of maintenance tasks	• Groundwater depths using piezometer network (Quarterly)
• Technology upgrading	• Handling and application of chemicals	• Provide quarterly report to the CMA on funding balances and targets
• Time and resource management of the Board	• Construction and installation of structures within the irrigation district	• Provide water efficiency training courses for JIL shareholders
• Staff and member communications	•	• Update funding spreadsheets
Current Position Holder		
s 22(1)(a)(ii)	s 22(1)(a)(ii)	s 22(1)(a)(ii)
Experience in this Position		
s 22(1)(a)(ii)	s 22(1)(a)(ii)	s 22(1)(a)(ii)

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Table 4.3 Jemalong Irrigation Limited Board Members and their experience

Board Member	Experience
s 22(1)(a)(ii)	

4.5 Operations Management and Maintenance

4.5.1 Water Ordering

Individual shareholders/customers notify the Jemalong Irrigation Limited scheme office of their desire to place a Water Order. The Senior Irrigation Officer then completes a State Water 'Water Order Form' and communicates with State Water over water delivery to Jemalong Weir.

Stock and Domestic water requests are generally delivered as they are received if larger amounts of water are also being delivered. In very low allocation years when irrigation water is not delivered, stock and domestic water may not be able to be delivered due to prohibitive transmission losses.

4.5.2 Water Delivery and Metering

The Senior Irrigation Officer advises the Channel Attendants of the date to commence operation of the scheme off-take at the Jemalong Weir and to which sections of the scheme water is to be delivered. The Channel Attendants are then responsible for ensuring that water is delivered to the appropriate location within the scheme.

Scheme channel inverts are generally lower than the surrounding fields and their on-farm channels. Farm off-takes are therefore generally high in the scheme channel bank. In order to deliver water from the channels to farms without pumping, the water level in the scheme channel must be raised almost to bank level. This is known as the 'full supply level'. To be able to maintain sections of channel at full supply level without filling the complete channel length, regulator or check structures have been constructed within scheme channels to stop water flowing further downstream, acting as weirs. These check structures consist of several 'drop boards' sitting one on top of the other with guides at either end to keep them in place. The water level in a particular reach is regulated by Channel Attendants adjusting the number of drop boards in the check structure.

The scheme is generally operated with the water level in the majority of channel reaches at or near full supply level for the 9 month irrigation season. Significant amounts of water are stored within the channels behind check structures. Water orders for shareholders at the downstream ends of the channel can be delivered by lifting drop boards further upstream and allowing stored water to pass through the system to its destination. This water is then replaced by flow delivered to Jemalong Weir once this has arrived. In this way, water can be delivered to shareholders sooner than the full delivery time from Wyangala Dam.

Channel Attendants are also charged with opening and closing the lateral or off-take gates of individual shareholders as required. Water passes through a meter which records the volume of flow delivered. Water metering is undertaken largely by Dethridge wheels. As part of the *Land and Water Management Plan*, Dethridge wheels are being strategically replaced by higher accuracy Water Management Outlets (WMOs) as referred to in Section 4.6.4.

The system operation is highly responsive to individual water orders. It is therefore highly dependent on the type, area and distribution of crop, weather conditions, rainfall, timing of orders throughout the scheme and how much water is stored in each of the channel reaches between check structures at any given time.

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4.5.3 Maintenance

Jemalong Irrigation Limited replaces structures as required. Channel maintenance also follows this policy and repair work is done when necessary. Channel maintenance includes desilting and reshaping of supply channels.

Assessing capital works is done on a regular basis with recommendations put forward periodically.

4.5.4 Billing

Revenue is collected through an access charge based on the access/delivery entitlement, and a separate charge for the actual volume of water delivered (per megalitre).

An additional levy is charged to implement natural resource management through *The Land and Water Management Plan*. This levy is based on the total cost of measures outlined in *The Land and Water Management Plan* divided over time. During recent times of very low allocation, production and income charges associated with *The Land and Water Management Plan* have been deferred.

4.5.5 Water Trading

To facilitate the best use of available water resources, the company encourages water trading and flexible management of resources. Existing Jemalong Irrigation Limited policies allow shareholders greater flexibility to manage water entitlements and allocations to suit individual needs. These initiatives are unavailable to riparian irrigators on regulated river systems.

4.5.6 External income streams

Jemalong Irrigation Limited generates income independent of shareholder contributions through an extensive investment portfolio to assist with the maintenance and renewal of infrastructure.

4.6 Jemalong Irrigation Limited Internal Review

In July 2007 Jemalong Irrigation Limited commissioned a *Survey of Shareholders of Jemalong Irrigation District (Hassell and Associates Pty Ltd 2007)* to identify operational and strategic issues within the scheme. The survey sought feedback from Jemalong Irrigation Limited shareholders on the company's current and future business planning activities. A mail survey was posted to 92 individual shareholders in June 2007. There were 23 mail survey responses. A telephone survey of 12 randomly selected shareholders was also conducted.

Shareholders were asked if they were confident that Jemalong Irrigation Limited has achieved results in the following areas:

- Managed projects in a cost effective way
- Developed good communication systems
- Addressed local needs
- Conducted business professionally
- Has had effective leadership
- Developed good management systems

Shareholders that responded to the written questionnaire were also asked the areas of Jemalong Irrigation Limited operations that they considered to be important to their own business. The overall ranking of priority issues based on responses was:

1. Irrigation water delivery
2. Communications with members and customers
3. Infrastructure maintenance and improvements
4. Policy development for water trading
5. Environmental management and the Land and Water Management Plan
6. Lobbying associated with national reforms and
7. Interaction with the Lachlan Valley Customer Services Committee

An additional 12 shareholders were contacted at random by telephone. For these shareholders, water availability was overwhelmingly mentioned as the number one issue facing irrigators. Other specific issues raised included the cost of water, particularly in years of little or no allocation, the length of irrigation season, stock and domestic access, and water trading policy.

Operational and Future Issues

- Infrastructure – respondents generally considered that the management of Jemalong Irrigation Limited water delivery infrastructure was good and established company programs to improve infrastructure rated positively.
- System planning – it was the view of respondents that Jemalong Irrigation Limited conducted system wide planning. Issues such as losses and channel management were not always readily understood by individual shareholders.
- Planning – respondents did not always identify the link between external government policy changes and Jemalong Irrigation Limited operational rules regards pricing, stock and domestic water, channel operations and water trading.
- Infrastructure – Channel seepage was identified as the most pressing issue for improvement. Shareholders are open to Jemalong Irrigation Limited being involved in water trading.
- Constitutional Changes – an option has been identified to have an independent director on the board.
- Policy development and communication – water trading and pricing issues were considered to be important policy issues.

It is important to note that shareholders in the Jemalong Irrigation District were considering these issues prior to the announcement of funding under *Sustainable Rural Water Use and Infrastructure*.

Recommendations and policies put in place as a result of survey feedback:

- A communication strategy has been developed to keep shareholders informed.
- A process of information sharing such as seminar style meetings and detailed newsletters has been undertaken to improve the understanding of shareholders on key policy.
- A review of Jemalong Irrigation Limited policies has been undertaken and the understanding by directors, management and staff should be clarified and agreed to.
- The policy making agenda and significant issues should be included in an annual strategic plan which would highlight and inform shareholders of up coming policy decisions (since adopted)

4.7 Physical Assets

Details of the physical assets of Jemalong Irrigation Limited are presented in Table 4.4

Table 4.4 Jemalong Irrigation Limited Asset Register

ASSET	AGE	CONDITION
Delivery system approx 300km	Approximately 69 years old	Good
Jemalong Weir off-take	Approximately 69 years old	Good
In channel structures	69–2 years old, constantly being upgraded	Good
Scheme office and freehold land	40 years old	Good
AFFRA meter	8 years old	Good
Work shop	50 years old	Good
Vehicles and plant	10 years old	Good
Dethridge wheels	Approximately 69 years old	Good
Water Management Outlets	Approximately 9 years old to new	Good

4.7.1 Delivery System

The 300km of channel operated by Jemalong Irrigation Limited are all earth channels. The channels are generally categorised into three types: those utilised for the majority of the irrigation season – the main channels; those utilised less frequently; and those used only when delivering water to adjacent properties – the spurs.

The Jemalong Irrigation District has two divisions:

- Division 1 –channels serviced by the Cadow Upstream main channel and generally more in the north of the scheme
- Division 2 – channels serviced by the Jemalong Main Upstream channel and generally more in the south of the scheme

In Division 1, the Warroo Main channel runs within a prior stream formation and is known to have high seepage in several locations (GHD 2008). The banks of this channel are perched slightly higher than the surrounding floodplain. In areas to the south, the channel is generally cut into soils with high clay content. Channels in Division 1 generally have higher infiltration rates than channels in Division 2.

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Figure 4.2 Divisions of the Jemalong Irrigation District

Source: Boyden & Partners

4.7.2 Jemalong Weir and Jemalong Irrigation Limited off-take

The Jemalong Weir is owned by State Water and is constructed of concrete and steel. It consists of 3 vertical lift gates, each measuring 12.2 m wide by 5 m in height. There are bypass gates located in each abutment and these gates are 1.8m wide by 1.4m high.

The Jemalong Irrigation District scheme is a gravity fed system. The scheme off-take is located on the south abutment of the Jemalong Weir and consists of a box culvert with a 4.1m wide by 1.5m high radial gate. The reported maximum capacity of the off-take supply is 800ML per day. The reported average off-take is approximately 450-600ML/day.

Figure 4.3 Jemalong Irrigation Limited scheme off-take

Source: Boyden & Partners

4.7.3 Structures

A comprehensive record of the existing structures and their location has been recorded within a database. Structure locations in the channel network locations have been determined by chainages along the length of each channel reach.

A breakdown of most of the structures created from data supplied to Boyden & Partners by Jemalong Irrigation Limited is presented in Table 4.5.

Table 4.5 Jemalong Irrigation Limited structure details

Type Of Structure	Qty
Road Bridge	99
Access Bridge	60
Road Culvert	79
Access Culvert	49
Access Bridge & Regulator	85
Road Bridge & Regulator	14
Access Culvert & Regulator	32
Regulator Check	260
Pipe Outlet	99
Siphon	14
Subway	64
Maintenance Culvert	3
Flood Escape	8
Other Structures	18
Inverted Siphon Metered Outlet	2
Abandoned / Removed Structure	1
Total	**887**

Records from the Jemalong Irrigation Limited database indicate that the majority of the structures were constructed around 1941; however upgrades have been on-going up to the present time.

The most common structure throughout the Jemalong Irrigation District is a regulator check gate. Pipe outlets are the second most common structure, followed closely by bridges.

Structure location data was supplied by Jemalong Irrigation Limited in the form of chainages along reaches. These chainages have been manually entered into a geographic information systems (GIS) computer mapping program, thus giving each structure an approximate location coordinate.

4.7.4 Meters

Jemalong Off-take

The main scheme off-take at the Jemalong Weir is fitted with water level gauges upstream and downstream and a device to measure the open height of the gate. Water flow rates and volumes are calculated from these three measurements.

Figure 4.4 Jemalong Irrigation Limited off-take at Jemalong Weir

Source: Boyden & Partners

In 2001-2002 Jemalong Irrigation Limited installed and calibrated an Acoustic Flow meter For Remote Areas (AFFRA) downstream from the scheme off-take at Jemalong Weir. This meter is an acoustic Doppler flow meter that continuously measures the velocity of flow.

The Doppler flow meter (or Ultrasonic meter) is a volumetric flow meter which measures the instantaneous and total water flow in channels and pipelines. The basic principle of its operation employs the frequency shift (Doppler Effect) of an ultrasonic signal when it is reflected by suspended particles in motion in the water (Hydro and Environmental 2007).

Figure 4.5 AFFRA meter installed by Jemalong Irrigation Limited

Source: Boyden & Partners

Doppler flow meters are reputed to operate over an extremely wide flow range (0.5 ML/day to 6,000 ML/day), are robust and require minimal maintenance. The Doppler flow meter can measure bi-directional flow and is easy to install (Hydro and Environmental 2007).

The accuracy of the Doppler flow meter can be affected by power supply fluctuations or if power is not being maintained, electronic components can suffer damage e.g. lightning damage. If the meter has not been installed or calibrated to manufacturer's specifications this can also affect the accuracy of the Doppler flow meter (Hydro and Environmental 2007). Jemalong Irrigation Limited has the Doppler flow meter calibrated twice per year.

Dethridge Wheels

The Dethridge wheel meter is a positive displacement meter invented in Australia in 1910 by John Dethridge, who was the Commissioner of the Victorian State Rivers and Water Supply Commission at the time. Until recently the Dethridge wheel meter has had widespread use with over 40,000 meters installed throughout most of the major irrigation water providers in Australia. The general design and dimensions of the Dethridge wheel have remained unchanged for more than 90 years (Hydro and Environmental 2007).

The Dethridge wheel meter measures and records the volume of water delivered with reasonable accuracy under controlled laboratory conditions, given that:

- Clearances and settings of the wheel relative to the concrete emplacement are within tolerance.
- The upstream and downstream water levels are within acceptable limits.
- Flow rates are limited to between 1 ML/d and 12 ML/d.
- Water is not allowed to jet under the upstream control gate into the vanes on the wheel (Hydro and Environmental 2007).

Tests carried out in the field commissioned by Goulburn-Murray Water, found that all Dethridge meters under-measured the volume of water delivered (Hydro and Environmental 2007). Volume inaccuracies were within a range of -24.1% to -1.5%, with an average of -10% which exceeds the industry standard tolerance allowances of ± 5.0% by a significant degree (Hydro and Environmental 2007). Dethridge meters generally under measured to a greater degree at lower flow rates (Hydro and Environmental 2007).

In 2008 the accuracy of Dethridge wheels was the subject of another study completed in the Goulbourn Murray Irrigation District (Hydro and Environmental 2008). This later study found that Dethridge wheels have an average meter error of up to 6.9% in favour of the irrigator. Although the results vary from the 2007 report to the 2008 it does highlight the level of inaccuracy that can be associated with the Dethridge wheel.

Figure 4.6 Dethridge wheel on Jemalong Irrigation Limited

Source: Boyden & Partners

The Jemalong Irrigation District uses Dethridge wheels to estimate water deliveries from scheme delivery channels to individual properties. There are approximately 135 Dethridge wheels in Division 1 and 112 in Division 2 of the Jemalong Irrigation District.

Water Management Outlets

Water Management Outlets (WMOs) are HDPE pipes with a vertical sluice gate that are manufactured on site at the Jemalong Irrigation Limited office. They can be linked to a SCADA remote control system, giving Jemalong Irrigation Limited greater control over its operations through being able to open and close the meters from the scheme office, although the office has yet to be fitted with this system. WMOs are fitted with a flow meter however the accuracy for water measurement in this configuration is yet to be fully tested and confirmed.

WMOs have the ability to deliver between 1-80ML a day which can increase an irrigator's capacity to irrigate more efficiently.

Figure 4.7 Water Management Outlet locally manufactured by Jemalong Irrigation Limited

Source: Boyden & Partners

Currently Jemalong Irrigation Limited has installed approximately 27 WMOs in Division 1 and 18 in Division 2.

4.8 Scheme Viability

Financial records for Jemalong Irrigation Limited demonstrate that it has been financially viable since its commencement in 1995. The Balance Sheet and Profit and Loss Statement from the 2007/08 financial report are provided in Appendix A in support of the scheme's viability. The independent audit report by AA Williams states that:

> "In our opinion, the financial report presents truly and fairly in accordance with applicable Australian Accounting Standards, Corporations Act and other mandatory professional reporting requirements in Australia the financial position of the company as at 30th June 2008, and the results of its operations and cash flows for the year then ended".

One issue in the management of the scheme is the ability of farmers to pay charges when little or no water is being delivered.

The viability of farms within the Jemalong Irrigation District is discussed in Section 6.6.

5 THE JEMALONG LAND AND WATER MANAGEMENT PLAN

In April 2001 Jemalong Irrigation Limited, with direction from the New South Wales State Government, finalised *The Jemalong Land and Water Management Plan* (*The Jemalong LWMP*) to address natural resource management issues in the district.

The Jemalong LWMP aims to guide the development of the Jemalong Irrigation District so that land and water resources are used in a way which is profitable and improves and sustains the environment and agriculture for current and future generations. The goals of *The Jemalong LWMP* determined by the Steering Committee to achieve this are:

1. To reduce accessions to the water table, thereby helping to minimise salinity and water logging
2. To increase the economic viability of the Plan area
3. To increase awareness of the value of land and water management planning
4. To increase the implementation of best management practices
5. To alleviate the adverse effects of local agricultural practices on soil and water quality

The irrigation district has previously experienced increases in water table levels, including surface drainage issues resulting in localised salinity outbreaks. Factors contributing to these issues have been land clearing, irrigation application and scheduling, grazing management, replacement of perennial pastures with annual plantings and recharge from flood events.

The Jemalong LWMP presents strategies and targets focusing on the on-farm options of land forming, farm planning, property management plans, recycling systems, high volume outlets (water management outlets), soil fertility testing and improved pastures. Regional options include fencing remnant vegetation, planting new trees and the construction of floodway levees and rain rejection storages.

The expected outcomes/benefits from introducing such strategies are in line with the broader objectives of LWMP's in general including: alleviate land and water degradation; improve natural resource management; and provide for environmental and agricultural sustainability. They include reduction in accessions to the watertable, reductions in water logging and salinity and improvements in farm productivity levels, protection of biodiversity, heritage values and aesthetic enhancement.

Implementation of the strategies outlined in *The Jemalong LWMP* is based on contributions from the Australian Government, New South Wales Government, the wider community and individual shareholder levies. An incentives program has been developed to encourage landholders to participate at an on-farm level.

To date the implementation of *The Jemalong LWMP's* strategies have been supported by landholders throughout the district.

In June 2008, an independent consultant was appointed to complete an extensive review of *The Jemalong LWMP*. There is opportunity to tailor the plan to include technologies and options that relate to irrigation and stock and domestic modernisation planning outcomes. This will ensure the successful continuation of *The Jemalong LWMP* strategies.

6 BASELINE IRRIGATION AND FARMING

6.1 Overview

The Jemalong Irrigation District was constructed in 1936 and began operations in 1941. The intended purpose of the scheme's development was to offer additional security to the region's water resources, thereby creating conditions for a prosperous agricultural industry. The Jemalong Irrigation District of today supports the water requirements of over 90 farms, the majority of which are family owned and operated.

The Jemalong Irrigation District's farming enterprises include a variety of dairy, horticultural, cropping and grazing activities. All farms rely to varying degrees upon a regular supply of water delivered by Jemalong Irrigation Limited. The security of available water resources and their capacity to sustain irrigation, livestock and household water requirements supports the survival of the local agricultural industry, schools and residents.

6.2 Irrigation Technology and Cropping

Water diverted for irrigation in the Jemalong Irrigation District historically enabled an area of approximately 40,000ha of agricultural land to be developed for irrigation. Presently, there is approximately 23,000ha utilised for irrigation. The availability of water has increased the diversity of agricultural commodities with citrus fruits, cereal crops, oil seed crops and fodder crops produced annually.

Once water is diverted on-farm from scheme channels, it is delivered to crops mostly through earthen infrastructure that includes supply channels ("head ditches"). These channels feed water into narrow elongated fields (known as border-check surface irrigation) or "flood bays" via in-bank or over-bank siphons, or larger bay outlets.

The recent water shortage has seen a growing number of farms initiate development of privately funded on-farm water efficiency projects. Such projects have been made possible by a rapidly evolving technology market. Improvements in water efficiency have been achieved through investment in precision delivery technology including low pressure pivot irrigation and sub-surface drip irrigation systems. Furthermore, technology has allowed for more efficient management of in-field water application rates through the incorporation of soil moisture sensors and data loggers. These instruments provide farmers with accurate crop water requirements, to which water delivery systems can be calibrated. A reasonable uptake of irrigation application and soil moisture monitoring techniques has occurred in the Jemalong Irrigation District. The capital cost of these technologies has been a factor in decreasing their widespread adoption.

The availability of water for irrigation offers Jemalong Irrigation District farmers a measure of security for crop production. In the absence of significant rain events, water can be applied to crops at regular intervals when required by plants. Regular waterings increase crop yields and provide options for greater diversity in crop production. An analysis of the 2002-03 season is indicative of the land area and diversity of crops that can be brought into irrigated production in a lower AWD or allocation year of

32%. 2002-03 incorporated both summer irrigated crops (including vegetables and irrigated pastures for livestock) and winter irrigated crops (including cereal crops, oilseeds and irrigated pastures for livestock) and brought a total of 8,459ha into production (Jemalong Irrigation Limited database information 2009). This area production was only part irrigated due to above average summer rainfall.

Figure 6.1 Flood bay irrigation

Source: Western Land Planning Pty Ltd

6.3 Grazing and Stock and Domestic Water Supply

A secure stock and domestic water supply is essential for the survival of rural communities. Stock and domestic water services the requirements of households and gardens as well as grazing animals. Information obtained from *On-Farm Water Efficiency Plans* estimates approximately 26,800ha of land in the Jemalong Irrigation District is currently used for livestock grazing.

Jemalong Irrigation Limited holds a water entitlement with a high allocation priority to service stock and domestic users within the district. At present stock and domestic water is delivered to farms through the Jemalong Irrigation Limited scheme network. In lower allocation years, the proportional losses that occur through delivery of stock and domestic water in open channel infrastructure are significant. Reducing water loss through delivery is therefore effectively managed in lower allocation years by providing stock and domestic water delivery only when bulk water deliveries are required. As a result, the provision of high security stock and domestic water entitlements is irregular and cannot be guaranteed during low allocation years when general security water is unavailable.

The importance of a secure stock and domestic system led Jemalong Irrigation Limited working with the NSW State Government working with Jemalong Irrigation Limited to develop several piped bore water schemes throughout the Jemalong Irrigation District. Small groups of neighbouring farms formed Bore Trusts. There was an opportunity to access $250,000 in government funds, including expertise in design and assistance in part funding of construction of piped systems serviced by community bores. However, the total program cost was in excess of $4 million, so substantial investment was required from farmers in addition to government funding. As a result, several Bore Trusts chose not to participate. Of those that did, costs were minimised in some cases by deliberately under-sizing the system to reduce expenses. Many members of Bore Trusts rely on stock and domestic water delivered by Jemalong Irrigation Limited to supplement their bore water delivery.

The high level of private investment that was put into the community bore scheme is indicative of the importance given by Jemalong Irrigation District landholders to increase the availability of high security stock and domestic water. While the piped community bore schemes have provided substantial benefit to sustaining farming families within Jemalong Irrigation District, the long term security of bore supplies has come into question. This, in addition to the deliberate under-sizing of some schemes, means that there is significant shortfall in the ability of the bore system as a whole to meet the stock and domestic requirements of the Jemalong Irrigation District.

6.4 Dryland Cropping

The Jemalong Irrigation District produces a variety of dryland crops over both summer and winter growing seasons. Dryland cropping refers to the production of crops without the assistance of irrigation water. The success of dryland cropping carries a much greater degree of uncertainty as crop water requirements are completely dependent upon adequate and timely rain events.

Information obtained from *On-Farm Water Efficiency Plans* estimates an area of approximately 45,700ha currently being used for dryland cropping in the Jemalong Irrigation District. Dryland cropping is an essential component of income generation for the majority of the Jemalong Irrigation District's farming enterprises. Dryland cropping is predominately a winter activity as expected evaporation rates are less and rainfall is more effectively stored in soil profiles. Winter dryland cropping in the Jemalong Irrigation District typically includes the production of:

- Cereal crops (wheat, oats, barley) for domestic consumption and export markets
- Seasonal oilseed crops (canola, jojoba) for domestic consumption and export markets
- Pulse crops (chick peas field peas, lupins) for domestic consumption and export markets
- Vegetables for domestic consumption and export markets

Summer dryland cropping in the Jemalong Irrigation District typically includes the production of:

- Fodder crops (lucerne, phalaris and rye grass) for livestock consumption
- Opportunity summer crops

6.5 Conservation Land Management

Conservation land management is given strong emphasis throughout the Jemalong Irrigation District. *The Jemalong LWMP* (JLWMP, 2001) is a pre-emptive report designed to provide guidelines for common environmental management. The report encapsulates the principles of sustainable agriculture and provides Jemalong Irrigation Limited shareholders with an action plan for conservation land management.

Property management in the Jemalong Irrigation District is responsive to the principles outlined by *The Jemalong LWMP* and widely demonstrates a range of innovative measures designed to deliver a sustainable farming future. Sustainable farming practices have been widely embraced including:

- Soil management practices that protect soil structure, fertility and moisture including minimal-till and zero-till cultivation, direct seed drilling and controlled traffic movement
- Investment in soil remediation works where soil degradation is evident including the rehabilitation of saline and/or scalded land through the establishment of saltbush plantations
- The control and eradication of noxious weeds through the establishment of perennial pastures
- The importance of maintaining and enhancing property vegetation and wetland environments within the Jemalong Irrigation District is recognised and addressed through:
  - Establishment of windbreaks on paddock boundaries that serves to minimise wind erosion and assists in building biodiversity
  - Ongoing protection of significant vegetation stands including those that are recognised as Endangered Ecological Communities. This includes the development of connecting vegetation corridors and fencing for livestock control
  - Management of private wetland sites in recognition of their significance as part of the region's lake and cowal systems. These sites support nesting areas and habitats for an abundance of wildlife including migratory birds

Figure 6.2 Remnant vegetation on a Jemalong Irrigation District property

Source: Western Land Planning Pty Ltd

6.6 Property Viability

The Jemalong Irrigation District offers an abundance of natural resource, transport and social attributes that have capacity to ensure the long-term viability of agriculture in the region. However, insecurity of water supplies has resulted in some doubt over the viability of irrigated production and the surety of income it provides in the long term.

Australia's rural community has a history in which farm ownership is family oriented. This tradition is maintained by succession, where the entitlements to a property are passed from each generation to the next, thus ensuring the enterprise remains within the family unit. Succession planning is however dependent on the prospect of property viability.

Fluctuations in commodity prices and more notably the upward pressure on the price of water for irrigation have combined to place additional strain on the viability of rural industries. These pressures have led some farmers to sell sections of their property to businesses outside the family sphere in order to service debts. While subdividing allows cash flows to be temporarily increased, maintaining the asset value and longer term viability of small scale farming enterprises is becoming increasingly difficult.

This climate of uncertainty has for many younger farmers made the prospects offered by rural industries less attractive. While fluctuations in seasonal conditions are an accepted aspect of the farming industry to which commendable adjustments in farming practices are made, the question of water availability and water security is central to farming enterprises.

The modernisation of water infrastructure offers an increase in water security where water delivery and use at low allocations becomes feasible, and Jemalong Irrigation District farmers are able to optimise their viability.

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7 ESTIMATED LOSSES WITHIN THE JEMALONG IRRIGATION DISTRICT

7.1 Scheme Losses

Jemalong Irrigation Limited regards "conveyance losses" as any water that is measured at the Lachlan River off-take for which no invoice is raised. These "conveyance losses" may take the following forms (GHD 2009):

- Evaporation – occurring from the water surface area in channels
- Channel infiltration – occurring through the 'wetted perimeter' (channel bottom and sides up to the water level) of the irrigation channels
- 'Wetting up' of channels – higher initial infiltration associated with filling the soil profile below a dry channel after channels have been empty for some time
- Leakage – occurring through cracks and fissures in channel banks and channel structures
- Metering inaccuracy – occurring when water is (i) diverted from the Lachlan River, and (ii) delivered at the farm gate, using inadequate and/or inaccurate meter (eg using meters for flows that are outside their calibration limit)
- Unrecorded usage – occurring when water is supplied to Jemalong Irrigation Limited's shareholders for no charge eg to carry out weedicide application
- Drainage escapes – occurring when water leaves the channel system of the Jemalong Irrigation District. No drainage escapes have been reported by Jemalong Irrigation Limited since July 2001
- Water that cannot be extracted – occurring when there is water left in the bottom of scheme channels that cannot be delivered to farms due to the water level being too low. Generally occurring at the end of delivery periods

This complete set of "conveyance losses" has been termed 'unaccounted water' throughout this report.

7.1.1 Hotspots Program

The Irrigation Infrastructure Hotspots Assessment Project (Irrigation Hotspots Project) is a key component of the $5.8 billion *Sustainable Rural Water Use and Infrastructure* program within the Australian Government's *Water for the Future* initiative (DEWHA 2008).

The Hotspots Program is proposed to use a consistent and science-based approach to identify the nature, location and quantity of water losses (known as "hotspots") in existing channel and piped irrigation delivery systems across Australia (DEWHA 2008).

A hotspots assessment is initiated to identify water losses at a whole-of-system and sub-system level, by incorporating local knowledge with data from the irrigation district operators and detailed on-site investigations (DEWHA 2008).

To ensure a consistent and robust approach, the Australian Government commissioned the CSIRO to develop the *Technical Manual for Assessing Hotspots in Channel and Piped Irrigation Systems* (Technical Manual). The manual was developed through a series of workshops that involved National and International experts in irrigation and hydrology, along with Australian and state government representatives (DEWHA 2008).

The Technical Manual outlines a range of hotspot assessment methods including:

- Water balances
- Remote sensing
- Electromagnetic and airborne electromagnetic surveys
- Geo-electrical resistivity surveys
- Groundwater monitoring
- Inflow-outflow methods
- Pondage tests

A draft *Hotspots desktop analysis and design* report was completed for the Jemalong Irrigation District by GHD in February 2009. This draft report provides a desktop analysis of the Jemalong Irrigation District. The report uses information provided in previous seepage study reports and Jemalong Irrigation Limited's database to estimate spatial water losses in the main delivery channel network. The draft report outlines the data gaps that exist within the system. These data gaps identified will provide information that may go into the design of an on-ground Hotspot Assessment.

The *Hotspots desktop analysis and design* report is yet to be finalised. Therefore, no information has been made publically available regarding the hotspots assessment of the Jemalong Irrigation District.

7.1.2 Scheme Loss Estimation Methodology

Two types of models have been prepared for this Modernisation Plan to estimate the operational losses associated with irrigation water diversions. These models are the "Weir-Storage Model" for regular scheme operations and the "Mass-Balance Loss Model" for open channel flows.

Both models can be classified as physically-based models. Physically based models have the ability to incorporate known physical properties such as soil percolation rates, evaporation rates and grade in predictions of actual channel behaviour. Physical models emphasise generality over precision and thus are suitable for use in an ungauged area (McKenzie 2007).

Weir-Storage Loss Model

The Weir-Storage Loss Model is a spreadsheet-based model used to determine 'losses' associated with operating the scheme using a system of 'check-gates' and the resulting storage of water behind the check-gates.

Depths of supply over the normal operational period of nine months were assigned in this model according to operator advice and experience and with regard to the 'Full Supply Level' recorded by the historic works-as-executed survey plans supplied by Jemalong Irrigation Limited.

The model calculates a continuous loss from both the infiltration associated with the wetted perimeter area, as well as the evaporation loss from the surface area of the regularly-operated channel reaches. The geometry and loss rates associated with each reach of the existing channel network form an integral component of loss estimations.

The Weir-Storage Model is the best representation of the existing Jemalong Irrigation Limited operation over a nine-month period of each year.

Mass-Balance Loss Model

The Mass-Balance Loss Model is also a spreadsheet-based model, similarly used to determine 'operational losses' via hydraulic distribution of diversions. This model operates without the check-gates in place and flows are uninhibited. Flows are adjusted by a 'mass water-balance' within each reach of the scheme channels.

The model is run by system capacities in accordance with experienced operator advice and uses the geometric characteristics of the scheme as recorded by historic survey plans. Hydraulic characteristics of the distributed flows, such as depth of flow, are solved by the model's operation. An estimation of the associated losses is calculated from the wetted perimeter and surface area as per the Weir-Storage Loss Model.

Although the Mass-Balance Loss Model is not a true representation of the regular operations of the Jemalong Irrigation District it is most representative for estimating losses associated with the unimpeded diversions to customers outside the Jemalong Irrigation District.

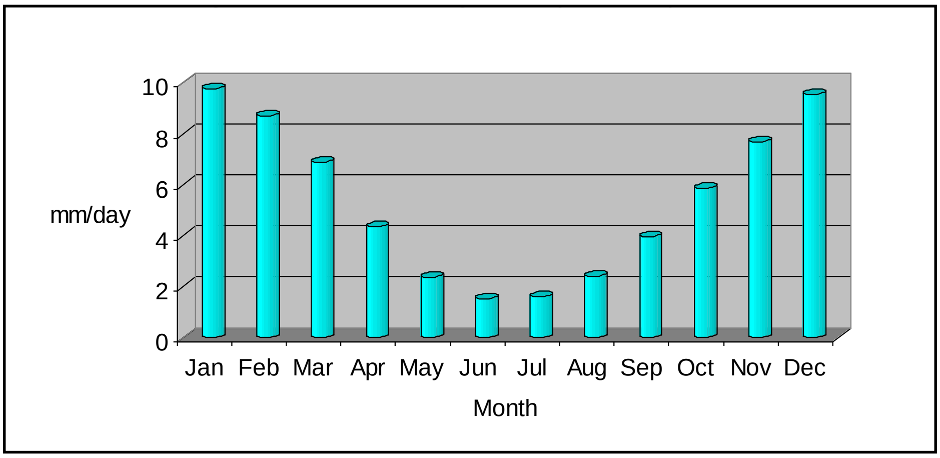
Evaporation

The historic evaporation loss rates used for the hydraulic modelling were derived from data provided by the Condobolin Agriculture Research Station (CARS). This data set was favourable over Forbes Bureau of Meteorology data set as it contained 20 years of recent, continuous and complete records.

An evaporation rate simulating the 'worst-case' scenario for the Jemalong Irrigation District has been used in the preliminary Mass-Balance Loss Models to simulate the potential maximum evaporation 'losses' that could be expected in the system. In this case, the 'average summer' evaporation rate of 9.4mm/day was adopted.

The verification of the Loss Models utilised average monthly evaporation rates shown in Figure 7.1.

Figure 7.1 Condobolin agriculture station average monthly pan evaporation rates 1989-2008



Source: Boyden & Partners

Infiltration

Infiltration rates were initially estimated using surface soil maps of the Jemalong Irrigation District. However, this was found to be unrepresentative of soil types at the depths that channels are excavated to. Additionally, the only information available for model verification incorporated losses from multiple sources in addition to infiltration. Therefore, a 'combined loss factor' was used to represent infiltration and all other losses apart from seepage. Refer Section 7.1.4 for further details.

Modelling Procedure

'Combined loss factors' for each channel reach in the loss models were determined by calibrating against the 'unaccounted water'. These 'combined loss factors' represent all of the losses that make up the difference between measured water diversions from the Lachlan River and invoices sent to water users, apart from evaporation.

The models were then used to determine the proportional losses during a year of 75% AWD (allocation) and 43% AWD (allocation). These are the two 'baseline' cases. 75% AWD represents the maximum volume that Jemalong Irrigation Limited are allowed to extract from their entitlement at present and the second being the average annual general security water availability.

7.1.3 Historical Loss Data

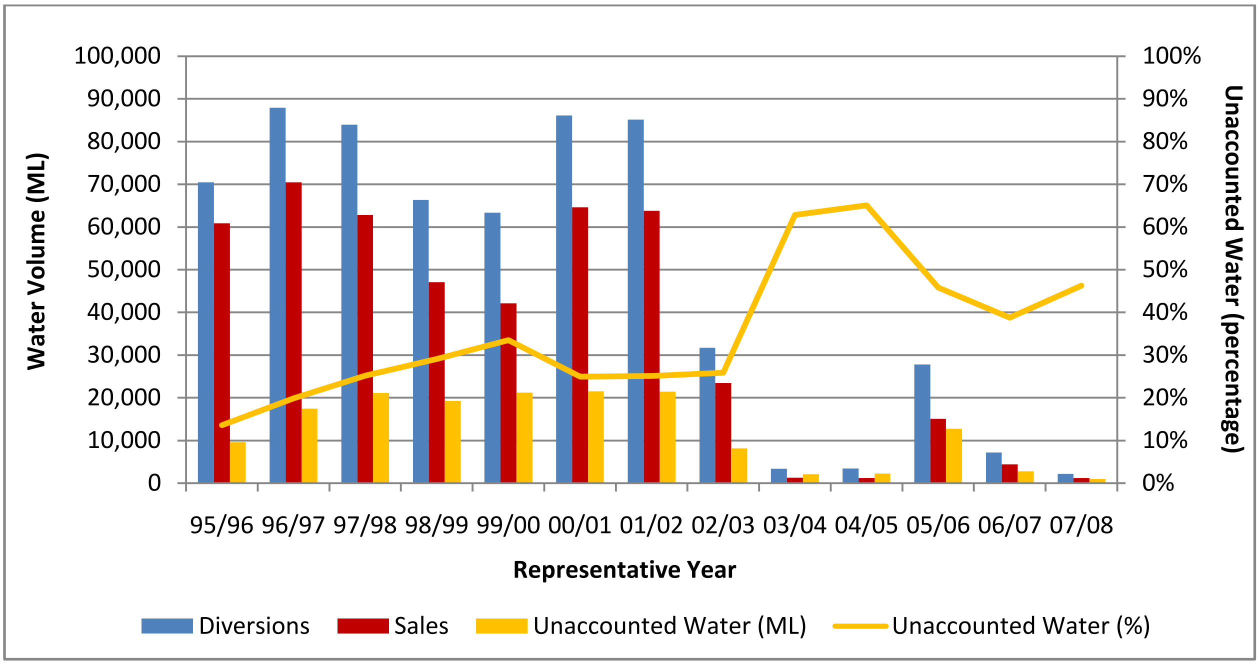
A historical water balance has been compiled using measured diversion and sales information supplied by Jemalong Irrigation Limited for the period since inception of the company, shown in Table 7.1. These figures are also illustrated in Figure 7.2 Sales are the amount of water delivered to farms as measured by Dethridge wheels (or WMOs as they were installed). Diversions are the volume of water diverted from the Lachlan River onto the scheme, as measured by meters at the Jemalong Irrigation District off-take adjacent to Jemalong Weir.

Table 7.1 Historical water balance records

YEAR	SALES	DIVERSIONS	'UNACCOUNTED WATER'	% "LOSS"
1996	60,893	70,465	9,572	14%
1997	70,492	87,953	17,461	20%
1998	62,795	83,952	21,157	25%
1999	47,085	66,376	19,291	29%
2000	42,135	63,358	21,223	33%
2001	64,600	86,134	21,534	25%
2002	63,788	85,191	21,403	25%
2003	23,498	31,687	8,189	26%
2004	1,259	3,385	2,126	63%
2005	1,212	3,470	2,258	65%
2006	15,055	27,786	12,731	46%
2007	4,399	7,180	2,781	39%
2008	1,174	2,184	1,010	46%

Note: The 'unaccounted water' represent all of the losses that make up the difference between measured water diversions from the Lachlan River and invoices sent to water users.

Figure 7.2 Historical records of diversions, sales and the resulting 'unaccounted water' or "losses"



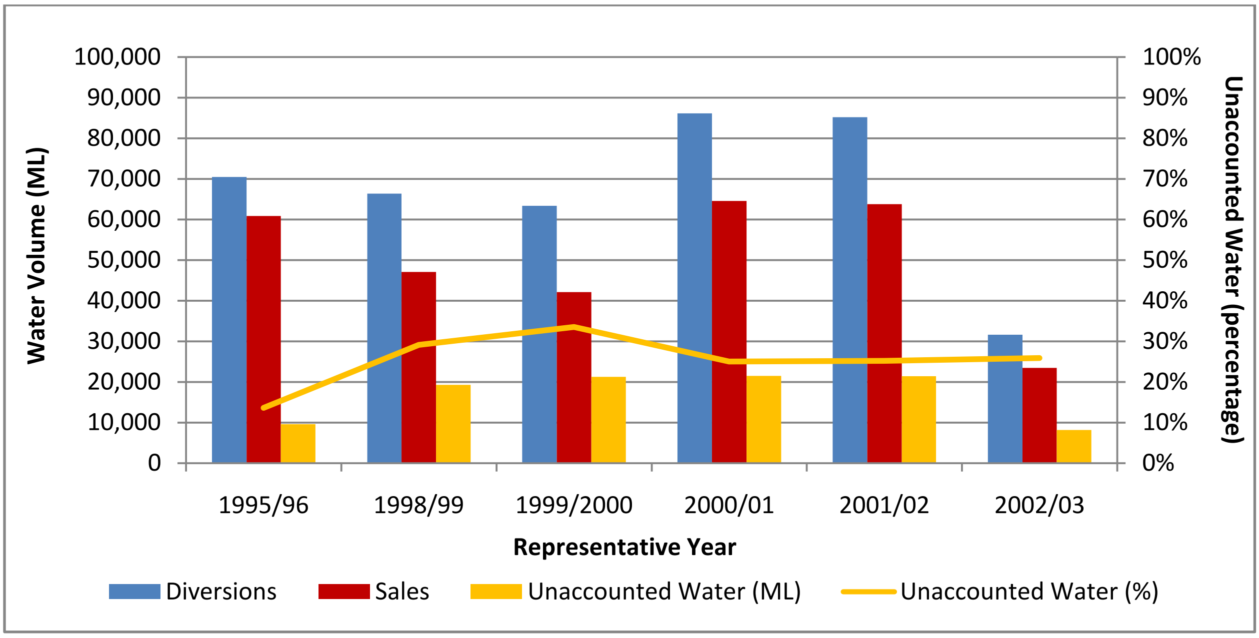
7.1.4 Scheme Loss Model Calibration/Verification

Preliminary analysis of the Jemalong Irrigation Limited delivery system was conducted using historic works-as-executed survey plans and a nine-month averaged flow of the maximum existing allocation. The system was initially modelled as an unrestricted hydraulic Mass-Balance Loss Model to quantify operational losses across all channel reaches. Losses were determined by the application of average seasonal evaporative rates and indicative soil type infiltration rates sourced from surface soil maps supplied by Jemalong Irrigation Limited and from field testing by Boyden & Partners during a field survey in October 2008.

The results of this procedure tended to produce unrealistically high quantities of water lost.Following a meeting with an experienced channel attendant in March 2009, it was established that it is not uncommon for the soil types in the lower sections of channels to differ markedly from those shown on the surface soil maps. The modelling procedure was modified to reflect the operator's experience of ponding time and additional volumes required to ensure correct volumetric delivery to various parts of the scheme. This provided an anecdotal representation of relative losses from the existing delivery system. These losses were represented as the 'combined loss factors' for each of the scheme channel reaches. The Weir-Storage Model was developed using this relative loss information.

'Representative years' were nominated by Jemalong Irrigation Limited for verification of the Weir-Storage Model. They included 1995/96, 1998/99, 1999/2000, 2000/01, 2001/02 and 2002/03. These years represent typical operations of the scheme over a range of diverted amounts. Recorded operational losses for these years were also provided by Jemalong Irrigation Limited, as shown Table 7.1 and illustrated in Figure 7.3

Figure 7.3 Jemalong Irrigation Limited historic diversions at the scheme off-take against sales and the resulting 'unaccounted water'

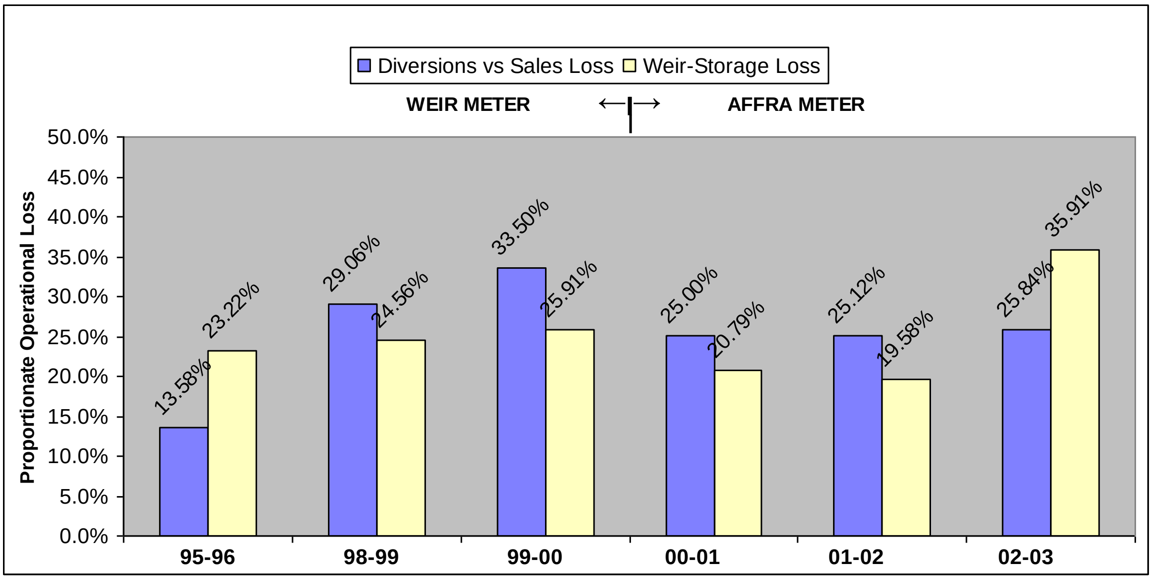


Source: Boyden & Partners

Adopting anecdotal reports of losses and operational depths, the preliminary Weir-Storage Model estimated an average "infiltration loss" of about 45-55ML/day, accounting for up to 80% to 95% of the daily 'unaccounted water' within the Jemalong Irrigation Limited. Note that these estimates are based on anecdotal information and the actual figure could be outside this range. 5% to 20% of the remaining 'unaccounted water' is attributed to evaporation.

With the exception of 1995-1996 and 2002-2003, the results shown in Figure 7.4 for the representative years indicate the average total 'unaccounted water' from the Weir-Storage Model is between 20% and 26%.

Figure 7.4 Historic water balance operational losses versus preliminary Weir-Storage Model losses



Source: Boyden & Partners

The historic measured diversion against sales report show 'unaccounted water' at about 25–34% of total recorded diversions. This also shows that the anecdotal infiltration loss rates adopted for the Weir-Storage Model appear to under-estimate the total losses by up to about 7%, or a 23% proportion of the comparable historic loss.

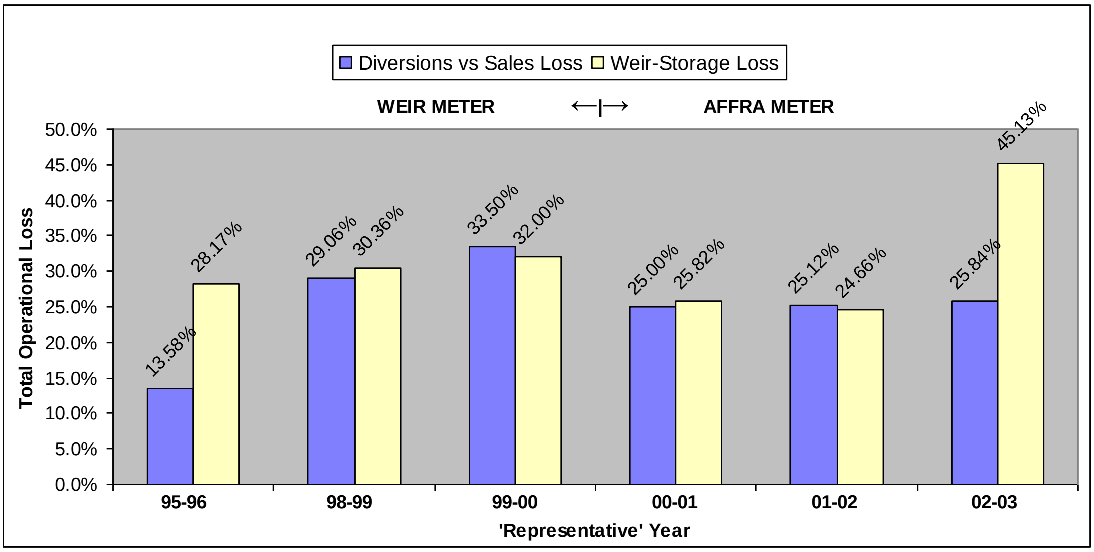
Evaporation rates within the model are based on scientifically researched values. Calibration of the models therefore focussed on 'combined loss factors' that represent all other losses in the 'unaccounted water' volume besides evaporation.

The Mass-Balance Loss Model was run for diversion supplies to Barrick Gold, downstream of "Jemalong No.2C" in Division 2. Results indicated an average daily loss of 3.3ML/day for an average diversion of 17.2ML/day (or 20%). This result was confirmed by Jemalong Irrigation Limited staff as being a good representation of their expectations and records. This indicated that the infiltration factors adopted for Division 2 were likely to be close to the anecdotal reports for the conditions of Barrick Gold water supply. The loss rates for Division 2 were adopted.

However, note that this event has a very low flow rate and as a result, the water level does not extend much higher than the channel base. Infiltration in the channel base may be much lower than in the channel sides due to sedimentation and it being cut lower, perhaps into underlying clay layers. Therefore, infiltration rates at higher water levels in Division 2 may be greater than those experienced in the Barrick Gold delivery run. Complete verification of 'combined loss factors' would require detailed soil testing the channels at several heights in the channel profile.

In order to match the historic water balance losses recorded within Division 1, calibration of the 'preliminary' Weir-Storage Model was conducted, by increasing 'combined loss factors' uniformly until model results reasonably matched recorded 'unaccounted water' values. The calibrated loss rates in Division 1 resulted in a close match within about 1.5% of the historic balance for four of the six representative years, as shown below in Figure 7.5.

Figure 7.5 Historic water balance losses versus calibrated Weir-Storage Model losses



Source: Boyden & Partners

This model calibration increased the average 'combined losses' for the calibrated Weir-Storage Model to about 55-65ML/day, accounting for up to 98% of the daily losses within the Jemalong Irrigation Limited. Note that these estimates are based on anecdotal information and the actual figure could be outside this range.

The modelled loss results of the representative years 1995-96 and 2002-03 were found to be inconsistent with the historic water balance of the other four tested representative years. Reasons for the comparative disparity of these results could include significant operational differences to other nominated years, large errors in flow measurements or some other unknown error.

On the basis of extensive modelling, subjective review of all known data, calibration and good agreement with the historic water balance for four of the six representative years, Boyden & Partners consider the Weir-Storage Loss Model to be a good representation of the 'unaccounted water' associated with the operations of the Jemalong Irrigation District.

In order to confidently advance the knowledge of specific loss rates experienced by Jemalong Irrigation Limited during operations, exhaustive infiltration testing in all operated channels would be required.

7.1.5 Baseline Scheme Losses

A summary of the estimated total losses associated with the regular operations of the existing and future Jemalong Irrigation Limited delivery system, as determined by the calibrated Weir-Storage Model is indicated in Table 7.2**.** The water year 2000-2001 were selected as a representative historic year for the determination of operations over 9 months with a high AWD. A 7 month scenario was also modelled for the 43% AWD year. This scenario represents the production regime that irrigators are likely to use during a year with 43% AWD.

Table 7.2 Estimated baseline scheme channel losses within the Jemalong Irrigation District

SCENARIO	Baseline	Baseline	Baseline
Scenario Description	9 month scheme operation, based on a typical year (2000/01)	9 month scheme operation, based on a typical year (2000/01)	7 month scheme operation, based on advice from the JIL Board
ANNUAL ALLOCATION (ML)	75% AWD 74,899	43% AWD 42,942	43% AWD 42,942
Total evaporation losses (ML/YR)	2,102	2,077	1,762
Proportion of evaporation losses to allocation (%)	2.8%	4.8%	4.1%
Total all other losses (ML/YR) (represented by the 'combined loss factors')	18,882	18,540	14,663
Proportion of all other losses to allocation (%)	25.2%	43.2%	34.1%
Σ ALL LOSSES (ML)	20,984	20,617	16,425
Total Proportion Loss of Allocation (%)	**28%**	**48%**	**38%**

7.2 On-Farm Losses

Information provided by Western Land Planning's *On-Farm Water Efficiency Plans* indicates that water loss during conveyance, storage, field application and recycle management may be significant in specific locations dependent on the size, composition and underlying geology of the delivery structure.

Table 7.3 Estimated baseline on-farm losses within the Jemalong Irrigation District

On-Farm Irrigation Component	Structure Dimensions	Losses
Estimated Irrigation Storages		
Total irrigation storage volume	1500 ML	
Estimated evaporation losses over 90 days in 43% AWD (allocation) year[a]		0ML
Estimated infiltration losses over 90 days in 43% AWD (allocation) year *		0 ML
Estimated On-Farm Channels		
Total irrigation supply channel length assumed utilised in a 43% AWD (allocation) year[b]	219km	
Estimated evaporation losses on channel length assumed to be used in a 43% AWD (allocation) year[b]		Negligible
Infiltration losses (supply only) on channel length assumed to be used in a 43% AWD (allocation) year [b]		1,421 ML
Estimated In-Field Application		
Field water use efficiency[c]	60%	
In-field losses for 43% AWD (allocation)		12,290 ML
Estimated Total On-Farm Losses (ML)		**13,711 ML**
Water delivered on-farm (43% AWD)		**33,930 ML**
Estimated Total On-Farm Losses (% of water delivered to the farm gate)		**40%**

[a] Evaporation and infiltration rates as determined for the *On-Farm Water Efficiency Plans*. It is assumed that in a 43% AWD year irrigation storages would not be utilised.

[b] Estimated infiltration losses have been calculated for supply channels only. Losses associated with tailwater management are included in "field water use efficiency". Tailwater drains in need of realignment and upgrading can yield an additional 15% efficiency gain (on water that flows out the downstream end of the field after application).

[c] This figure does not account for rainfall. Rainfall will supplement water requirements at a rate of 1ML per hectare for 100mm of rainfall. Under average conditions the Forbes district can expect approximately 287mm of rainfall over the summer or winter cropping season.

The baseline level Water Use Efficiency (WUE) of 60% is obtained from flood irrigation on land-planed irrigation land (*On-Farm Water Efficiency Plans*, Western Land Planning 2009). This WUE increases to 70% for upgraded (laser-levelled) land, tail water reuse and irrigation scheduling and management that adheres to data from soil moisture sensors. The Jemalong Irrigation District irrigators have generally laser-levelled their fields and installed tail water systems; however there is not a widespread use of soil moisture sensors.

7.3 Total Losses

The combined losses that could be anticipated to occur during a year with a 43% AWD are shown in Table 7.4

Table 7.4 Estimated losses within the Jemalong Irrigation District during a 43% AWD (allocation) year

Component	Volume
Scheme Losses	**16,425 ML**
On-farm Losses	**13,711 ML**
TOTAL LOSSES FROM SCHEME OFF-TAKE TO PLANT ROOT (ML)	**30,136 ML**
TOTAL VOLUME ALLOCATED AT 43% AWD	**42,473 ML**
TOTAL LOSSES FROM SCHEME OFF-TAKE TO PLANT ROOT (% OF AWD)	**71%**
Note: there are several assumptions in the derivation of this figure that may lead to a higher value than would actually occur. The assumption that is likely to have the largest impact is that all of the main scheme channel sections are assumed to be at full supply level for the entire 7 month duration. In reality, it is unlikely that this would actually occur. However, without means to make an accurate assessment of how much of the channel would actually be utilised and for what duration, the most conservative approach has been taken.	

8 ALTERNATIVE PRACTICES AND TECHNOLOGY UPGRADE OPTION ELEMENTS

This section sets out in detail the various components that are available for modernisation of the Jemalong Irrigation District's channels and on-farm infrastructure. These are referred to as Option Elements. Option Elements that have progressed beyond initial assessment have been combined into the Modernisation Options.

The Option Elements provide improvements to water efficiency through infrastructure development and/or water management practices. It is the aim of the Jemalong Irrigation District to develop future projects that could be considered under the *Sustainable Rural Water Use and Infrastructure Program* to support the implementation of water saving measures. In addition to these measures, there are also changes to agronomic practices in the district that will improve farmers' ability to adjust to reduced water availability in the future as set out in section 8.3.

8.1 Scheme Engineering Option Elements

8.1.1 Scheme Channel Upgrade

Upgrade option elements for the main delivery channels that are considered feasible for the Jemalong Irrigation District include the following:

Table 8.1 Scheme channel upgrade technologies relevant to the Jemalong Irrigation District

<table>
<tr><th>General Technology Type</th><th>Technology Sub-Type</th></tr>
<tr><td rowspan="3">Synthetic lining</td><td>High Density Polyethylene (HDPE)</td></tr>
<tr><td>Ethylene Propylene Diene Monomer (EPDM)</td></tr>
<tr><td>Coated Geo membrane</td></tr>
<tr><td rowspan="2">Pipes</td><td>HDPE PIPES</td></tr>
<tr><td>Concrete pipes</td></tr>
<tr><td rowspan="2">Earth liners</td><td>Selected Clay lining</td></tr>
<tr><td>Modified Clay</td></tr>
<tr><td rowspan="2">Concrete lining</td><td>Trowel led</td></tr>
<tr><td>Shot Crete</td></tr>
</table>

A complete assessment of all possible technologies is provided in the Product Review in Appendix C.

Channel Option Elements assessment

Each of the modernisation elements that were considered to be applicable to the Jemalong Irrigation District channels underwent analysis using a multi criteria matrix system. Each technological option was scored against a set of suitability scores, 3 for most suitable, 2 for just suitable and 1 for least suitable.

The parameters that each element was scored against included the following:

- Infiltration (vertical)
- Infiltration (lateral)
- Evaporation
- High Watertable
- Channel Downtime during construction
- Prone to Stock/Animal damage
- Requires to be fenced off
- Small channel dimensions
- Large channel dimensions
- High water velocity
- Ongoing channel maintenance
- Weed spraying
- Lifespan
- Material supply Cost

The scores were tallied and the elements that scored the highest were considered to be the most suitable. Those that scored the least were considered to be less suitable

8.1.2 Scheme channel gating and metering

Modernisation of irrigation infrastructure may involve retrofitting automated or remote controlled control gates within Jemalong Irrigation Limited scheme channels to replace the existing manual operated check gates and regulators. Modern controllable and metered gates enable accurate flow and water level measurement at each structure, as well as providing labour and time savings in gate operation.

Supporting the gate and meters is a system wide controller which includes a computer with real time communications, modelling and control software.

Gates

Gating is dependant to an extent upon the nature of the infrastructure modernisation. Where pipes are proposed to be used, gating will be dependant on the location of flows splits as opposed to controlling ponding systems. Where lining is proposed, gate upgrades are recommended to further improve operation efficiency.

The type of gate used is dependant on the flow conditions required for the location. A gate’s physical function is commonly one of the following three forms:

- Undershot gates

- Overshot gates
- Undershot/overshot gates

Undershot/overshot gates provide a controlled method of retaining water. The gate can be opened at either the bottom or the top. This function is ideal for carefully adjusting the level at which water is retained.

A modern overshot gate such as a Flume gate is preferred due to its ability to accurately measure and control flows. It is proposed that each of these gates be controlled via telemetry and be metered.

Figure 8.1 Flume gate and attached control box

Source: Rubicon

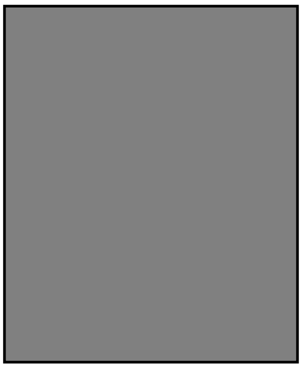
Metering

Under the terms and conditions of water extraction licences, water extractors in NSW are required to have a meter fitted to the extraction works.

The NSW Water Extraction Monitoring Policy addresses the use of water meters and other monitoring techniques in NSW. In addition, the Department of Water and Energy, in conjunction with State Water, has developed the NSW Water Extraction Monitoring Standards which set criteria for the installation of water measurement devices. National standards for water meters are currently being developed under the *National Water Initiative*. These will apply to meters that are used by State Water for billing purposed and that are installed after the date that the National Standard commences.

There is a possibility that all metering considered for Jemalong Irrigation Limited main delivery channels and farm off-takes could comply with the above standards when they are announced, this will be in line with best management practice. Gate upgrades may include metering connected to a channel control system that will give Jemalong Irrigation Limited greater control over the delivery system.

Figure 8.2 Flume gate with control



Source: Rubicon

8.1.3 Lateral Off-take Metering at Farms

Compliance with new national non-urban water meter standards (ATS 4747, NMI M10 and NMI M11) may be required for the individual farm off-takes within the Jemalong Irrigation District as these locations are used for the billing of water. The upgrade of farm off-takes has been commenced within the Jemalong Irrigation District to bring the scheme up to best management practice standards and improve internal measurement and accountability, as discussed in Section 4.7.4. Jemalong Irrigation Limited plans to continue this replacement program in line with *The Jemalong LWMP.* Patent approval is pending on these meters. All meters that are required to meet the new standards will need to be replaced with approved models within 10 years of the legislation coming in to force.

The conversion of Dethridge wheels to Water Management Outlets (WMOs) improves measurement accuracy greatly, assisting Jemalong Irrigation Limited in irrigation scheduling and delivery management of the scheme. The larger capacity of the WMOs can also improve the water efficiency of irrigation application.

8.1.4 Scheme off-take upgrade

The off-take for the Jemalong Irrigation Scheme is adjacent to the Jemalong Weir. This off-take currently has the capacity to deliver the required volume through the system. If sections of the system were to be piped in a pressurised pipe, a pump station would be required to be installed at the off-take. The existing Jemalong Weir off-take would still remain if required to augment flows in remaining open channels.

8.1.5 Jemalong Weir Upgrade

At present the upgrading of the Jemalong Weir was not considered as it would be a costly exercise and would achieve very little in terms of water saving.

8.1.6 Scheme management

For options that utilise a gravity system, the system would be required to run in a similar fashion to the existing system to be able to meet irrigators' demand. Other scheme management technologies that could be considered by Jemalong Irrigation Limited to manage this operation include:

- Water Level Sensor Managers

- Camera operation/observation of water levels
- Automation of weir and water balances

8.1.7 Stock and domestic water delivery upgrade

The Jemalong Irrigation Limited water licensing agreement includes an obligation to supply a high security stock and domestic allocation to shareholders. Under the present stock and domestic supply system Jemalong Irrigation Limited experiences significant losses.

Four preliminary stock and domestic systems are proposed for review by the Jemalong Irrigation Limited Board. Each system has been based on the stock and domestic entitlement held by Jemalong Irrigation Limited.

Table 8.2 Stock & domestic water supply upgrade alternatives reviewed

Stock and Domestic System Number	Description
SDF1	The pipelines in this option follow the existing channel system. The stock and domestic requirement is delivered over a 24hr period for 365 days.
SDF2	The pipelines in this option follow the existing channel system. The stock and domestic requirement is delivered over a 12hr period for 365 days.
*SDF3	This option features a layout that follows the roads where possible and has the ability to deliver the required volume of water over 24hrs for 365 days
*SDF4	This option features a layout that follows the roads where possible and has the ability to deliver the required volume of over a 12 hour period for 365 days of the year

*Use of the road reserves in these alternatives is subject to conditions that are set by Council and/or the RTA as the road authority.

8.1.8 Option elements progressed to detailed investigation

After initial assessment, the most appropriate materials and technologies within each of the following option elements were progressed to more detailed analysis:

- Scheme Channel Upgrade
- Scheme channel gating and metering
- Lateral Off-take Metering at Farms
- Scheme off-take upgrade
- Stock and domestic water delivery upgrade

8.2 On-Farm Technology Option Elements

The following technology and management practices have been identified in the *On-Farm Water Efficiency Plan* process as potential upgrade elements for the Jemalong Irrigation District:

- On-farm reticulation of stock and domestic water
- On-farm water delivery channel upgrade, reconfiguration and lining
- In-field water application technology. This has been matched to high quality water holding capacity soils through the *On-Farm Water Efficiency Plans*. In-field technology includes sub-surface drip systems, lateral move and pivot overhead sprays and flood upgrade configurations.
- In-field soil moisture probes to optimise irrigation scheduling and water use
- On-farm recycling systems to include holding areas that are subdivided and deepened to reduce evaporation and infiltration losses. Surface coverings for protection to reduce evaporation remain under development. As they become commercially available, individual irrigators may choose to utilise the technology
- Farm off-take metering upgrades
- Increased use of vegetation to assist in reducing evaporation for irrigation fields and water storages

8.2.1 In-field Soil Moisture Probes

A probe is inserted into the soil at specified sites in the field. The probe detects a reading that corresponds to soil moisture. Readings are taken at representative intervals, which are recorded by a data logger. The sensors are located to suit the rooting depth of the crop and can be connected to a central data logger by cabling or radio frequency to record readings at pre-determined intervals. The system provides the irrigator with information to analyse soil moisture levels in order to interpret scheduling requirements for the crop demands. This will ensure water application rates match crop demands and prevent over watering by the operator.

8.2.2 In-field Irrigation Application Technology

Lateral move irrigation

Lateral moves are characterised by a boom, mounted on wheels, which extend the width of the field. The boom moves down the length of the field, powered by a diesel motor at one end. Water is drawn from the same end of the boom, either from a supply channel or hose that runs the length of the field. Sprinkler heads, dropped vertically from the boom hose by connector hoses, or ‘socks’, are spaced at 1-2m intervals. The vertical drop from the boom reduces carriage by wind and evaporation and can be adjusted according to crop type and height. Lateral move irrigators are generally suitable to rectangular fields, and are a flexible irrigation option in that they can be moved from one field to another.

Centre pivot irrigation

Centre pivots also have a boom with sprinkler heads dropped vertically, however one end is fixed at the centre of the field and the boom ‘pivots’ around the centre in a radial fashion. Centre pivots apply water using the same boom fit-out as lateral moves with the main point of difference being that the system draws water from a fixed supply pipe. While the circular irrigation field that results may under-utilise

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potential irrigation land, benefit is gained in water efficiencies through the piped supply system. Centre pivots are not easily moved from one field to another.

Sub-surface drip irrigation

Sub-surface drip irrigation consists of permanently placing drip tape/pipe underground at an approximate depth of 20–40cm. This tape or pipe has small emitters at various spacing's that deliver water to the plant root zone. Evaporation and wind drift are negated by the water being applied within the soil. This system has the capacity to precisely apply liquid fertilisers. It can also be automated with integrated moisture probes enabling micro pulse applications which prevent overwatering and deep drainage.

Upgraded flood irrigation

Flood irrigation fields can be upgraded for greater efficiency via irrigation scheduling, more efficient water application techniques and laser-levelling and water recycling systems. Upgraded flood irrigation will also include EM 38 survey work to identify water holding capacities (WHC) for various soil types. The results of these surveys will determine sites for installation of capacitance probes for water scheduling management.

In-field irrigation application technology efficiency rates and uptake

Information on each of the irrigation application technologies is summarised in Table 8.3. Average water use efficiency for the different technologies has been verified by a range of industry groups.

Table 8.3 Field Infrastructure Water Balance

System	Average water use efficiency	Cost	Comments
Lateral	70-80%	$3000-5000/ha[a]	• Potential for water loss, especially on crusted soil types • Mobile, limited only by channel length • Relatively simple to upgrade or modify
Pivot	75-85%	$3000-$4000/ha	• Potential for water loss, especially on crusted soil types • Can draw from piped source • Not mobile, limited to 80 hectares • Good for light textured soils
Drip	88-95%	$7000-$8000/ha	• Comparatively good water use efficiency • Can be drawn from a piped source • Not mobile • Will last for up to 25 years • Relatively difficult to upgrade or modify
Flood Upgrade	60-70%	Up to $1000 /ha	• Cost effective for smaller areas • Can be applied as a supplementary upgrade • Limited water efficiency increases • Low capital investment

Note: [a] An approximate cost per hectare is difficult to determine as costs are dependant more on the width of field irrigated and thus on the number of spans.

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The *On-Farm Water Use Efficiency Plans* completed for every property within the Jemalong Irrigation District highlight the preferred upgrade technology for each farm, as matched to the most suitable soil types. Aggregated estimates for water savings associated with the proposed technology uptake of each farm are provided in Section 12.2.

These plans were developed individually with close consultation with land managers. A detailed review of the *On-Farm Water Efficiency Plans* will be required before finalisation of contractual agreements relating to modernisation infrastructure funding.

8.2.3 On-farm storage recycle systems

In addition to benefits in water use efficiency, irrigation water recycling systems ensure pesticide runoff does not contaminate waterways, clean irrigation water & stock/domestic supplies. If storages are to be used, water efficiency can be optimised by small strategic, deep structures. Lining of the storages is a possibility and research into various types of surface protection to reduce evaporation is feasible and will be highlighted in the product review in Appendix C.

8.2.4 On-farm channel upgrade

Infiltration rates of less than 1 mm per day are possible through the refurbishment of existing channels. The most cost effective method of increasing water efficiency of on-farm channels is to line them, for which a wide range of materials is available on the market.

8.2.5 On-farm stock and domestic water upgrade

Surface water for stock and domestic use is currently sourced from the main scheme supply channel. When water is available to service stock and domestic requirements, supplies are generally stored in dams to ensure continuous supply to stock. During times of low AWD, there may not be sufficient water to cover transmission losses in the delivery of stock and domestic requirements.

The provision of a secure stock and domestic piped water delivery system is being assessed under the engineering option elements. On-farm components of an upgraded stock and domestic system include the provision of tanks and troughs with associated on-farm pipe network.

A secure stock and domestic system will guarantee access to water for households and livestock throughout the Jemalong Irrigation District. On-farm stock and domestic reticulation and storage upgrade will reduce evaporation and infiltration losses, reduce ground water demand from local bore resources and will ensure the viability of dry land agriculture independent of irrigation resources. These benefits are particularly important during low allocation years.

8.3 Opportunities for Alternative On-Farm Land Use and Management

8.3.1 Alternative winter cropping

Farmers within the Jemalong Irrigation District have suggested through the *On-Farm Water Efficiency Plans* that they will target early winter/spring season crops during times of below-average allocation to reduce water demands. Alternative winter cropping regimes are considered to be the most feasible option to best utilise available water allocations, system peak demands and crop requirements. However, decisions regarding water use will also take into consideration commodity prices.

Opportunities for alternative winter cropping were highlighted in the *On-Farm Water Efficiency Plans* produced for each farm, utilising data sources and templates for comparative crop gross margin analysis shown in Table 8.4.

Table 8.4 Gross margin analysis for winter cropping

Crop	Irrigation requirement (ML/ha)	Production estimates (units/ha)	Gross Margin returns ($/ML)	Gross margin returns ($/ha)
Oilseeds	4	2.5 tonnes	$322	$484
Cereals	4	5 tonnes	$153	$384
Lucerne	6	6-8 tonnes	$211	$1269
Horticulture	2-4	Boxes	$562	$2250

Notes: These values are an average for NSW provided by the NSW DPI.

8.3.2 Alternative summer cropping

Alternative summer cropping options are considered to be less feasible due to higher plant water demands as a result of heat stress and evaporation conditions. However, consumer demand for summer crops can influence commodity prices such that they are a viable option for irrigators.

Table 8.5 presents the data sources and templates used for the comparative crop gross margin analysis of summer cropping alternatives sourced from the NSW Department of Primary Industry.

Table 8.5 Gross margin analysis for summer cropping

Crop	Irrigation requirement (ML/ha)	Production estimates (units/ha)	Gross Margin returns ($/ML)	Gross margin returns ($/ha)
Maize	10	10.5	$189	$1890
Lucerne	13	15 tons	$192	$2496
Pasture	5	10-12 DSEs	$22/DSE	$220

Notes: These values are an average for NSW provided by the NSW DPI.

In the *On-Farm Water Efficiency Plans* farmers acknowledged the potential of utilising water on high value crops as presented in the table above.

8.3.3 Horticulture

The Lachlan Valley has an extensive history of high value horticulture crops including viticulture, citrus, native foliage, vegetables and miscellaneous stone fruit production. The ability to deliver water more consistently and utilise it more efficiently would allow expansion of these crops which would in turn increases the return per megalitre of water within the region.

8.3.4 Intensive livestock

The Jemalong Irrigation District has the capacity to graze up to 4.5 to 12 dry sheep equivalent (DSE) per hectare on a rotational plan. During periods of low pasture production stock feed may be supplemented with fodder crops including hay and/or grain crops.

Jemalong Irrigation Limited and its shareholders have a diverse range of livestock enterprises including:

- Dairy production including fresh milk production (cows and goats)
- Prime lamb production for local and export human consumption
- Beef production including feedlots for local and export markets

A secure quality stock and domestic water delivery system will ensure livestock production continues for direct human consumption markets particularly during low AWD (allocation) years and irrespective of climate change.

8.3.5 Natural Resource Management Opportunities

Improved grazing management

A guaranteed separate stock and domestic water delivery system will also promote the development of best practice rotational grazing systems and promote animal health through quality drinking water. This will have a direct impact on maintaining ground cover and reducing the impact of sediment runoff.

Soil management

Jemalong Irrigation District farmers have high utilisation levels of best management practice for soil management, including stubble retention, which assists in maintaining soil structure, nutrient loads and in reducing soil evaporation and excessive storm water runoff.

Areas that require remediation were identified through the "On-Farm Water Efficiency" planning process. Vegetation corridors were also identified through the plans. These offer benefit to irrigation and cropping soil by reducing soil erosion and maintaining soil moisture.

Vegetation enhancement

There are extensive remnant areas of vegetation covering a large proportion of grazing land and perimeter areas of dryland and irrigated land throughout the Jemalong Irrigation District. These remnant communities have generally been managed effectively. Grazing has been restricted for a large proportion of vegetation communities for a number of years, with active regeneration and recruitment activity ensuring the sound structure of communities continues.

Enhanced conservation of the vegetation natural resource base includes the option of designated grazing zones as identified in the *On-Farm Water Efficiency Plans*. The management of these zones, including restricted grazing to allow for vegetation regeneration where appropriate, will assist in maintenance and improvement of the condition of threatened habitat and ecological communities.

Potential areas for new vegetation plantings were also identified in the *On-Farm Water Efficiency Plans*. Increased vegetation can reduce wind shear and subsequent leaf tissue damage and foliage deterioration, aid in soil management as discussed above and increase habitat value and fauna adaptation to climate change, particularly when connecting existing stands of remnant vegetation.

Wetlands and conservation areas

Wetland areas and areas for conservation have been identified on private properties through the *On-Farm Water Efficiency Plans*. Additional fencing infrastructure may be required for livestock management. However, once established, areas designated for the regeneration of vegetation will be able to support short spells of opportunity grazing. On-farm wetlands have been identified as significant environmental assets in their ability to link together other major wetlands, and also for local aquatic plants and fauna habitat values.

Carbon capture

Property owners have expressed interest in evaluating options for native vegetation and its potential economic value as a carbon commodity. A developing market for carbon trading and carbon sequestration may enhance the commercial value of less developed agricultural areas on-farm carbon projects can participate in the Australian Government for Emission Reduction Scheme Initiatives projects.

8.4 Water Market Exit/Rationalisation

Modernisation planning analysis did not incorporate any information regarding the Australian Government's *Restoring the Balance in the Murray-Darling Basin* Program (‘water entitlement purchases’ or ‘water-buyback’) or Rationalisation Programs under the *Water for the Future* framework. As yet, little information is available on irrigation rationalisation as it may be implemented in the Jemalong Irrigation District.

Jemalong Irrigation Limited has given considerable thought to potential rationalisation of the scheme. Current thoughts and potential decisions of individual shareholders regarding rationalisation are being raised through the *On-Farm Water Efficiency Plan* and board consultation process. Rationalisation is a decision that will have a significant impact on the future of individuals and the whole scheme.

Should rationalisation of some Jemalong Irrigation Limited shareholders proceed, it will impact on the overall costs, water savings and technology requirements presented within this Modernisation Plan. Potential rationalisation within the Jemalong Irrigation District will be addressed in detail should Jemalong Irrigation Limited choose to apply for funding for infrastructure modernisation.

9 FUTURE SUSTAINABILITY CHALLENGES AND ISSUES

9.1 Water Availability in the Year 2030

The CSIRO Murray-Darling Basin Sustainable Yields Project was convened by the Prime Minister on the 7th November 2006. The project's aim is to provide governments with a robust, basin wide estimate of water availability taking into account climate change predictions and other risks (CSIRO 2008).

Currently there are 18 Sustainable Yields project reports that cover a range of regions. The Jemalong Irrigation District falls into the Lachlan Regulated River Source which forms part of the Lachlan Region as defined in the Murray-Darling Basin Sustainable Yields Project.

The Sustainable Yields project assesses the likely reduction in rainfall using 15 global climate change models and three global warming scenarios, taking into account different changes in each of the four seasons as well as changes in the daily rainfall distribution, to estimate changes in average annual runoff associated with climate change.

It also determines the likely future development of farm dams and forestry that may impact on water availability. In the Lachlan Catchment, the increase in development to the year 2030 is likely to reduce water availability by 2% under the best estimate.

Combining the reduction in water availability and increase in development, under the Best Estimate Future Climate, Future Development model for the year 2030, the CSIRO predict that there would be a 10% reduction in total net diversions, and a 15% reduction in end of system flows in the Lachlan River Region (CSIRO 2008). High Security town water supplies would not be impacted; however the Lachlan River Environmental Contingency Allowance (ECA) would be reduced by 12% (CSIRO 2008).

The extreme estimates of high global warming predicted by CSIRO modelling result in mean annual runoff changes ranging from a 34% reduction to a 17% increase. The range from the low global warming scenario is a 12% reduction to a 4% increase in mean annual runoff.

To determine the average water availability for general security users for the year 2030, the conservative approach of taking both the reduction in rainfall and increase in development was considered. The Long-term Average Annual Extraction Limit of 305,000ML/yr was reduced by 10% to 274,500ML/yr (the best estimate net reduction predicted by CSIRO). All water entitlements with a high priority were subtracted from this figure, and the result divided by the number of general security unit shares. The resulting Average Annual General Security Available Water Determination is 36%.

Adopted 2030 Average Annual General Security Available Water Determination

36%

9.2 Changes in Water Management

9.2.1 Water Sharing Plan for the Lachlan River Water Source

The future water availability figure of 36% is based on CSIRO Murray-Darling Basin Sustainable Yields Project *Water Availability in the Lachlan* and the *Water Sharing Plan for the Lachlan Regulated Rivers Water Source*. The Water Sharing Plan will remain in effect until 2013. Review of the Water Sharing Plan after this date may affect water availability and management into the future beyond this date.

9.2.2 Murray-Darling Basin management

The shift from state-based management of the Murray-Darling Basin to national control under the Murray-Darling Basin Authority is likely to impact on future water availability and management. In particular, the Murray-Darling Basin Authority is currently preparing the first Murray-Darling Basin Plan, as required by the Water Act 2007. It is due to commence in 2011.

The Water Act specifies some content of the Basin Plan, including (MDBA 2009):

- limits on the amount of water (both surface water and groundwater) that can be taken from Basin water resources on a sustainable basis
- identification of risks to Basin water resources, such as climate change, and strategies to manage those risks
- requirements that state water resource plans will need to comply with if they are to be accredited under this Act
- an environmental watering plan to optimise environmental outcomes for the Basin
- a water quality and salinity management plan and
- rules about trading of water rights in relation to Basin water resources

The Australian Government's *Sustainable Rural Water Use and Infrastructure* program, under which this Irrigation Modernisation Plan is funded, is anticipated to help irrigation communities make early adjustments in anticipation of the new Murray-Darling Basin cap on water extractions.

9.2.3 New metering standards

Paragraph 88 of the National Water Initiative (NWI) requires the development of water meter specifications, water meter installation standards and standards for ancillary data systems. These standards will apply to water extraction points that are utilised by State Water for monitoring and billing purposes.

A $90 million dollar program announced in July 2008 is aimed at replacing all privately owned extraction meters with patent approved extraction meters that meet the new standards. These will be owned, maintained and managed by State Water.

All other meters within the Jemalong Irrigation District (eg within scheme channels and at each farm off-take) may be required to conform to the new metering standards.

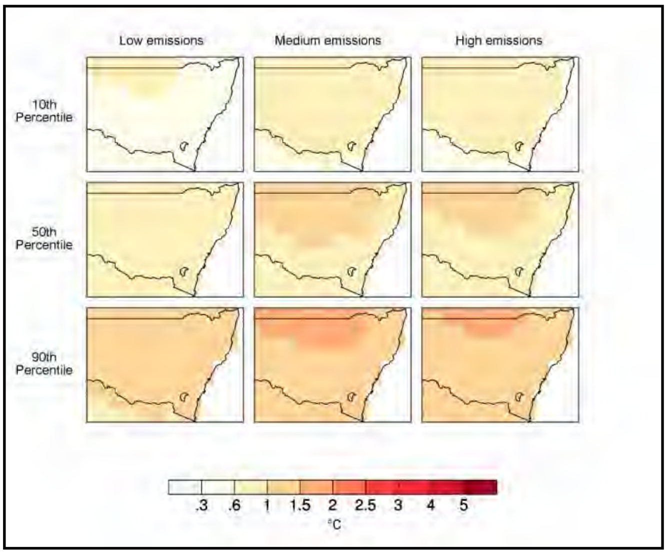
9.3 Climate Change

In 2004 the CSIRO and the Bureau of Meteorology released a report on behalf on the NSW Government which looked at past and likely future changes to NSW's climate. This report predicted that by the year 2030:

- NSW is likely to become warmer than it was in 1990
- There will be more hot days over 35°C and fewer frost days below 0°C
- Annual rainfall is likely to decline
- Rainfall runoff and stream flows will be reduced by 11%
- Water diversions will be reduced by 8%
- Droughts are likely to become more severe
- The risk of bushfires is likely to increase
- Extreme rainfall may become more intense in central and south-east NSW

The *Climate Change in Australia: Technical Report 2007* (CSIRO/Bureau of Meteorology) utilises data from 23 climate models to provide an estimate on the probable expected changes in climate over Australia up to the year 2030.

Figure 9.1 Anticipated changes in temperature in NSW as a result of climate change



Source: www.climatechangeinaustralia.gov.au

The above table for temperature prediction estimates that for New South Wales and in particular Forbes and surrounding area, the temperature will be 1.5 to 2 degrees warmer by the year 2030.

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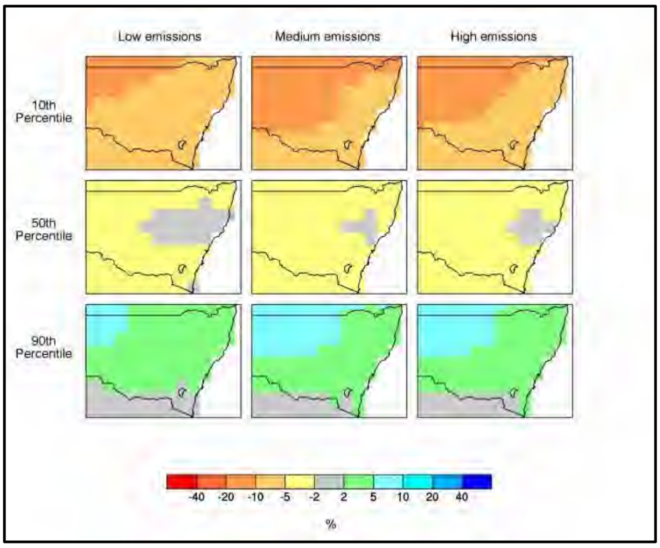
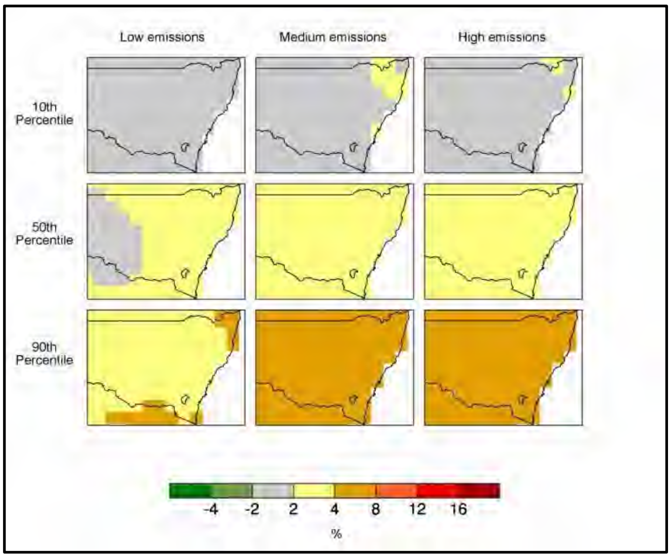
Figure 9.2 Anticipated changes in rainfall in NSW as a result of climate change



Source: www.climatechangeinaustralia.gov.au

The above table for anticipated rainfall in New South Wales predicts that for the Forbes area average rainfall will be 2% to 5% lower by the year 2030.

Figure 9.3 Anticipated changes in evapotranspiration in NSW as a result of climate change



Source: www.climatechangeinaustralia.gov.au

The above table for anticipated changes in evapotranspiration for New South Wales predicts that for the Forbes area it will be 2% to 4% higher by the year 2030.

9.3.1 Climate change and production

Climate change within the Lachlan Valley will have a direct impact on rainfall and corresponding runoff, most likely decreasing both. Additional impacts include a combination of both positive and negative benefits for a variety of crops and their productivity. The Lachlan Valley supports significant irrigated agriculture including cereal, fibre, horticulture and pasture. Higher levels of carbon dioxide in the atmosphere and low to moderate warming of temperatures may enhance plant growth and extend growing seasons. However, there may be negative impacts including lower protein content in those plants, a significant rise in the number of very hot days could lead to crop damage and yield reductions and increases in evaporation associated with increased temperature will directly contribute to reductions in soil moisture and crop water efficiency conversions.

Higher temperature levels will also put heat stress on livestock, which can affect growth and productivity.

For agriculture to remain viable in the Lachlan Valley, climate change management in the following areas is important:

- Improving water-use efficiency
- Changing to crops that are more tolerant of heat and drought
- Changing planting times and practices for crops
- Providing more shade and cooling for livestock
- Provide migration corridors for vulnerable animal species
- Review flood and fire management arrangements

9.3.2 Climate change and the environment

The management of environmental assets will also be affected by climate change. The extent to which changing temperatures, rainfall and extreme events will alter ecosystems is difficult to determine. However, the CSIRO and DECC anticipate that “reductions in stream flows are likely to have a negative impact on aquatic biodiversity, wetland ecosystems and associated waterbirds. Plants and animals may become ‘stranded’ in isolated remnants of vegetation as climate zones change due to a lack of suitable habitat for migration and more frequent droughts and fires are likely to increase stress on plants and animals” (CSIRO 2007).

Some of the listed plant and animal species under threat include:

- Box Gum and Grey Box Woodland ecosystems
- Grey-Crowned Babbler
- The Superb Parrot
- Regent Honeyeater

Climate change will heighten the need for conservation efforts to protect the environment.

9.3.3 Climate change and communities

There have been many detailed studies completed on how climate change may affect communities. The CSIRO (2007) have listed many of the potential impacts:

- Warmer winters – are likely to reduce cold-related illnesses, but warmer summers are likely to increase the risk of heat-related health problems, especially in the elderly.
- Warmer temperatures – may contribute to the spread of infectious diseases.
- Houses, infrastructure, commercial buildings and other physical assets – building design and performance will also be affected by climate change as aspects like structural standards and cooling and heating demand will need to be taken into greater consideration. For example, higher summer temperatures may induce the revaluation of building design and standards to

ensure thermal comfort at minimal cost. Any potential increases in extreme winds may necessitate more robust construction.

- A study done by Austroads (2004) concluded that climate change would contribute to increases in road maintenance costs in NSW of up to 25% by 2100, largely due to assumptions about the effects of climate change and population growth on traffic volumes.
- Increases in the intensity of extreme rainfall events would increase both flash flooding and strains on water infrastructure such as sewerage and drainage systems, particularly in population centres. For example, a study by Minnery and Smith (1996) found that climate change may double flood-related damages in population centres of NSW.
- Insurance risk assessments and premiums are likely to be affected if property is lost or damaged by flooding, winds or bushfires.

9.4 Lachlan Catchment Action Plan

The Mid-Lachlan Valley is contained within the Lachlan CMA. The *Lachlan Catchment: Catchment Action Plan 2006-2016* details four (4) themes, bio-diversity and native vegetation, water aquatic ecosystems, land management and people and the community. These themes reflect the priority natural resources in the catchment and targets that aim to protect and enhance the resources.

Any water savings achieved and delivered by Jemalong Irrigation Limited Irrigation Modernisation Plan and On-Farm Water Efficiency Planning Projects can substantially enhance key “Water and Aquatic Ecosystems” catchment targets, including:

- By 2016: 10,000 ML of water delivered more efficiently to benefit of riverine ecosystems and for identified Aboriginal Cultural purposes
- By 2016: complete and implement a water use efficiency strategy in cooperation with water users
- By 2016: manage 8 nationally significant wetland sites and 5 regionally significant wetlands for biodiversity conservation
- By 2016: improve in stream habitat for 80 sites

Water transfer to the CEWH that might occur as part of irrigation modernisation would assist in achieving these targets.

9.5 Commonwealth Environmental Water Holding

The Australian Government is currently purchasing water from within the Lachlan River catchment through the Restoring the Balance in the Murray-Darling Basin Program. These water entitlements will be used to benefit the environmental assets within the Lachlan Catchment as described in this report.

Entitlement Type	2007-08 Government Purchases (ML)	2007-08 Purchases as a proportion of issued entitlements (%)	Water available for the environment
General and High Security	7,514	1.21	3,330

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Water savings achieved by any Jemalong Irrigation Limited Irrigation Modernisation Planning and *On-Farm Water Efficiency Planning* Initiatives can substantially add to the Commonwealth Environmental Water Holding Programme for all users on the Lachlan system.

9.6 Water Trading

Permanent transfers within the irrigation districts and from the river have historically accounted for a small number of water trades. There is anecdotal evidence to suggest that a substantial proportion of permanent water trades relate to land sales. The number of permanent trades has increased with the Australian Government's *Restoring the Balance* program.

Temporary transfers account for the majority of water trades. It has been previously quoted that 90% of the volume of water traded in the Murray-Darling Basin was temporary transfer water (MDBC Water Audit Monitoring Report – various). Previously unused water known as "sleepers" have been activated and traded on the temporary market on a regular basis.

Water trading market participants are mostly other water users within the region supplementing existing water entitlements. Therefore, most trades occur within the irrigation districts or sections of the valley.

The market price per ML is currently depressed due to low available allocations and supply levels. There are currently restrictions on the tradability and alternative uses of high security water entitlements

IN the future, frameworks, mechanisms and policies facilitating temporary water trading markets coupled with irrigation modernisation will:

- Ensure the most efficient use of a scare resource
- Ensure supplementary water is available to support scheme and farm upgrades/ technologies
- Enhance water security for sustainable production level of high value food crops
- Enhance and maintain production levels supporting employment and local communities
- Enable water to be temporary purchased for supplementing environmental flows and environmental management projects

Frameworks, mechanisms and policies facilitating permanent water transfers out of production within the district will:

- Have a negative impact on the local economy
- Reduce employment opportunities within local communities
- Reduce water security levels available for the region
- Reduce risk management mechanisms for climate change
- Reduce the availability of temporary water and the benefits associated by this type of trading.

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9.7 Changes in Agriculture, Irrigation and Land Use

9.7.1 Changes in Agronomic Practices

Adapting to climate change will involve the development of farming practices and management that is both flexible and responsive to fluctuations in climate and water availability. The management of farming enterprises may become conditioned to maximising opportunities when favourable seasonal conditions are prevalent. In response, farm infrastructure, planning and production methods will require the flexibility required for low, medium and high allocation years.

Increasing the diversity of crop production in areas such as the Mid-Lachlan Catchment is essential in enhancing the economic resilience of farm enterprises. Recent years have shown that the opportunity for seasonal irrigated and dryland cropping is not always provided as a consequence of low rainfall and depleted water resources. The value of cropping as part of the farm production cycle is therefore most apparent in its potential for integration with livestock enterprises. Cropping can be adapted to the production of higher value and water intensive cropping when water is available and soil moisture levels are sufficient, while farms can remain viable in low rainfall years with the production of less water intensive fodder crops.

The potential for change in water management within the agricultural industry is dependent upon the opportunity for cultural change within farming communities. The development of alternative industries that will support water efficient cropping and the selling, servicing and implementation of new irrigation technology are critical to the sustainability of agricultural production in the Mid-Lachlan Catchment. Such changes will be underpinned by the availability of skill development and knowledge based training programs made accessible to rural communities.

Future trends have been collated from Jemalong Irrigation Limited farms participating in the *On-Farm Water Efficiency Plans* project. Overall trends include:

- A focus on winter production crops which can be effectively grown in conjunction with seasonal rainfall events, coupled with conservation moisture retention technology that will enable the farmer to produce in very low allocation years. Small amounts of irrigation water will ensure the security of the crop under climate change seasonal influences.
- Security of and value adding to livestock production. Drought proofing the district via intensive irrigation of fodder production will provide security in climate change events. Livestock enterprises ensure farmers remain viable in low rainfall years. A secure reliable stock & domestic water supply will underpin this enterprise.
- Reconfiguring on-farm irrigation infrastructure based on likely future allocation predictions. Landholders are re-prioritising irrigation fields & conveyance networks based on water use efficiency properties. The aim is to target more efficient layouts to better utilise smaller allocations during dry years to sustain some production.

9.7.2 Changes in Irrigation Practices

The options for maintaining viable irrigated farming will encompass a synthesis of management techniques. These include the production of less water intensive crops, changing farm rotations for seasonal water fluctuations, sowing crops on soils which contain a sufficient moisture profile and securing on-farm water supplies to finish crops.

The storage, reticulation and application of on-farm water have also been identified as areas where proposed investment in new technology can play a significant role in increasing water use efficiency in irrigated cropping systems. These technologies enhance irrigation prospects by providing additional water security.

Industry advances in irrigation practices are presented below, based primarily on the succinct summary provided in Raine (date unknown):

- Changing the irrigation season focus from summer to a winter irrigation cycle. Jemalong Irrigation Limited members have nominated a shift to winter irrigation for more efficient production in low allocation years.
- Improving the precision of irrigation applications (i.e. improved selection, design, installation and maintenance of irrigation application systems and reduced scale of temporal and spatial irrigation management)
- Greater matching of irrigation technology to soil type
- Increasing the use of tail water capture and recycling systems
- Reducing evaporation and seepage losses from recycle water storages and distribution systems
- Increasing the use of automation and control systems
- Improving the feedback and management linkage between water supply and demand requirements
- Increasing the use of routine monitoring and reporting systems
- Improving the identification of appropriate irrigation prescriptions and scheduling (i.e. how much and when to apply water)
- Increase/improving the use of marginal water quality

Significant research and development is being undertaken into these technologies by innovative irrigators and groups such as the Co operative Research Centre (CRC) for Irrigation Futures, Water CRC, CSIRO, the Irrigation Research and Extension Committee (IREC), irrigation product producers and tertiary education centres.

In looking at applying these new technologies and practices, a strong theme that came through the *On-Farm Water Efficiency Plan* project was the requirement for change to enable the farming enterprise to adapt for a changing climate.

9.7.3 Land use change

Climate change and water availability has influenced continued changes in land use to the Lachlan River Catchment in regards to irrigation production.

There are several scenarios that may eventuate:

- A reduction in overall irrigated areas
- A change in cropping regimes from irrigated pasture to high yielding small area alternatives
- The development of prioritised application areas and crop alternatives and

- The development of production to support value adding enterprises such as feed lots, dairy and horticulture.

Much of this change will largely depend on the extent to which farmers embrace change and adopt modern technology.

9.7.4 Irrigation Water Delivery Product Development

At present products are being developed to improve the efficiency of conveyance systems and on-farm application options. Some of these products are not new, however most were developed for high volume application methods and are being customised for lower allocation applications. Examples include:

- Pipe alternatives including size diameters, reducing material grading based on application requirements
- Earth liners, new soil additives and construction methods
- Hard surface liners including adapting traditional products to meet the requirements of irrigation channels
- Flexible membrane liners including rubber products and other material alternatives
- Retrofitting gating systems to conveyance products
- Irrigation recycling, storage products and management
- Low pressurised irrigation systems reducing energy demands
- Reducing the cost and complexity of telemetry systems
- Trialling and improving metering application and accuracy
- In field management tools and techniques

These products are currently being trialled in regards to their potential application for circumstances similar to Jemalong Irrigation District water delivery.

9.8 Challenges and Opportunities Specific to the Jemalong Irrigation District and Jemalong Irrigation Limited

The following issues have been collated from consultation with Jemalong Irrigation Limited shareholders.

9.8.1 The Jemalong Land and Water Management Plan

Jemalong Irrigation Limited identified challenges that face the irrigation district in their *Land and Water Management Plan,* as follows:

Original strategies for the district included the following targets to be achieved by 2015:

- Landforming – 90% of delivered water must be applied to either:
  - Surface irrigation layouts that are land formed
  - Sprinkler irrigation layouts
  - Micro irrigation layouts
- Farm planning – 90% of the delivered water to be supplied to farms which have a farm plan

- Recycling system – 90% of the delivered water to be supplied to paddocks that can be serviced by a recycling system
- Water Management Outlets – strategic installation of WMO meters
- Soil Fertility Tests – all paddocks undergo soil fertility tests every three years
- Improved pastures – replace 10,400 hectares of annual pastures with perennial pastures
- Fencing Remnant Vegetation – 2,800 hectares of remnant vegetation to be fenced off
- New Tree Plantings – 300 hectares of new trees to be planted
- Flood Way Levies – construct all exclusion levies
- Rain Rejection Storages (storages to contain ordered water that is no longer required due to rainfall) – construct all storages

Work is currently underway to meet these targets. Concurrently, the *Land and Water Management Plan* is currently being updated.

9.8.2 Jemalong Irrigation Limited Internal Survey

In July 2007 Jemalong Irrigation Limited commissioned a *Survey of Shareholders of Jemalong Irrigation District (*Hassell and Associates Pty Ltd 2007*)* to identify operational and strategic issues within the scheme. Mail respondents totalled 23 and a further 12 shareholders were contacted by telephone.

Future issues that were highlighted in this survey that are yet to be addressed include:

- Infrastructure – Channel seepage was identified as the most pressing issue for improvement. Shareholders are open to Jemalong Irrigation Limited being involved in water trading.
- Constitutional Changes – an option has been identified to have an independent director on the board.

As mentioned previously, it is important to note that shareholders in the Jemalong Irrigation District were considering these issues prior to the announcement of funding under *Sustainable Rural Water Use and Infrastructure*. It is also noteworthy that these two issues are assessed within this Irrigation Modernisation Plan.

9.8.3 Modernisation Consultation Planning Findings

Issues being discussed in the modernisation consultation process with landholders involved in developing *On-Farm Water Efficiency Plans* include:

- A target for water loss reduction to less than 25% over a range of allocations
- To strategically manage water runs with members to reduce the number of wet-up losses associated with the scheme delivery system
- Continual investment in the development of automated metering outlets over time for accurate data management and better scheduling practice
- Investigate ways to strategically upgrade channel hot spots (high loss areas) to maximise channel efficiencies in high use sections of the scheme
- Investigate alternative channel management options for stock & domestic purposes

Where does Jemalong Irrigation Limited see itself in the year 2030?

- Maximising technology uptake for efficiency purposes for both scheme and on-farm
- Flood irrigation upgrades and more appropriate in-field technology utilisation for high value crop alternatives
- Promote the long term sustainability of farms including the support of non irrigation enterprises and farm family benefits via a secure stock and domestic water supply system
- Enact the environmental projects for vegetation management, soil structure management and the protection of environmental assets coupled with sustainable farm production practices set out in the Land & Water Management Plan
- A final challenge for Jemalong Irrigation Limited is the management of changes to memberships in response to the Water Market Rules 2009 and Water Charge (Termination Fees) Rules 2009

9.8.4 Constraints for Modernising the Jemalong Irrigation District - Ground water

Groundwater levels in the Jemalong Irrigation District have been high previously. Separate to the influence that irrigation may or may not have on groundwater levels, there is potential that they may rise again in response to recharge from significant flood events.

This is a major issue for any engineering upgrades to be carried out in the channel. In the case that the water table levels rise to within 2m of the surface, there is a potential risk that infrastructure such as channel linings may float above the water table and thus suffer major damage.

9.8.5 Constraints for Modernising the Jemalong Irrigation District - Grades

Through a grade analysis that was carried out on the Jemalong Irrigation District it has been established that many of the channels have grades in the order of 0.02%-0.03% and some with as little as 0.01%-0.02%. Lack of grade makes it very difficult to recommend a wide variety of pipe types. The roughness of the pipe's internal diameter becomes especially important with low grade. Therefore, only a limited number of pipe types are suitable for transporting water through the Jemalong Irrigation District.

10 CONSULTATION METHODOLOGY AND OUTCOMES

10.1 Consultation Methodology

It was considered that the most useful information regarding individual or group's thoughts on the future of irrigation in the region could be gained by meeting with stakeholders on a one-on-one basis.

Meetings were held with representatives of groups that play a role in agriculture, irrigation, water and environmental management within the Mid-Lachlan Region. Questionnaires were distributed to these representatives to gain feedback on standardised issues. A copy of the questionnaire is contained in Appendix B.

Individual farmers within the Jemalong Irrigation District were consulted through the *On-Farm Water Efficiency Plan* project. Information on the aims of the Irrigation Modernisation Plan and the process of irrigation modernisation through the *Sustainable Rural Water Use and Infrastructure* program was provided to farmers. Of equal or greater importance, the views and future plans for each farmer was discussed. This accrued into substantial knowledge regarding the potential future of the Jemalong Irrigation District.

Regular meetings with the Jemalong Irrigation Limited board maintained the flow of information and ensured that the Modernisation Plan reflects the desires of the Jemalong Irrigation District.

10.2 Stakeholders Consulted

10.2.1 Key Water, Irrigation and Agriculture Industry Groups

Key industry groups relating to irrigation and agriculture in the Mid-Lachlan Region incorporated Lachlan Valley Water, the CRC for Irrigation Futures and NSW Irrigators' Council were consulted.

Representatives from State Water provided valuable information on the management and operation of the Lachlan Regulated River Water Source and historical water availability data.

10.2.2 Government

The two main local government bodies within the study area are Forbes Shire Council and the Lachlan Shire Council. Discussions held with each of these focussed on the importance of irrigation within their region, the potential impact of reduced irrigation under a climate change scenario, the potential impact of irrigation infrastructure upgrade and socio-economic information available for their council area.

In addition to local government, discussions were held with the NSW Department of Primary Industries, NSW Department of Water and Energy and the Murray-Darling Basin Commission (now Authority).

10.2.3 Economic and Regional Development Groups

Groups concerned with the development of rural and regional areas and their economic viability were consulted regarding the role of irrigation within the Mid-Lachlan Region and the potential benefits of the Irrigation Modernisation Project. The NSW Department of State and Regional Development, Central

NSW ACC, the Commonwealth Bank of Australia, ABARE and the Bureau of Rural Science were included in these discussions.

10.2.4 Indigenous Groups

Possibilities for indigenous employment opportunities arising out of infrastructure construction and increased long-term farm labour requirements were discussed with the Indigenous Coordination Centre.

10.2.5 Jemalong Irrigation District Infrastructure Users

As one of the major non-shareholder users of the Jemalong Irrigation District infrastructure, Barrick Gold was consulted regarding their anticipated future water requirements.

10.3 Consultation Findings

Trends have been drawn from the consultation process, are presented below.

The majority of stakeholders believe irrigation in the Jemalong Irrigation District needs to become more efficient to remain viable with lower water availability (either due to climate change or less being available to buy off-river).

Over the last 6 years with minimal allocations, some landholders have learnt to live as dryland operations but smaller landholders rely on irrigation. However, there have been significant negative impacts:

- People have had to sell water to stay viable – however this has impacts on the long-term socio-economics of the region.
- There has been a noticeable reduction in industry, school and general population as farmers cannot support their own families let alone workers (and their families).
- This has the obvious flow on effect to all local businesses and has the corresponding compounding effect.
- School numbers have reduced as less farm labour is required.
- Suppliers of rural inputs are under great financial pressure because of some producers' inability to pay for inputs.
- There has been a cost to the community health.
- The use of bore water has increased and placed greater pressure on the stressed aquifer underlying Jemalong.

The main pressures on water resources over the next 20 years are perceived to be irrigation and the environment. Urban expansion is considered to have a slightly smaller impact, along with mining.

The irrigation industry is seen as shifting towards higher value crops utilising more efficient irrigation. An anticipated increase in technology is frequently noted, from automation of irrigation water application and delivery to online water ordering.

The importance of commodity prices and the possibility of these increasing as the world population grows and water and land become more scarce is also noted in regard to the viability of irrigation in the long term. "If food security becomes an issue we could see a swing back to more emphasis placed on irrigation" (Jemalong Irrigation Limited Board/review panel member).

There is concern regarding the amount of buyback and its impact on the regional economy. In parallel with this is the perceived continuing trend of population decrease in the region. "It concerns me that as the rural population continues to decrease there will be a lack of expertise in the district to guarantee proper management of the assets." It is largely felt that if food production becomes paramount, there may be an increase in rural populations, counterbalanced by technology upgrade.

The "competing needs of humans for food and fibre (and now bio-energy) versus human desire to provide environmental flows and a sustainable environment" were highlighted (Jemalong Irrigation Limited Board/review panel member).

The most important regional environmental assets were identified as wetlands (especially Lake Cowal in the local area), the Lachlan River, the people, groundwater, remnant vegetation and sustainable farmland. In order to protect and enhance these assets, suggestions included putting water aside to maintain them, sensible results governing river operation making as much use as possible of synergistic water delivery between the environment and extractive uses, and trying to mimic a more natural flow regime.

11 OPTIONS FOR IRRIGATION MODERNISATION

The proposed options for modernising the Jemalong Irrigation District are presented in Table 11.1. Each component of the options is outlined below.

11.1 Scheme Channel Components of Modernisation Options

Information collected from loss modelling and assessment of the Jemalong Irrigation District's physical characteristics has enabled identification of channels within the Jemalong Irrigation District that suffer the greatest proportional losses. From this information decisions regarding the most appropriate upgrade options have been proposed.

Anecdotal and modelling results have shown that Division 1 accounts for a relatively higher proportion of losses than Division 2. Therefore, decisions based on water savings against capital input indicate that upgrading the channels in Division 1 may have a higher cost/benefit ratio on a 'whole of Division' basis. However, it is likely that targeting discrete areas of higher losses in Division 2 would be highly beneficial also. Additional information on infiltration losses throughout the scheme would allow an improved understanding in this regard.

Given the amount of data available at present, the Options presented in this Modernisation report present blanket technology upgrades for Division 1 and Division 2.

11.1.1 Option 1: 'Do nothing'

Option 1 represents a 'no change' scenario. Scheme channels, management gates, on-farm infrastructure, stock and domestic supply and management operations are anticipated to continue as they are at present.

11.1.2 Option 2: Stabilised Backfill

This option involves lining the existing channel network with a stabilised backfill. Backfill material of a suitable standard is very important. Soils must be low in permeability, free from shrinkage and swelling, and should have good stability and erosion resistant properties for use in side slopes. The backfill would ideally be ameliorated with a binder such as cement. An infrastructure upgrade would also be necessary and would include the replacement of Dethridge wheels with Water Management Outlets and the replacement of check gates with modern flow control gates with the capacity to be fitted with meters.

Figure 11.1 Example configuration of stabilised backfill

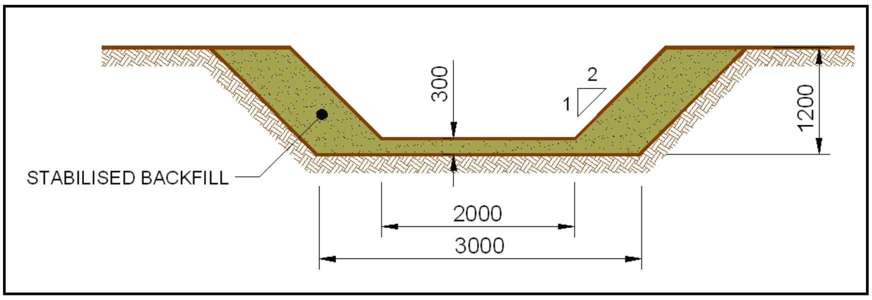


Table 11.1 Jemalong Irrigation Limited Irrigation Modernisation Options

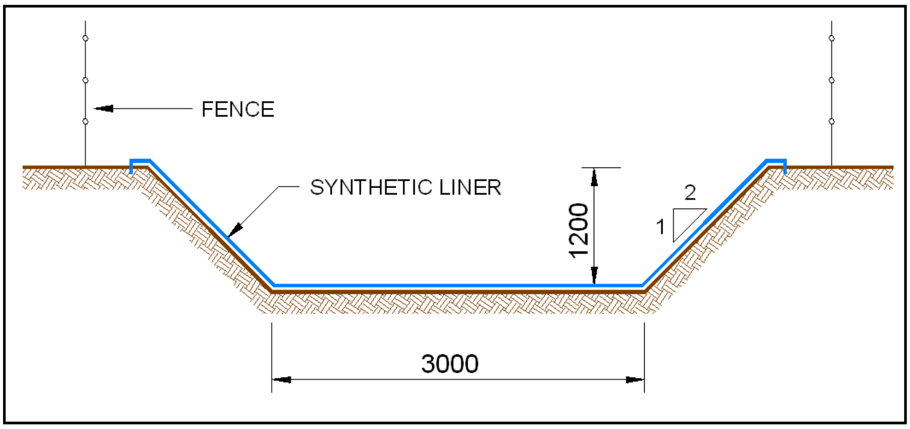
Option Number	Division 1 Channels	Division 2 Channels	Scheme gating and metering[a]	On-farm irrigation infrastructure	On-farm channels upgrade and soil moisture monitoring	Stock and domestic delivery
Option 1	Existing	Existing	Existing	Existing	Existing	Existing
Option 2	Stabilised Backfill	Stabilised Backfill	Upgrade scheme gates and meters	As identified in *On-Farm Water Efficiency Plans*	As identified in *On-Farm Water Efficiency Plans*	Upgrade [b]
Option 3	Geofabric Liner	Geofabric Liner	Upgrade scheme gates and meters	As identified in *On-Farm Water Efficiency Plans*	As identified in *On-Farm Water Efficiency Plans*	Upgrade [b]
Option 4	HDPE Liner	HDPE Liner	Upgrade scheme gates and meters	As identified in *On-Farm Water Efficiency Plans*	As identified in *On-Farm Water Efficiency Plans*	Upgrade[b]
Option 5	EPDM Liner	EPDM Liner	Upgrade scheme gates and meters	As identified in *On-Farm Water Efficiency Plans*	As identified in *On-Farm Water Efficiency Plans*	Upgrade[b]
Option 6	HDPE pipe system + Line existing Channel	Synthetic Liner	Upgrade scheme gates and meters	As identified in *On-Farm Water Efficiency Plans*	As identified in *On-Farm Water Efficiency Plans*	Upgrade[b]
Option 7	HDPE pipe system	Synthetic Liner	Upgrade scheme gates and meters	As identified in *On-Farm Water Efficiency Plans*	As identified in *On-Farm Water Efficiency Plans*	Upgrade[b]

Notes: [a] Includes upgrading farm off-take meters
[b]The preferred stock and domestic water delivery system will be finalised prior to any application for infrastructure funding. It will be directly influenced by the selected infrastructure Options for the scheme and preferences of stakeholders. Details of stock and domestic water supply alternatives are discussed separately throughout.

11.1.3 Options 3, 4 and 5: Synthetic Liner

These options involve lining Division 1 & Division 2 in a synthetic liner such as a coated geomembrane, HDPE or EPDM liner. Infrastructure upgrades with this option would include the replacement of Dethridge Wheels throughout the Jemalong Irrigation Limited scheme with Water Management Outlets. Regulator Check gates would be upgraded with modern control gates equipped with metering capacity.

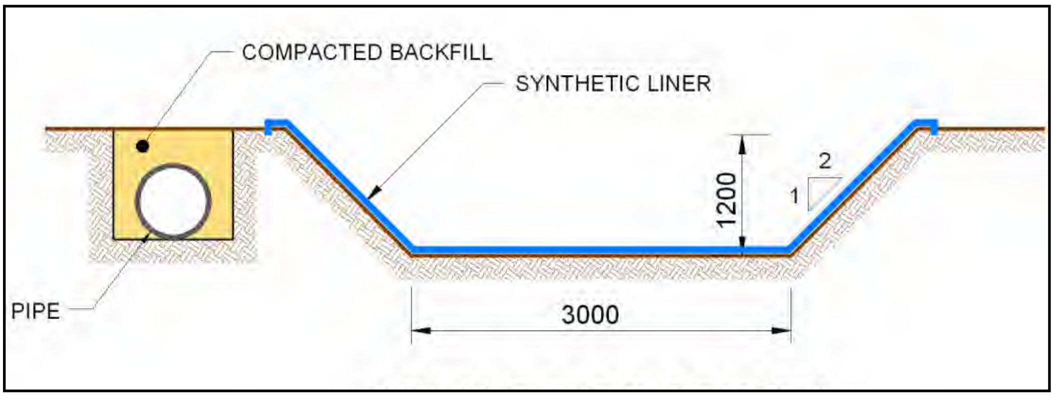
Table 11.2 Example configuration of synthetic liner options



11.1.4 Option 6: Pipe and lining

This option involves a pressurised pipe system through Division 1 with capacity able to deliver volumes based on future operations. The pipe is proposed to be placed next to the existing channel network thus allowing for the channel to be maintained. The existing channel would be lined and would include infrastructure upgrades such as the inclusion of Water Management Outlets to replace Dethridge Wheels, and the upgrade of scheme gating with modern control gates with the capacity to be fitted with meters.

Table 11.3 Example pipe and lining configuration



In this option, Division 2 may be lined with any of the synthetic liners if felt appropriate.

11.1.5 Option 7: Single HDPE pipe and potential liner

This option has a single large capacity pressure pipe sized to deliver the current capacity of the channel system throughout Division 1. The pipe would be laid next to the channel as above. It is proposed that Division 2 be upgraded in the form of one of the three liner types that have been assessed.

11.2 Stock and Domestic Delivery Components of Modernisation

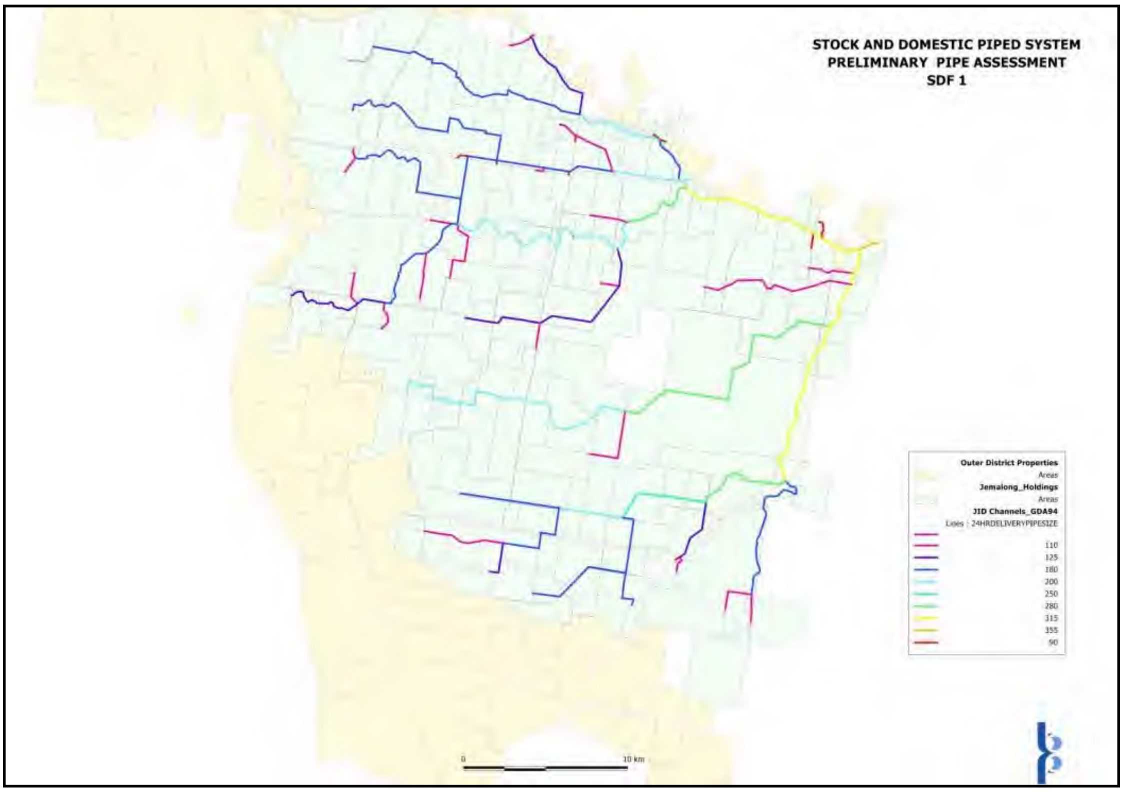
Jemalong Irrigation Limited has a stock and domestic entitlement of 1756ML per year that it is bound to deliver to its shareholders. Four alternatives have been identified as most appropriate for upgrading the delivery of this entitlement, all of which consist of a piped/pumped system separate to irrigation water delivery. Within the four alternatives there are two options for the layout of the pipe network and two options for pipe sizing based on delivery rate, as shown in Table 11.4.

Table 11.4 Stock and domestic alternatives

Stock and domestic alternative	Layout	Delivery regime
SDF1	Alongside existing channel	12 hours per day, 365 days per year
SDF2	Alongside existing channel	24 hours per day, 365 days per year
SDF3	Primarily within road reserves	12 hours per day, 365 days per year
SDF4	Primarily within road reserves	24 hours per day, 365 days per year

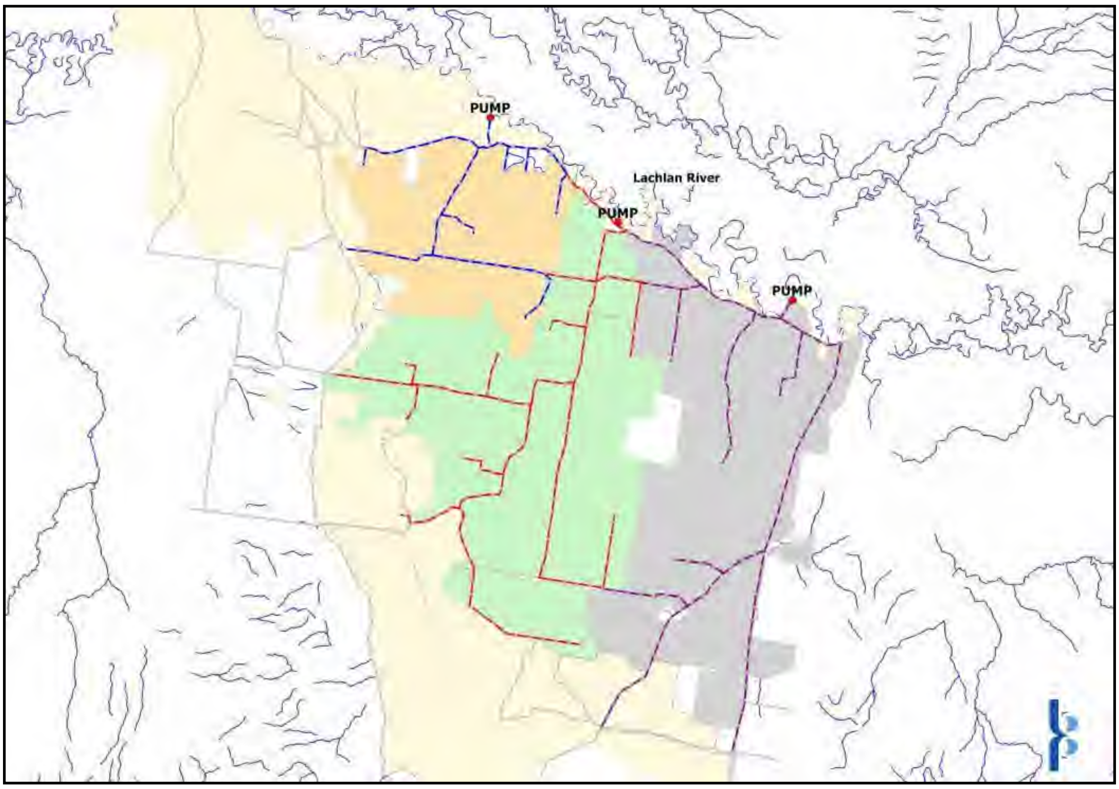
The first layout follows the route of the existing channel system, being laid in a trench next to the channel. The second follows the district roads as much as possible, with three subsystems SD1, SD2, and SD3 each with its own supply pump at the Lachlan River. These layouts are illustrated in Figure 11.2 and Figure 11.3.

Figure 11.2 Layout of stock and domestic system following existing channel



Source: Boyden & Partners

Figure 11.3 Layout of stock and domestic system following district roads



Source: Boyden & Partners

The first delivery flow rate has the stock and domestic water entitlement of each landholder delivered over 24hrs of each day over 365 days. This system will require greater on-farm storage to store water for the periods when demand is higher than the delivery rate. The second has the same entitlement delivered over a 12hr period over 365 days. This system has greater capacity to deliver peak demands (the pumps could run 24hrs per day if required) or in the case of breakdown.

11.3 Scheme Gate and Metering Components of Modernisation

If Jemalong Irrigation Limited were to upgrade the channel system using a liner then current operation procedures are likely to be maintained. Through the upgrading of all check and regulator gates to modern controllable gating technology the Jemalong Irrigation Limited can efficiently deliver and monitor deliveries to all irrigators.

11.4 On-Farm Components of Modernisation Options

For the purposes of this Irrigation Modernisation Plan, on-farm modernisation is assumed to be contained in all modernisation options aside from Option 1 (the ‘do nothing’ case). The on-farm upgrade components in Option 2 to 7 include the following:

- In-field irrigation technology as defined in the *On-Farm Water Efficiency Plans* including subsurface drip, pivot and lateral surface spray systems and flood upgrade layouts.
- In-field soil moisture probes. Moisture probes are a cost effective way to optimise irrigation scheduling and water use. One unit at $6,000 per unit was allowed for low allocation priority plots per farm

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- On-farm water delivery channel upgrade using potential lining options
- Farm recycling system upgrades. Consisting of lined strategic sized storage cells to restrict cells to reflect water management events and crop requirements for lower allocation years. This reduces evaporation and infiltration and maximised infrastructure efficiency.
- On-farm reticulation of stock and domestic water using a central stock and domestic tanked supply linked to fully reticulated paddock tank and trough systems.
- A temporal irrigation shift towards greater winter production. All Options for the year 2030 include a water application split of 60% winter and 40% summer.
- Increased vegetation (windbreaks) to assist in the management of reducing evaporation for irrigation fields and water storages.

The degree to which these measures might be implemented on each farm in reality is dependent on the individual farmer. Details of the actual amounts that might be included in modernisation will be determined if an application for funding for modernisation is made.

12 ANALYSIS AND RANKING OF MODERNISATION OPTIONS

12.1 Engineering Assessment of Modernisation Options

12.1.1 Assessment Methodology

Irrigation channel modernisation involves the assessment of available techniques based on site conditions, objectives, economic analysis and consideration of all options. Modernisation works require a maintenance program and ongoing monitoring of effectiveness.

Each of the elements or techniques that make up the modernisation options have been chosen through research into the most appropriate methods for open channel remediation.

The Weir-Storage Loss Model was altered to reflect the conditions of each of the future options for modernisation (including the 'do-nothing' case) to determine the changes in associated water loss. For each option, the evaporation rate and 'combined loss factor' for each channel were altered in line with technology upgrade. The duration of operation of the scheme was also adjusted to represent a shift to a greater proportion of winter production. This operation change was advised by the Jemalong Irrigation Limited Board as the most likely response to reduced water availability associated with climate change.

The options for channel upgrade were assessed against another set of parameters in a similar fashion to the elements, with the most suitable option being a score of 3, a just suitable option scoring 2, and a least suitable option scoring 1, based on the following criteria:

- Channel downtime during construction
- Infiltration
- Evaporation
- Fencing required
- Capacity
- Maintenance costs
- Construction costs
- Operation/ management

12.1.2 Assessment findings

Scheme Channels

The seven options for the upgrade of the scheme channels in Division 1 and Division 2 that progressed to preliminary design have been assessed against each other in terms of water saving capabilities, construction costs, maintenance costs, suitability to the site conditions and long term viability. This assessment was undertaken assuming climate conditions in the year 2030. The water savings made for each channel option is presented in Table 12.1. The cost associated with each of the options is presented in Table 12.2. The ranking of the scheme channel upgrade options is presented in Table 12.3.

Table 12.1 Scheme channel losses associated with all scenarios

SCENARIO	Baseline	Option 1	Option 2a	Option 2b	Option 3	Option 4	Option 5	Option 6	Option 7
Scenario Description	EXISTING SYSTEM	DO NOTHING	HIGH INFILTRATION STABILISED BACKFILL	LOW INFILTRATION STABILISED BACKFILL	GEO-FABRIC LINER	HDPE LINER	EPDM LINER	PIPE AND LINER	PIPE
Year-Average Annual AWD	2009–43%	2030–36%	2030–36%	2030–36%	2030–36%	2030–36%	2030–36%	2030–36%	2030–36%
AVERAGE ANNUAL ALLOCATION (ML)	42,942	35,951	35,951	35,951	35,951	35,951	35,951	35,951	35,951
Total evaporation losses (ML/YR)	1,762	1,762	1,762	1,762	1,762	1,762	1,762	874	815
Total evaporation losses (%)	4%	5%	5%	5%	5%	5%	5%	2.4%	2.3%
Total all other losses (ML/YR) (represented by 'combined loss factors')	14,663	14,663	13,078	5,635	0	0	0	0	0
Total all other losses (%) (represented by 'combined loss factors')	34%	41%	36%	16%	0%	0%	0%	0%	0%
TOTAL LOSSES									
TOTAL OF ALL LOSSES (ML)	16,425	16,425	14,840	7,397	1,762	1,762	1,762	874	815
Total Losses as Proportion of Allocation (%)	38%	46%	41%	21%	5%	5%	5%	2.4%	2.3%
Potential Water Savings (ML) [(a)]	0	0	1,585	9,028	14,663	14,663	14,663	15,551	15,610

Notes: [(a)] Potential water savings are an annual volume of water. Savings are calculated against the 'do nothing' case for the year 2030 – i.e. Option 1.
[(b)] All options have been assessed with the scheme operating at or near full supply level for 7 months.

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Table 12.2 Cost summary (in millions of dollars) of channel upgrade options

OPTION	MAIN SUPPLY CHANNEL		DIVISION 1						DIVISION 2						TOTAL SCHEME	
			CHANNEL		SPURS		TOTAL		CHANNEL		SPURS		TOTAL		TOTAL	
	CONSTRUC-TION COST ($M)	MAINTEN-ANCE COST OVER 20 YEARS ($M)	CONSTRUC-TION COST ($M)	MAINTEN-ANCE COST OVER 20 YEARS ($M)	CONSTRUC-TION COST ($M)	MAINTEN-ANCE COST OVER 20 YEARS ($M)	CONSTRUC-TION COST ($M)	MAINTEN-ANCE COST OVER 20 YEARS ($M)	CONSTRUC-TION COST ($M)	MAINTEN-ANCE COST OVER 20 YEARS ($M)	CONSTRUC-TION COST ($M)	MAINTEN-ANCE COST OVER 20 YEARS ($M)	CONSTRUC-TION COST ($M)	MAINTEN-ANCE COST OVER 20 YEARS ($M)	CONSTRUC-TION COST ($M)	MAINTEN-ANCE COST OVER 20 YEARS ($M)
1 Do Nothing	n/a	0.43	n/a	8.97	n/a	5.01	n/a	13.98	n/a	7.40	n/a	1.72	n/a	9.12	n/a	23.53
2 Stabilised Backfill	0.98	0.43	21.29	8.97	11.10	5.01	32.40	13.98	16.67	7.40	3.86	1.72	20.52	9.12	53.90	23.53
3 Geofabric Liner	0.29	0.19	18.94	13.41	12.75	7.33	31.69	20.73	18.55	11.00	5.08	2.55	23.63	13.55	55.61	34.47
4 HDPE Liner	0.32	0.17	20.68	12.05	13.76	6.58	34.43	18.63	20.04	9.88	5.45	2.29	25.48	12.17	60.23	30.97
5 EPDM Liner	0.31	0.16	20.44	11.79	13.62	6.45	34.06	18.24	19.83	9.68	5.40	2.24	25.23	11.92	59.60	30.32
6a HDPE Pipe and Geofabric Liner	n/a	n/a	62.72	13.41	31.41	7.33	94.14	20.73	18.55	11.00	5.08	2.55	23.63	13.55	117.77	34.28
6b HDPE Pipe and HDPE Liner	n/a	n/a	64.46	11.79	32.42	6.45	96.74	18.24	20.04	9.88	5.45	2.29	25.48	12.17	122.23	30.41
6c HDPE Pipe and EPDM Liner	n/a	n/a	64.23	11.79	32.28	6.45	96.51	18.24	19.83	9.68	5.40	2.24	25.23	11.92	121.74	30.15
7 HDPE Pipe	n/a	n/a	155.75	n/a	46.54	n/a	202.29	n/a	20.04	9.88	5.45	2.29	25.48	12.17	225.92	13.55

Notes: The "Main Supply channel" in the above table refers to the short section of channel between the scheme take-off at Jemalong Weir and where the channel splits into Division 1 and Division 2.

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Table 12.3 Ranking of scheme channel Modernisation Options

Options	Option 1	Option 2	Option 3	Option 4	Option 5	Option 6	Option 7
Channel downtime	3	1	1	1	1	2	3
Infiltration	1	2	3	3	3	3	3
Evaporation	1	1	1	1	1	2	3
Fencing required	0	1	1	1	1	1	3
Capacity	3	3	3	3	3	3	3
Maintenance costs	1	1	2	2	2	2	3
Construction costs	0	3	2	2	2	1	1
Operation/ management	1	1	1	1	1	2	3
Score	10	13	14	14	14	16	22
Ranking	7	6	3	3	3	2	1

The results of the engineering assessment reveal that piping of Division 1, although not the cheapest option may be the most desirable from an engineering perspective in terms of providing a complete upgrade of the system that would allow maximum water savings and flexibility in terms of operations for Jemalong Irrigation Limited and the irrigator. Piping may be able to deliver water in lower allocation years whereas the operation of the open channel system means that delivery to every irrigator in the scheme would be limited. Piping Division 1 also negates the need for a fence to be erected to protect it from damage; piping does not require that all check and regulator gates be upgraded. From an installation point of view the installation of a pipe would not disrupt irrigation practices as the channel would still function whilst the pipeline is being installed.

Based on information received from the operations manager at Jemalong Irrigation Limited, there are comparatively less losses in Division 2 than Division 1. Therefore, piping of the whole of Division 2 is less attractive in terms of potential water savings than piping the whole of Division 1. Therefore, Options 6 and 7 include lining of Division 2. Further investigation is required to determine the location sections of channel that have relatively lower losses and might require a lower level of upgrade than presented in the Modernisation Options. Similarly, sections of channel that may have higher losses than assumed here should also be identified. Piping of Division 2 will be considered once this information has been obtained and prior to any application for infrastructure funding.

The three lining options are very close in terms of cost outlay, maintenance and water saving capacity. Of the three liners the EPDM and the HDPE are the recommended choices based on historical evidence of these liners being used extensively as channel liners and their effectiveness over a 20 year lifecycle.

Scheme channel gates and meters

Scheme gating and metering upgrades have been based on current locations of regulator check gates and Dethridge wheel locations. Jemalong Irrigation Limited has advised that upgrade is to be sized for the maximum current scheme flow. Relative costs for in-channel regulator upgrades have been based on the existing structure being replaced with a modern flume gate or the like.

A gate system, such as a flume gate, can cost between $13,000 and $50,000 depending on the size required. This cost includes all software and metering equipment to allow the system to be fully automated and has been supplied by gate/meter manufacturers and suppliers. An average cost for each of the elements has been used, i.e. medium gate costs have been adopted throughout.

It should be noted that gate and meter upgrades as presented within this report are only applicable if the Jemalong Irrigation District is to operate as it currently does. If pressurised pipe systems are utilised, regulator check gates would not be required.

The phasing out of the Dethridge wheel and replacement by Water Management Outlets (WMOs) is ongoing in the Jemalong Irrigation District. The cost of future WMO installation has been included in the upgrade estimates in this report. WMOs are predominantly made in 3 sizes: 600mm, 750mm and 900mm. Their costs as provided by Jemalong Irrigation Limited range from $16,000 for the 600mm, to $18,000 for the 750mm and to approximately $20,000 for the 900mm, including installation.

A range of sizes and costs has been utilised, with the total costs for each division shown in Table 12.4. These costs are preliminary only. The specific sizes of each upgrade should be determined during detailed design.

Table 12.4 Flume gate and meter upgrade costs

ASSET	DIVISION 1	DIVISION 2
Gates with Meters		
Regulator check gates	$2.11M	$1.32M
Access Bridge Regulators	$0.69M	$.63M
TOTAL	$2.80M	$1.95M
Meters		
Water Management Outlets	$2.43M	$2.02M

Source: Boyden and Partners Pty Ltd (2009) – refer Appendix D

Stock and Domestic Water Supply Alternatives

The cost, advantages and disadvantages of each of the stock and domestic water supply alternatives is shown in Table 12.5.

Table 12.5 Advantages and disadvantages of stock and domestic water delivery alternatives

S&D water delivery alternative	Description	Cost	Advantages	Disadvantages
SDF 1	Alongside existing channel, 24hr delivery	$8.78M	• Follows an already existing route • Delivers a consistent flow over 24hrs • Is not as expensive as SDF 2	• May not be able to deliver peak demand • May require on-farm tanks to store water for peak demand • Following existing route is long, i.e. lots of bends etc, (this could be straightened) • If pump fails system is shut down
SDF 2	Alongside existing channel, 12hr delivery	$11.39M	• Follows existing route • Has a larger capacity, thus may deliver peak demand capacities • May not require the use of on-farm tanks	• Higher capital outlay than SDF 1 • Following existing route is long, i.e. lots of bends etc, (this could be straightened) • If pump fails system is shut down
SDF 3	Beside roadways, 24hr delivery	$5.05M	• Re-routing may reduce total length of pipe required • Pipe sizes can be reduced • Individual networks may be linked • Network pump could be shut down for maintenance during which time another network pump may take over • Less capital outlay compared to other options	• 24hr delivery may not meet peak demands • On-farm tanks may be required to store supply for peak demand • Farm off-take points may be a long way from homesteads • Extra cost for trenching maybe incurred for road crossings • Construction may require roads to be temporarily closed • Three pumps may incur higher maintenance costs
SDF 4	Beside roadways, 12hr delivery	$9.91M	• Re-routing may reduce total length of pipe required • Pipe sizes can be reduced • Individual networks may be linked • Network pump could be shut down for maintenance during which time another network pump may take over • Capacity to deliver a higher volume • May negate the need for on-farm tanks to meet peak demands.	• Extra cost for trenching maybe incurred for road crossings • Construction may require roads to be temporarily closed • Higher capital outlay • Three pumps may incur higher maintenance cost

12.1.3 Ranking of Stock and Domestic Alternatives

Ranking of the stock and domestic options was done simply by taking into account the advantages and disadvantages of the four options assessed. From our assessment the following order of ranking was reached:

1. SDF 4, although the most expensive of the road routing options this option has the extra capacity that allows for greater flexibility in terms of water management.
2. SDF 3, the cheaper of the road routing options however constrained by its capacity to deliver peak flows, farm tanks would probably be required.
3. SDF 2, the most expensive of the existing channel route options and also the most expensive overall, however it has the capacity to deliver a larger volume thus providing some flexibility for the landholder.
4. SDF 1, the cheapest of the existing channel route options, however does not provide flexibility in water management due to its restricted capacity, this option may require on-farm tanks to buffer peak supply demands.

12.2 Assessment of Options from an On-Farm Perspective

12.2.1 Assessment Methodology

The modernisation option elements for upgrading the on-farm components of the irrigation system have been identified through the *On-Farm Water Efficiency Plan* phase based on reduced allocation predictions and land capability characteristics.

The methodology adopted to assess the benefit of technology upgrade on-farm compares the losses that would result if existing flood irrigation methods are used against the losses that would result if technology upgrade as per the *On-Farm Water Efficiency Plans* is utilised. This assessment assumes that an individual's entitlement at the farm gate is not changed as a result of modernisation of the scheme based on the existence of the conveyance WAL.

It has been assumed for the purposes of this assessment that all savings made from the on-farm upgrades are available for use on-farm. Areas of in-field technology were adjusted for each scenario to utilise the available water, while keeping the proportions of each of sub-surface drip, centre pivot, lateral move and flood upgrade technology as identified through the *On-Farm Water Efficiency Plans*.

At this stage, a reasonable indication has been provided with regards to the in-field technology that might be adopted by irrigators. It is this technology that is the key to enterprise change and water savings on farm. It is only this component that has been included in the analysis at this stage. The quantity of the remainder of the on-farm components will be finalised prior to any application for infrastructure funding, along with confirmation of in-field technology quantities

Analysis included water used on-farm in a 43% AWD year (2009), compared to a 36% AWD (2030) and what effect the nominated technology would have on production in a very low (10%) AWD year if this water could be delivered to the farm gate.

12.2.2 Assessment Findings

In a 43% AWD 34,120 ML is delivered to the farm gate. Reducing this by the requirements for existing stock and domestic use, and on-farm delivery channel system losses, 30,940 ML of this is delivered to the field. This amount of water is able to support 3,710ha of flood irrigation across the entire scheme under existing cropping regimes. That is, out of the 23,000ha of land formed fields laid out for flood irrigation just 16% of irrigation fields are able to be utilised with a 43% AWD. These figures are based on the assumption that no effective in crop rainfall occurs. While this is unlikely to happen, the variability of rainfall makes its inclusion difficult. The irrigation volume that has been assumed to be applied in ML/ha allows for consistent crop waterings that provide for high production yields. It should be noted that, in 2003, approximately 23,500ML was delivered to Jemalong Irrigation District farms. This was applied at a rate of 2.78ML/ha over approximately 8460ha. However, yields over this area are likely to have been lower than those used in the calculations here.

By the year 2030 if the district is not upgraded and farming systems not changed, the reduction in average available water to 36% AWD will result in just 2,835ha being supported by flood irrigation (again, assuming high rates of water application that result in high yields).

Areas of upgraded irrigation application infrastructure (spray, drip irrigation and upgraded flood etc) will utilise any AWD water more efficiently and the increased proportion of winter irrigated production that upgraded scheme delivery allows, increases water use efficiency further.

If in-field technology is upgraded, 4,150ha of irrigated land can be supported in a 36% AWD year (assuming high rates of water application that result in high yields). This is a 30% increase in productive area.

12.2.3 Assessment Summary

- Option 1 - 'do nothing' case. No in-field technology is incorporated in this option and no benefits are obtained.
- Options 2 to 7 – with in-field technology upgrades, up to 7,420ML of water is saved if upgraded technology is applied to the same area as currently possible with flood irrigation under a 36% AWD. If water savings are utilised to increase production, the more efficient technology means that overall losses are still much lower than current flood irrigation. A total of 4,810ML is made in efficiency gains associated with the upgraded technology. The cost of the in-field technology in this scenario is $12.3 million.

In addition to water savings, the following on-farm benefits also result from infrastructure upgrade:

- A clean stock and domestic water supply will guarantee improved animal health
- Updated new technology will minimise losses and enable the full utilisation of low allocations for high value cropping opportunities
- Matching available irrigation technology to sustainable land capability has the capacity to reduce the impacts on salinity and storm water contamination issues
- Guaranteed stock and domestic water supply will reduce the impact of ground water extraction on local aquifers

There are some negatives associated with upgrading on-farm irrigation and stock and domestic infrastructure, including the impact on energy use, costs and associate carbon emissions. The current gravity fed surface irrigation system has minimal ongoing energy requirements and carbon emissions.

New technology will require energy and emit carbon in its manufacture, installation and ongoing operation and maintenance. Concerns over the impact that increased carbon emissions might have on irrigators with the introduction of a carbon trading scheme. However, some farmers consider that there may be opportunities to develop carbon sequestration sites within the Jemalong Irrigation Limited to offset increased carbon emissions. Any uptake of these opportunities by individuals will be outside of this Irrigation Modernisation Plan. It is recommended that individuals investigate these opportunities fully before committing to them.

Table 12.6 On-Farm Water Savings with Upgraded Infrastructure as per *On-Farm Water Efficiency Plans* in 2030 (36% AWD)

On-farm infrastructure	Total water delivered to field (ML)	Plant water use (ML)	Total area irrigated (ha)	In-field Losses (ML)	Water efficiency gains (ML)	Total Cost ($M)
Existing	23,633	14,180	2,835[(a)]	9,450	-	-
On-farm upgrade technology	26,767	20,748	4,150[((a)b)]	6,020	4,810[(c)]	12.3

Notes: [(a)] the total area irrigated assumes that high application rates of water are used to produce high yielding crops.
[(b)] All savings are assumed to be utilised in increasing production area. Some savings are likely to be traded for infrastructure if an application for such funding is successful. However, the actual amount that might be traded will be determined at a later date.
[(c)] Water efficiency gains take account of improvements in stock and domestic water storage and on-farm supply channel lining in the modernised case.

12.2.4 Indicative Jemalong Irrigation Limited and Jemalong Irrigation Limited shareholder co-contribution

The following components of the on-farm infrastructure modernisation may form the basis for Jemalong Irrigation Limited member co-contribution:

- Farm off-take metering upgrade
- Irrigation storage upgrade
- Soil moisture probes
- Stock and domestic water reticulation on-farm

The total cost of this co-contribution will be determined prior to an infrastructure funding application.

12.2.5 Ranking of On-Farm Upgrade Alternatives

The on-farm alternatives assessed in this Irrigation Modernisation Plan are 'do nothing' and 'upgrade according to the technology nominated in the *On-Farm Water Efficiency Plans*'. Option 1 of the Modernisation Options includes the 'do nothing' scenario for on-farm works. Modernisation Options 2-7 include the 'upgrade' alternative.

The 'upgrade' alternative provides significant benefit in terms of the ability to irrigate in years of lower water availability, for cropping alternatives, water savings and increased production.

12.3 Socio-Economic Assessment of Options

12.3.1 Assessment Methodology

An input-output model of the Mid-Lachlan Region was developed by Lawrence Consulting to analyse the potential economic and employment impact of irrigation modernisation on the surrounding community. This analysis incorporates the most fundamental factors that can be quantified, primarily additional production resulting from increased water efficiency of on-farm irrigation technology. This analysis is a preliminary assessment of the minimum quantifiable benefit that could result from irrigation modernisation of the Jemalong Irrigation District. The impact of modernisation in the year 2030 has been assessed. Therefore, all potential production data is based on a 36% AWD.

There are multiple additional benefits, both quantifiable and not, that may be experienced by the Jemalong Irrigation District and Mid-Lachlan Region if upgrade of the scheme proceeds. These have been grouped loosely into direct and indirect impacts.

Note that the input-output analysis utilises calculations of irrigated area that are based on high water application rates that produce high yielding crops. It is anticipated that if water was utilised at a lower rate, yields would also be lower and total production value would be approximately equivalent to that shown below.

12.3.2 Preliminary Economic and Employment Impacts of Modernisation Options

The current Jemalong Irrigation District would generate economic activity for the Mid-Lachlan Catchment region through total enterprise income of approximately $23.7 million per annum in 2030, based on a 36% AWD. The direct, indirect and induced economic impacts associated with the scheme as determined by Lawrence Consulting (refer Appendix E) under this scenario are shown in Table 12.7 and include:

- An estimated direct output of $23.7 million annually and additional flow on increases in output of $20.0 million through other industries, for a total industry impact of $43.7 million annually. Over 20 years, this represents $874 million. A further $12.9 million in output in the region can be associated with consumption induced effects;
- Estimated direct income (wages and salaries) of $1.7 million, with $2.7 million in additional income generated through flow on effects in other industries and a further $1.6 million from household spending;
- Approximately 181 direct full-time equivalent (FTE) employment positions, with an estimated additional 92 employment positions gained indirectly through other industries for a total industry employment impact of 273 FTEs; and
- An estimated contribution to GRP of $12.3 million from direct effects, with a further flow on impact of $8.4 million through other industries for a total industry value added of $20.7 million. An additional $2.9 million in gross regional product can be attributed to consumption induced effects.

Table 12.7 Input-output modelling results for existing on-farm infrastructure with 36% AWD

	Direct (D)	Indirect (I)	Total Industry Impact (D + I)	Consumption Induced (C)	Total (D + I + C)
Output ($m)	23.7	20.0	43.7	12.9	56.6
Income ($m)	1.7	2.7	4.4	1.6	6.1
Employment (fte persons)	181.1	92.2	273.2	37.3	310.5
Value added ($m)	12.3	8.4	20.7	2.9	23.7

Note: The level of direct wages and salaries returned to agricultural sectors is generally proportionally lower than other industries due to a higher level of compensation derived through gross operating surplus/gross mixed income.
Source: Lawrence Consulting 2009

If irrigation infrastructure is upgraded, the resultant additional production would increase the gross product of the region, and underpin and increase employment. The total enterprise income is anticipated to increase to $26.3 million with modernisation of on-farm infrastructure (Lawrence Consulting 2009). The direct, indirect and induced economic impacts for the Mid-Lachlan Catchment region associated with this increase are shown in Table 12.8 and discussed below:

- An estimated direct output of $26.8 million and additional flow on increases in output of $22.2 million through other industries, for a total industry impact of $49.0 million. This represents $980 million up to the year 2030. A further $14.8 million in output in the region can be associated with consumption induced effects;
- Estimated direct income (wages and salaries) of $2.1 million, with $3.0 million in additional income generated through flow on effects in other industries and a further $1.9 million from household spending;
- Approximately 198 direct full-time equivalent (FTE) employment positions, with an estimated additional 95 employment positions gained indirectly through other industries for a total industry employment impact of 293 FTEs; and
- An estimated contribution to GRP of $14.0 million from direct effects, with a further flow on impact of $9.3 million through other industries for a total industry value added of $23.4 million. An additional $3.4 million in gross regional product can be attributed to consumption induced effects.

Table 12.8 Input-output modelling results for upgraded on-farm infrastructure with 36% AWD

	Direct (D)	Indirect (I)	Total Industry Impact (D + I)	Consumption Induced (C)	Total (D + I + C)
Output ($m)	26.8	22.2	49.0	14.8	63.9
Income ($m)	2.1	3.0	5.1	1.9	7.0
Employment (fte persons)	197.7	102.8	300.6	42.9	343.5
Value added ($m)	14.0	9.3	23.4	3.4	26.7

Note: The level of direct wages and salaries returned to agricultural sectors is generally proportionally lower than other industries due to a higher level of compensation derived through gross operating surplus/gross mixed income.
Source: Lawrence Consulting 2009

The net impact of upgrading on-farm technology is shown in Table 12.9 and includes:

- An increase in total net industry impact of $5.3 million annually. Over the 20 year horizon of this Irrigation Modernisation study, this equates to $106 million in monetary benefit to the regional community. Consumption induced impacts would increase this value further to $144 million.
- There would be an increase of over 27 full time equivalent positions required to service the upgraded technology.

Table 12.9 Input-output modelling results – impact of upgraded on-farm infrastructure with 36% AWD

	Direct (D)	Indirect (I)	Total Industry Impact (D + I)	Consumption Induced (C)	Total (D + I + C)
Output ($m)	3.0	2.2	5.3	1.9	7.2
Income ($m)	0.3	0.3	0.7	0.2	0.9
Employment (fte persons)	16.7	10.7	27.3	5.6	32.9
Value added ($m)	1.7	1.0	2.6	0.4	3.1

Note: The level of direct wages and salaries returned to agricultural sectors is generally proportionally lower than other industries due to a higher level of compensation derived through gross operating surplus/gross mixed income.
The figures presented in this table may be slightly dissimilar to the difference between those in the tables above due to decimal rounding.
Source: Lawrence Consulting 2009

Should some of the water savings made in scheme channels as a result of modernisation be passed on to irrigators, these impacts would increase substantially.

12.3.3 Social Impacts

Rural communities are well known for their strong undercurrent of resilience and strength in facing a variety of demands, hardships and change. Support for change in water use to help adjust to future changes in water availability will ensure the longevity of rural communities through the following ways:

Direct impacts on irrigators, graziers, their families and the irrigation industry:

- Stable farm enterprises.
- Increased employment and profit within industries that support irrigation as detailed in the economic analysis above.
- Increased income for farming families, particularly during times of low allocation.
- Increased ability to provide children with a higher level of education.
- Increased quality of life – increased ability to participate in community leisure activities, happiness, security, reduced incidence of family and relationship dysfunction and break down.
- Male farm owners and managers commit suicide at around twice the rate of the national average (NSW Farmers Mental Health Network). Reduced levels of stress, depression and the resulting improvements in other areas of health are an important benefit of stabilising farm income.
- Nearly all farms in the Jemalong Irrigation District have diversified into sheep and/or cattle. At present, high security stock and domestic allocations cannot be delivered through the open channel system during times of low water availability, when they are most critical. During times of drought, it is extremely difficult to sell stock as other farmers are generally in the same predicament. Prices are low due to lack of fodder and there is an abundance of drought affected stock on the market. In extreme cases, farmers may be left with no alternative but to destroy

severely drought affected livestock. Secure stock and domestic water systems reduce this mental stress, resulting in a more secure income from stock and enable more controlled management of the land.

- Secure stock and domestic systems also allow maintenance of gardens around farm houses. The psychological benefits of having water to sustain a garden, which may be generations old, are significant.
- Many farmers hope to one day pass a valuable and healthy resource, a lifestyle, viable business and family tradition on to their children. Increased likelihood of family succession on farms will be promoted by greater volumes and stability of irrigation and stock and domestic water supply
- Increase in asset values due to increased reliability of irrigation leads to increased irrigated property values.
- Increased ability to access finance due to increased confidence of financial institutions.
- Long term sustainability of farming becomes more easily achievable as management of irrigation systems is more controlled with modernised infrastructure, there is less stress on dry land cropping areas to produce and stock numbers are more easily maintained at sustainable levels.
- Modernisation of on-farm irrigation systems leads to a reduction in the number of hours worked compared to flood irrigation. Flood irrigation requires a siphon hose to be started by hand for every row of crop. Starting and stopping siphons can take hours and is quite often required to be done in the middle of the night. The set up time for spray irrigation is generally less, and is minimal for drip irrigation.

Flow on impacts to local and regional communities:

- Increased spending by irrigators in the local community as detailed in the economic analysis above.
- Increased stability of small businesses and services.
- Increased likelihood of value adding enterprises to emerge within the region following stable production.
- The retention of expertise including agricultural specialists, banking and professional services and social support such as health and education resources.
- Increased employment opportunities for younger people, increasing rural social opportunities and reducing the exodus of youth to larger urban areas.
- Development of an environment that will be encouraging for the return of people to the region following the completion of further/specialised education.
- An overall increase in employment and in particular the delivery of employment options to support the indigenous population.
- There are undeniable benefits to be had within the regional indigenous population as a direct result of securing stable long-term employment and stable family income.
- Increased viability of small towns.
- Promotion of amenity value and community identity.
- Increased social well-being – attachment to place, access to social networks – increased 'social capital'.

- Stable family units will impact on the level of domestic violence and other related social problems and pressures
- Increased property values improve local government rate base and thus local government services

Flow on impacts to consumers and broader economy:

- Increased and stable national production of food
- Decreased reliance on food importation
- Decreased risk of potential health and quarantine issues associated with imported food. Not all global food producers have health regulations in line with Australia
- Increased export earnings
- A lowering of the dependence on social welfare – with respect to agriculture exceptional circumstances support and unemployment benefits
- Reduction in costs associated with physical and psychological health issues in rural areas

12.3.4 Ranking of Options from a Socio-Economic Perspective

The Options have been grouped for socio-economic assessment into 'do nothing' and 'upgrade'. The 'upgrade' alternative provides significant benefit in terms of increased economic activity, employment and social and cultural advantages.

12.4 Environmental Impacts of Modernisation Options

Total water savings of up to 20,420ML (in a 36% AWD year) are potentially possible through scheme channel and on-farm modernisation of irrigation in the Jemalong Irrigation District. It is anticipated that a substantial amount of this could be transferred to the CEWH to provide for lasting improvements in river and environmental health. This amount of water would add significantly to the 7,500 ML currently held by the Commonwealth Environment Water Holder (CEWH) in the Lachlan River.

Water transfers to the CEWH would equate to up to twice as much water in Wyangala Dam due to operational losses that result from transmitting the water from the dam to the Jemalong Irrigation District off-take at Jemalong Weir. The CEWH may then manage environmental water so as to reduce such operational losses in delivering environmental water. However, it is acknowledged that these surpluses – or transmission losses – provide significant benefit to riverine health themselves. Therefore, the total increase in water that is available to the CEWH in Wyangala Dam – up to twice that transferred by Jemalong Irrigation Limited – can be considered environmental water.

There are highly valuable environmental assets within the Lachlan River catchment that have potential to benefit from CEWH managed environmental water.

12.4.1 Nationally Important Wetlands

Nationally Important Wetland sites are an environmental feature of the catchment. There are eight such wetlands that are important for a variety of ecological reasons or because they bear historical significance or have high cultural value, particularly to Indigenous people. Of particular note are Lake Cowal/Wilbertroy Wetlands, the Booligal Wetlands and Great Cumbung Swamp.

The Booligal Wetlands has breeding colonies of up to 80,000 pairs of waterbirds (CSIRO, 2008). This area is considered to be one of the top five breeding sites for three species of waterbirds (CSIRO, 2008).

The Great Cumbung Swamp, with a core area of approximately 4,000ha and maximum area of 16,000ha is known for its vegetation species and numerous species of waterbird (CSIRO, 2008).

12.4.2 Private and Disconnected Wetlands

In addition to Nationally Important Wetland Sites, smaller wetlands on private land and unconnected wetland areas are important in catchment wetland health. These wetlands occur both on riparian properties and further from the river along cowals and old drainage lines. Some of them may only require up to a few hundred megalitres of water each year to be sustained. Small volumes of water saved through irrigation modernisation can provide targeted benefit to discrete wetlands. Diversion of water from the river is relatively simple, and can be timed such that water released from dam is directly applied without the significant transmission losses associated with delivering water to the environmental assets.

12.4.3 Farm Resource Management

If a farmer is unable to irrigate during low allocation years, they are more likely to consider more intensive dryland farming or increasing stock numbers. Farmers do not like placing their soils and other natural resources under such stress; however it may be considered necessary to provide enough income to service debts and subsist. Increasing a farmer’s income from irrigation during low water availability will reduce the impact of drought to farm enterprises and reduce the potential stress on the natural resources.

12.4.4 Vegetation Enhancement

Engagement of Jemalong Irrigation Limited shareholders through the *On-Farm Water Efficiency Plan* process, in conjunction with *The Jemalong Land and Water Management Plan* has increased the likelihood of vegetation enhancement. Discussions on the benefits of vegetation to soil and crop management, faunal habitat and biodiversity, potential funding availability for vegetation management, and the identification of areas of remnant and existing vegetation conservation are likely to increase the chances of farmers of being proactive in their vegetation management. Increases in vegetation corridors will become especially critical as the climate begins to change and fauna migrate to new areas.

12.4.5 Salinity

It is accepted that in the Lachlan River system salt and salinity is a part of the natural landscape. The construction of Wyangala Dam has contributed to maintaining acceptable levels of salt due flood mitigation effects and water release management from the dam.

It has been generally found that, while flood events raise groundwater levels, they may lower salt concentration levels. When water is released from the dam it flushes the salt concentration downstream through the river system.

Irrigation land can be managed effectively through soils that are both permeable and drainable, and the rate of application of irrigation water is controlled (Miyamato and Galceran, 1999). The Jemalong

Irrigation District soils fit this description. Well planned irrigation will allow enough excess water onto the crop to flush salts from the root zone, while not allowing an excessive rise in the water table (Australian and New Zealand Environment and Conservation Council, 1992).

The Jemalong Irrigation Limited *On-Farm Water Efficiency Plans* assessed all irrigation modernisation proposals on the basis of land capability and its impact on the key environmental indicators.

12.4.6 Energy Use and Carbon Emissions

Unfortunately, irrigation application technologies that increase water use efficiency generally have greater energy demands and carbon emissions than existing flood irrigation. The production and placement of pipe, synthetic liner or clay lining requires energy and resources. Sub-surface drip, pivot and lateral irrigation machinery also uses energy in production, and has an ongoing energy demand in use. These operational energy demands and carbon emissions for in-field technology are shown in Table 12.10.

Table 12.10 Energy requirements and carbon emissions associated with in-field irrigation technology

In-field Irrigation Application Technology	Required Pressure Head	Energy Consumption per ML of water pumped		Carbon Emissions (tonnes) per ML of water pumped	
		Electric Motor (kWh)	Diesel Motor (litres)	Electric Motor	Diesel Motor
Flood/furrow	10m	45 kWh	13.33	0.045	0.04
Lateral mover	85m	385 kWh	106.66	0.385	0.322
Centre pivot	40m	181 kWh	62.22	0.181	0.188
Sub-surface drip	50m	226 kWh	62.22	0.226	0.188

Source: Smith (2004), Smith (2008), NSW DPI (2009)

Offsetting carbon emissions associated with technology upgrades against the increase in local food production will have a direct impact on the reduction of other associated carbon outputs such as transport and additional economic expansion.

12.4.7 Environmental Water Delivery

Several wetlands, primarily Lake Cowal/Wilbertroy Wetlands within the Mid-Lachlan Region, have been signalled by DEWHA as priority assets to receive water held by the CEWH. Water cannot be delivered directly to Lake Cowal/Wilbertroy Wetlands through the Lachlan River system. There greatest potential for efficient water delivery to this system is through the utilisation of Jemalong Irrigation Limited's infrastructure. The scheme channels provide the most direct access for water from the Lachlan River to Lake Cowal/Wilbertroy Wetlands system.

12.4.8 Ranking of Options from a Socio-Economic Perspective

The Options that provide the greatest degree of water savings have the greatest potential for environmental benefit. This is compounded by considering the benefit of delivering water the Lake Cowal/Wilbertroy Wetlands system through a more efficient network.

12.5 Assessment of Legal Issues

12.5.1 Water Market Rules and Water Charge (Termination Fees) Rules

On 11th February 2009 the Minister for Climate Change and Water announced a proposal to make *Water Market Rules* and *Water Charge (Termination Fees) Rules* under Sections 97(1) and 92(1) of the *Water Act 2007*.

12.5.2 Commencement of the Rules

The *Water Market Rules 2009* legislation commences from the date of registration on the Federal Register of Legislation Instruments with a transitional period in relation to existing contracts and arrangements which expires on 31st August 2009. By which time Jemalong Irrigation Limited will be required to comply with Rule 6 that is to develop and make available their procedures. The transitional arrangements in place under Rule 4 mean that until 1st September 2009 the *Water Market Rules 2009* do not affect any existing contracts, arrangements or understandings.

The *Water Charge (Termination Fees) Rules 2009*, with the exception of Rules 1-4 and Rule 8 (which commence on the day after the Termination Fees Rules are registered in the Federal Register of Legislative Instruments), commence on 1st July 2009.

Rules 1 to 4 are formal and Rule 8 allows the ACCC to approve an additional termination fee between an operator and an irrigator over and above the Rule 7 calculated fee of a maximum of ten times the irrigator's annual total network access charge.

Subject to Jemalong Irrigation Limited deciding, as a policy matter, that it will apply to the ACCC for a higher termination fee in accordance with Rule 8 (which may not be available to Jemalong Irrigation Limited in any event: see the provisions of Rule 8) the amendments to policies etc required by the *Water Charge (Termination Fees) Rules 2009* relating to termination fees will need to be in place prior to 1st July 2009.

12.5.3 Other Draft Rules

There are additional draft Rules developed by the ACCC which have not yet been dealt with by the Minister. These are:

- Water Charge Rules – Irrigation Operators (excluding Termination Fees)
- Water Charge Rules – Bulk Water
- Water Charge Rules – Water Planning and Management

12.5.4 Articles of Association/Constitution

Jemalong Irrigation Limited will need to determine, as a policy matter, whether it wishes to continue with its existing Articles of Association for amendment to incorporate the necessary changes required by the *Water Act 2007* and the Rules, or whether it wishes to move to a Constitution.

In either event, the relevant provisions of the Act and the Rules will need to be included so far as required and any provisions currently in the Articles which are contrary to the Act and the Rules must be deleted.

At this point it's not proposed to prepare a detailed amendment of the Articles as legal opinion recommends proceeding to a Constitution. This can be done at a later date if necessary once Jemalong Irrigation Limited has decided on whether to proceed to a Constitution. The existing Articles do not mention delivery entitlements or termination fees and the *Water Charge (Termination Fees) Rules 2009* which will come into force effectively on the 1st of July 2009 can be dealt with by way of appropriate amendments to the Water Entitlement, Delivery Entitlement and Transformation Policy (028) revised September 2008.

12.5.5 Water Entitlement, Delivery Entitlement and Transformation Policy

The Water Entitlement, Delivery Entitlement, Transformation Policy (028) does comply with the *Water Charge (Termination Fees) Rules 2009* to provide for:

- termination fees to be a maximum of ten times annual access fee
- option to the landholder to maintain delivery entitlement by payment of annual access fee or to terminate

Part 2 of the Water Market Rules 2009 requires Jemalong Irrigation Limited:

- As soon as possible after the commencement of the Rule (N.B. not 1st September 2009 but *the day after they are registered)* to inform each shareholder that the Rules have been made, how copies can be obtained and how the ACCC can be contacted.
- To establish clear procedures for transformation of irrigation rights and make details of those procedures available to irrigators no later than 31st August 2009.

The ACCC has advised that it is developing forms for applications for transformation and these will be reviewed prior to determining the appropriate forms for Jemalong Irrigation Limited.

Rule 10 allows for security to be taken for payment for fees or charges for delivery of water in the circumstances set out in that Rule and lays down detailed requirements in relation to such security.

Transfer Rules

These will need to be amended by the 31St of August 2009 to incorporate the matters referred to in the *Water Market Rules 2009.*

In that regard Rules 2, 3 and Rule 4(b) to (m) should be deleted, Rule 6 modified and Rule 10 extended to refer to the *Water Act 2007* and the Rules approved there under.

Water Supply Contract (WSC)

It is recommended that the WSC which is headed as an annexure to the Articles of Association be removed from the Articles (or the Constitution) so that it can be more readily updated, as required from time to time, without a reference to a general meeting of the Company.

The WSC should be updated to incorporate the principles of delivery entitlements and the relevant parts of the *Water Market Rules* and *Water Charge (Termination Fees) Rules 2009.*

WESTERN LAND PLANNING

Stock and Domestic Permanent Water Transfer Policy

At this stage stock and domestic water cannot be traded.

Charges Policy

A Jemalong Irrigation Limited Charges Policy will need to be developed to deal with termination fees and water charges when these policies are approved by the Minister.

12.6 Assessment Summary

Table 12.11 provides a summary of the findings from each of the assessments detailed in this chapter.

Note that in relation to the scores provided, each of the components (engineering, socio-economic etc) has been given the same weighting, and each of the criteria within these components has also been given the same weighting.

Note also that the benefit-cost ratio calculated in this table a preliminary assessment of the net industry impact divided by capital cost.

Table 12.11 Combined assessment of Modernisation Options

Option		TOTAL POTENTIAL WATER SAVINGS 36% AWD (ML)	TOTAL POTENTIAL WATER SAVINGS 75% AWD (assuming in-field upgrade for 36% AWD only) (ML)	Capital cost of infrastructure Scheme and on-farm infrastructure ($M)	Total maintenance cost of scheme channel infrastructure to 2030 ($M)	Potential increase in employment above the 'do nothing' case (FTEs)	Potential direct economic benefit over 20 years to 2030 compared to 'do nothing' case ($M)	Preliminary cost-benefit ratio. Capital cost to direct benefit only (multiple indirect benefits will also occur but are not factored here)	Engineering score	On-farm score	Socio-economic score	Environmental score	Cost	Total score	Rank
1	Do Nothing	0	0	0	23.5	0	0	-	1.25	0	0	0	3	4.25	10
2a	Stabilised Backfill – High Infiltration	6,400	6,880	86.8	23.5	27.3	106	1.24	1.63	2.5	2.5	0.5	2	9.13	9
2b	Stabilised Backfill – Low Infiltration	13,840	16,450	86.8	23.5	27.3	106	1.24	1.63	2.5	2.5	1	2	9.63	8
3	Geofabric Liner	19,470	23,680	88.5	34.5	27.3	106	1.22	1.75	2.5	2.5	2.8	1.5	11.05	1
4	HDPE Liner	19,470	23,680	93.1	31.0	27.3	106	1.16	1.75	2.5	2.5	2.8	1.5	11.05	1
5	EPDM Liner	19,470	23,680	92.5	30.3	27.3	106	1.17	1.75	2.5	2.5	2.8	1.5	11.05	1
6a	HDPE Pipe and Geofabric Liner	20,360	24,790	150.7	34.3	27.3	106	0.72	2.00	2.5	2.5	2.9	1	10.90	4
6b	HDPE Pipe and HDPE Liner	20,360	24,790	155.1	30.8	27.3	106	0.70	2.00	2.5	2.5	2.9	1	10.90	4
6c	HDPE Pipe and EPDM Liner	20,360	24,790	154.6	30.2	27.3	106	0.70	2.00	2.5	2.5	2.9	1	10.90	4
7	HDPE Pipe and EPDM Liner	20,420	24,830	258.8	13.5	27.3	106	0.42	2.75	2.5	2.5	3	0	10.75	7

Notes:

- All employment and economic benefit values are based on a 36% AWD – the average annual water availability anticipated for the year 2030 accounting for climate change
- No score has been provided for carbon emissions and energy use due to complexities in estimation and weighting against environmental benefits. In general, the Options that result in the greatest water savings also result in greatest energy requirements and carbon emissions.
- Co-contributions have not been assessed at this stage.
- On-farm costs account for in-field technology only.

13 CONCLUSION

The Modernisation Options presented in this report and shown in Table 13.1 are characterised by the potential technology upgrade for scheme channels. The 'do nothing' case represented by Option 1 provides no water savings but has been included to provide comparison against the other options with regard to costs and benefits between now and the year 2030. Options 2 to 7 all incorporate upgrade of scheme gating and metering, depending on the requirements of the channel upgrade. On-farm infrastructure is included in all upgrade options, as determined in the *On-Farm Water Efficiency Plans*. There are four alternatives for stock and domestic water delivery that could be employed in conjunction with each of the channel Modernisation Options.

Table 13.1 Jemalong Irrigation Limited Irrigation Modernisation Options

Option Number	Division 1 Channels	Division 2 Channels	Scheme gating and metering[a]	On-farm irrigation infrastructure	On-farm channels upgrade and soil moisture monitoring	Stock and domestic delivery
Option 1	Existing	Existing	Existing	Existing	Existing	Existing
Option 2	Stabilised backfill	Stabilised backfill	Upgrade scheme gates and meters	As identified in *On-Farm Water Efficiency Plans*	As identified in *On-Farm Water Efficiency Plans*	Upgrade [b]
Option 3	Geofabric liner	Geofabric liner	Upgrade scheme gates and meters	As identified in *On-Farm Water Efficiency Plans*	As identified in *On-Farm Water Efficiency Plans*	Upgrade [b]
Option 4	HDPE liner	HDPE liner	Upgrade scheme gates and meters	As identified in *On-Farm Water Efficiency Plans*	As identified in *On-Farm Water Efficiency Plans*	Upgrade[b]
Option 5	EPDM liner	EPDM liner	Upgrade scheme gates and meters	As identified in *On-Farm Water Efficiency Plans*	As identified in *On-Farm Water Efficiency Plans*	Upgrade[b]
Option 6	HDPE pipe system + Line existing Channel	Possible Synthetic Liner or piping of sections	Upgrade scheme gates and meters	As identified in *On-Farm Water Efficiency Plans*	As identified in "On-Farm Water Efficiency Plans	Upgrade[b]
Option 7	HDPE pipe system	Possible Synthetic Liner or piping of sections	Upgrade scheme gates and meters	As identified in "On-Farm Water Efficiency Plans"	As identified in "On-Farm Water Efficiency Plans"	Upgrade[b]

Notes: [a] Includes upgrading farm off-take meters
[b]The preferred stock and domestic water delivery system will be finalised prior to any application for infrastructure funding.

The options generally involve uniform treatment of all channels across the scheme. This provides valuable information regarding the relative cost and water savings associated with alternative technologies. Combinations of each of the treatments throughout different sections of the scheme may be investigated further should an application for infrastructure be made.

The *Sustainable Rural Water Use and Infrastructure* program under which this Irrigation Modernisation Plan has been developed aims to promote projects that:

1. Deliver substantial and lasting returns of water for the environment
2. Secure a long-term future for irrigation communities
3. Deliver value for money in the context of the first two tests

Modernisation of scheme channels and on-farm infrastructure in the Jemalong Irrigation District has potential to save up to 20,420ML in an average year in 2030 (36% AWD). This value is equivalent to the total of the environmental contingency allowances to be held in Wyangala Dam and Lake Brewster as set out in the *Water Sharing Plan for the Lachlan Regulated River Source*.

The percentage of the savings that might be traded to the Commonwealth Environment Water Holder (CEWH) in return for infrastructure has not been identified in this Irrigation Modernisation Plan as there are complex and difficult decisions to be made by each individual JIL shareholder. However, in practice, the amount of water that would be held in Wyangala Dam is likely to be over twice the traded amount due to savings made in transmission losses between the dam and Jemalong Weir.

Water transferred to the CEWH through the *Sustainable Rural Water Use and Infrastructure* program will be of the form of water entitlement. The CEWH will then have the enduring ability to deliver water to environments within the Lachlan Catchment that reflect the Australian Government's priorities. Several wetlands of national importance, along with smaller wetlands of great significance and overall river health have potential to experience real and substantial benefit, particularly during crucial times of very low allocation.

The Lake Cowal/Wilbertroy Wetlands system has been identified by the Australian Government as a key environmental priority in the Lachlan Catchment. This system is on a tributary of the Lachlan River and water cannot be delivered to it simply by releasing from Wyangala Dam. The most direct way in which water can be conveyed to the Lake Cowal/Wilbertroy Wetlands system is through the Jemalong Irrigation District network. Thus, there may be compound benefit to the CEWH in upgrading this network to a highly water efficient system.

The benefits of upgrading the Jemalong Irrigation District are also compounded throughout the local, regional and national community. Upgrading the on-farm infrastructure throughout the Jemalong Irrigation District has potential to generate over $100 million in additional output over 20 years. However, this benefit will be ongoing well beyond the year 2030. Similarly, the 29 additional full-time equivalent positions that might be required following modernisation will endure into the long term.

Secure irrigation production will support regional banking, finance, professional services, education and health and drive regional investment and development. It will help irrigation communities make early adjustments in anticipation of the new Murray-Darling Basin cap on water extractions and climate change. It will also help secure long-term national food production.

Securing access to stock and domestic water through any of the four alternatives presented in this report will provide enormous benefit to stock health, sustainable production in low allocation years, and farming families mental and general wellbeing. Piped bore water stock and domestic systems have been constructed throughout much of the Jemalong Irrigation District. However, most of these systems aren't capable of providing total necessary stock and domestic water requirements and there are concerns over the long-term sustainability of groundwater resources in the region.

A preliminary cost-benefit analysis (calculated as net industry impact divided by capital cost) has been undertaken for each of the options presented. The benefits outweigh the costs for Options 2 to 5. Options 6 and 7 have a lower value for benefit as defined for this preliminary assessment than the costs.

However, if the longevity of the pipes in these options is considered, over their 60 year lifespan, the benefits of increased production are likely to far outweigh the costs.

A few of the multitudes of additional benefits that are not costed in this test include: the environmental benefit associated with water transfer to the CEWH; the ability to efficiently deliver water to the Lake Cowal/Wilbertroy Wetlands system; the reduced reliance on social services; increased taxation from increased production throughout the region; and increased equality in service provision throughout all Australians.

Options 3 to 7 provide the greatest level of water savings of the alternatives presented in this report, and therefore the greatest potential environmental benefit. Although piping within Options 6 and 7 has a greater capital cost, there are significant advantages to these options such as the ability to deliver water in lower allocation years, reduced risk associated with maintenance costs and greater operational flexibility.

The findings of this report rely on estimates of ‘losses’ throughout the channel network. The nature of the soil structure throughout the scheme means that existing information is insufficient to determine accurate rates of infiltration. Therefore, estimates of potential water savings in this report rely on high levels of anecdotal information. The key to obtaining more accurate assessment of water savings is the collection of information on infiltration rates and hotspots throughout the scheme. It is strongly recommended that this testing be undertaken prior to submission of an application for infrastructure funding.

A more detailed cost-benefit analysis is also recommended if an application for infrastructure funding is to be made, along with consideration of rationalisation and cost sharing arrangements.

Modernisation of the Jemalong Irrigation District has great potential to fulfil the aims not only of the *Sustainable Rural Water Use and Infrastructure* program but also the four key priorities of the *Water for the Future* initiative. Irrigation modernisation within the Jemalong Irrigation District will help farmers and the broader community adapt to climate change. It will promote water being used wisely and it will secure water supplies for the population within the district. Finally, it will provide water to maintain healthy rivers and waterways.

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JEMALONG IRRIGATION LIMITED

IRRIGATION MODERNISATION PLAN

APPENDICES

Prepared for Jemalong Irrigation Limited

With the assistance of The Australian Government

Prepared by Western Land Planning Pty Ltd

DOCUMENT CONTROL SHEET

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Title :	Jemalong Irrigation Limited Irrigation Modernisation Plan Appendices

DISTRIBUTION

DESTINATION	VERSION					
	1		2		3	
	Date	Number	Date	Number	Date	Number
DEWHA	09/06/09	1				
Jemalong Irrigation Limited	09/06/09	1				

ACKNOWLEDGEMENTS

Western Land Planning wish to acknowledge the contributions and support of the following people and organisations in the development of this report: the Jemalong Irrigation Limited sub-committee and board; Jemalong Irrigation Limited shareholders; Forbes Shire Council; State Water, particularly s 22(1)(a)(ii) ; Lachlan Valley Water; Bureau of Rural Science; Lachlan CMA; CRC for Irrigation Futures and all other people who have been generous with their time and information.

This document has been prepared for Jemalong Irrigation Limited, funded through the Australian Government's *Sustainable Rural Water Use and Infrastructure* program. Contributing consultants are Western Land Planning Pty Ltd, Francis, Kelly and Grant solicitors, Boyden & Partners Pty Ltd, Lawrence Consulting and Goodfellow and Associates.

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Jemalong Irrigation Limited has relied on independent consultants to provide information and findings in this report.

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APPENDIX A: JEMALONG IRRIGATION LIMITED FINANCIAL VIABILITY DOCUMENTATION

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Jemalong Irrigation Limited
Balance Sheet
As at 30 June 2008

	Note	2008 $	2007 $
Current Assets			
Cash and Cash Equivalents	3	2,431,119	806,408
Trade and Other Receivables	4	111,557	104,007
Financial Assets	5	5,895,307	6,179,580
Other Current Assets	7	331,522	-
Total Current Assets		8,769,505	7,089,995
Non-Current Assets			
Property, Plant and Equipment	11	7,982,070	7,988,731
Intangible Assets	8	125,227	125,227
Deferred Tax Assets	6	88,475	185,588
Total Non-Current Assets		8,195,772	8,299,546
Total Assets		16,965,277	15,389,541
Current Liabilities			
Trade and Other Payables	9	250,474	111,154
Financial Liabilities	10	2,764,391	774,574
Short Term Provisions	12	22,500	25,500
Total Current Liabilities		3,037,365	911,228
Non-Current Liabilities			
Deferred Tax Liabilities	6	477,935	391,569
Long Term Provisions	12	11,200	10,500
Total Non-Current Liabilities		489,135	402,069
Total Liabilities		3,526,500	1,313,297
Net Assets		13,438,777	14,076,244
Equity			
Issued Capital	13	81,189	81,189
Reserves	13	12,645,354	13,835,546
Retained Profits	13	712,234	159,509
Total Equity		13,438,777	14,076,244

Statement of Appropriations
For the Year ended 30 June 2008

	2008 $	2007 $
Retained Profits - Beginning of Year	159,50	-474,711
Profit before Income Tax	736,204	854,113
Income Tax Expense	-183,479	-219,893
Unappropriated Profit at 30 June 2008	712,234	159,509

Jemalong Irrigation Limited
Trading, Profit and Loss Statement
For the Year ended 30 June 2008

	2008 $	2007 $
Income		
Sales Water	1,116,685	540,486
Less Cost of Sales		
Water Charges	370,614	175,646
NSW Irrigators Levy	6,364	4,750
Licences	7,500	7,500
	384,478	187,896
Gross Profit from trading	732,207	352,590
Expenditure		
Administration Costs	42,505	32,567
Auditor's Remuneration	10,000	10,000
Board Member Expenses	105,875	91,484
Consultancy Fees	56,186	24,246
Depreciation	155,154	137,501
Insurance	33,570	37,438
Motor Vehicle Expenses	74,746	69,956
Provision employee entitlements	-	7,000
Repairs & Maintenance	95,874	86,840
Staff Training & Welfare	6,052	5,435
Wages	232,842	218,480
	812,804	720,947
Income		
Managed Fund Distributions	502,646	383,623
Dividends Received	15,131	-
Interest Received	44,567	39,050
Management Fee - Barrick	238,017	108,000
Sundry Income	14,140	33,090
Employee entitlements overprovided	2,300	-
LWMP-WMO's	-	190,000
Managed Funds-Gain	-	468,707
	816,801	1,222,47
Operating Profit before Income Tax	736,204	854,113
Income Tax on operating income	183,479	219,893
Operating Profit after Income Tax	552,725	634,220

APPENDIX B: CONSULTATION QUESTIONNAIRES

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JEMALONG IRRIGATION LIMITED IRRIGATION MODERNISATION PLAN

COMMUNITY GROUP CONSULTATION QUESTIONNAIRE

Jemalong Irrigation Limited has engaged Western Land Planning to develop an Irrigation Modernisation Plan. This Plan aims to identify current water use, and investigate where efficiency gains might be made with the aim to ensure sustainable environment, society and production outcomes.

As part of this process, we are trying to gauge the community's perceptions and expectations for agriculture, irrigation and water use within the Lachlan Valley surrounding Jemalong over the next 20 years. We appreciate your thoughts relating to the following questions, and on any other aspect of the project.

If we are unable to collect this questionnaire in person, we would be grateful for your posting it to:

Western Land Planning
PO Box 2705
Dubbo NSW 2830

Or by email to:
s 22(1)(a)(ii)

Name and Organisation (optional): ______________________________

Question 1: Do you believe irrigated agriculture within Jemalong and in the surrounding Lachlan Valley is sustainable in its current form, from an individual farmer's financial perspective as well as natural resource sustainability? If not, what changes do you believe are necessary to promote sustainability?

Question 2: Do you believe the population of the Lachlan Valley surrounding Jemalong will increase, decrease or stay the same over the next 20 years? What factors do you see as important in relation to population change?

Question 3: How important an impact do you believe the following pressures will have on water resources over the next 20 years (please circle)?

• Urban expansion	Very important	Mildly important	Neither	Mildly unimportant	Very unimportant
• Mining	Very important	Mildly important	Neither	Mildly unimportant	Very unimportant
• Environment	Very important	Mildly important	Neither	Mildly unimportant	Very unimportant
• Irrigation	Very important	Mildly important	Neither	Mildly unimportant	Very unimportant

- Other

Question 4: How important an impact do you believe the following pressures will have on land use over the next 20 years (please circle)?

• Urban expansion	Very important	Mildly important	Neither	Mildly unimportant	Very unimportant
• Mining	Very important	Mildly important	Neither	Mildly unimportant	Very unimportant
• Food production	Very important	Mildly important	Neither	Mildly unimportant	Very unimportant
• Biofuels development	Very important	Mildly important	Neither	Mildly unimportant	Very unimportant
• Environment	Very important	Mildly important	Neither	Mildly unimportant	Very unimportant

- Other

Question 5: In your view, how important are the following industries to the economy of the Lachlan Valley surrounding Jemalong?

• Dryland agriculture	Very important	Mildly important	Neither	Mildly unimportant	Very unimportant
• Irrigated agriculture	Very important	Mildly important	Neither	Mildly unimportant	Very unimportant
• Food processing	Very important	Mildly important	Neither	Mildly unimportant	Very unimportant
• Mining	Very important	Mildly important	Neither	Mildly unimportant	Very unimportant
• Agricultural equipment and services	Very important	Mildly important	Neither	Mildly unimportant	Very unimportant

Question 6: What do you anticipate to be the important economic growth areas in the Lachlan Valley over the next 20 years and what factors do you think will be important in this expansion?

Question 7: What do you believe to be the most important local environmental assets? What could be done to protect these assets?

Question 8: Do you believe it is important for additional water to be made available for the environment?

Question 9: How important do you see the following to the sustainability of the community in the Lachlan Valley surrounding Jemalong?

• Food production	Very important	Mildly important	Neither	Mildly unimportant	Very unimportant
• Irrigated agriculture	Very important	Mildly important	Neither	Mildly unimportant	Very unimportant
• Stock & domestic water	Very important	Mildly important	Neither	Mildly unimportant	Very unimportant
• Jemalong Irrigation	Very important	Mildly important	Neither	Mildly unimportant	Very unimportant

Other/Comments:

Additional comments you might have regarding irrigation in the Lachlan Valley surrounding Jemalong:
(Please feel free to attach additional pages if required)

Thank you for your time in completing this questionnaire. Your thoughts are important to the Jemalong Irrigation District Irrigation Modernisation Plan

JEMALONG IRRIGATION LIMITED IRRIGATION MODERNISATION PLAN

JIL BOARD AND REVIEW COMMITTEE CONSULTATION QUESTIONNAIRE

The Jemalong Irrigation Limited Irrigation Modernisation Plan will develop case confirming that irrigation production is positive and sustainable within the JIL district and worthy of the Australian Government investing in infrastructure in the district. A part of this case includes the current perceptions and trends within agriculture and water use, and socio-economic and community factors within and surrounding the JID (eg population change, the importance of irrigation to the local economy). Another part of the case is where JIL sees itself in the short term (2012) and long term (2030).

To develop this case, we would appreciated if you could complete the following survey and relay your thoughts relating to the following questions, and on any other aspect of the project you feel relevant. Can you please return this questionnaire by posting or emailing to s 22(1)(a)(ii) at Western Land Planning:

Western Land Planning
PO Box 2705
Dubbo NSW 2830

s 22(1)(a)(ii)

Name (optional): ______________________________

Question 1: Do you believe irrigated agriculture within Jemalong and in the surrounding Lachlan Valley is sustainable in its current form, from an individual farmer's financial perspective as well as natural resource sustainability? If not, what changes do you believe are necessary to promote sustainability?

____

____

____

____

Question 2: Do you believe irrigation in the Jemalong Irrigation District (JID) will be viable in the future if scheme losses are reduced and the average allocation is:

15%?	Yes	No	30%?	Yes	No
37%?	Yes	No	40%?	Yes	No
45%?	Yes	No			

What factors do you see as important in determining the threshold of viability?

____

____

Question 3: What do you see as the future trends in agronomic and irrigation practices within the JID and broader agricultural community?

Question 4: What has been the impact of minimal general security (irrigation) allocations over the last 6 years on the local community? Eg have there been any banks, schools, shops, abattoirs close? Has the general community feeling changed?

Question 5: How important an impact do you believe the following pressures will have on water resources over the next 20 years (please circle/highlight)?

• Urban expansion	Very important	Mildly important	Neither	Mildly unimportant	Very unimportant
• Mining	Very important	Mildly important	Neither	Mildly unimportant	Very unimportant
• Environment	Very important	Mildly important	Neither	Mildly unimportant	Very unimportant
• Irrigation	Very important	Mildly important	Neither	Mildly unimportant	Very unimportant

- Any others?

Question 6: What do you believe has been or will be the impact of open market water trading, the ACCC recommendations on Water Market Rules and the buy back scheme within the Lachlan River?

Question 7: Are there any changes to river operations/ storages /Jemalong weir that could be made to improve delivery system efficiency?

Question 8: Describe how you see Jemalong Irrigation Limited functioning in the year 2030. What is the structure of JIL management, how does the scheme operate? What are the strategies for JIL over the next 20 years?

Question 9: Do you believe that family succession will play an important role in the future of farming in the Jemalong District?

Question 10: What other issues do you see playing a role in the future of JIL and irrigation in the district?

Question 11: Do you believe the population of the Lachlan Valley surrounding Jemalong will increase, decrease or stay the same over the next 20 years? What factors do you see as important in relation to population change?

Question 12: What do you anticipate to be the important economic growth areas in the Lachlan Valley over the next 20 years and what factors do you think will be important in this expansion?

Question 13: What do you believe to be the most important local environmental assets? What could be done to protect these assets?

Please note any specific people or organisations that you feel should be included in the consultation process. Additional comments you might have regarding irrigation in the Lachlan Valley surrounding Jemalong:
(Please feel free to attach additional pages if required)

Thank you for your time in completing this questionnaire. Your thoughts are important to the Jemalong Irrigation District Irrigation Modernisation Plan

APPENDIX C: IRRIGATION PRODUCT REVIEW

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2009

To:

Jemalong Irrigation Limited

ACN: 067197782

Jemalong Weir
Lachlan Valley Way
Forbes NSW 2871

Irrigation Product Review

GOODFELLOW & Associates Pty Ltd
ABN 89 535 895 771

ACT/NSW Office
'Coolawin'
Gundaroo NSW 2620
Phone 02 6236 8511
Facsimile 02 6236 8522

Document Details

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Client: Jemalong Irrigation Limited, PO Box 520, Forbes NSW 2871

Author(s): s 22(1)(a)(ii)

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To	Type	No. of copies
JIL	Hard copy	1
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Contributors

This report has been completed with contributions from Goodfellow & Associates professional associates as follows:

Prohort Management
Phone: 02 69266419
Facsimile: 02 69225352
Email: enquiries@prohort.com.au

www.prohort.com.au

Wagga Office
32 Patamba St
Wagga Wagga NSW 2650
Central West NSW
7 Eucalyptus Dr
Montefiores NSW 2820

AND

GOODFELLOW & Associates Pty Ltd
ABN 89 535 895 771
s 22(1)(a)(ii) Director
'Coolawin'
Gundaroo NSW 2620
Phone 02 62368511 Fax: 02 62368522
Email: s 22(1)(a)(ii)@goodfellow.com.au

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1. INTRODUCTION

s 22(1)(a)(ii) from Jemalong Irrigation Limited (JIL) instructed Goodfellow & Associates to report on water delivery, management and application products that may suite irrigation scheme and on farm irrigation modernisation. This report reviews various irrigation products identified as relevant to irrigation modernisation.

1.1. Scope of Works

Goodfellow and Associates understand that a report reviewing irrigation-related products will include, but is not limited to, water delivery, water management and water application products available within Australia that would suit both an irrigation scheme and on-farm modernisation programme. This review should, where possible, cover the following topics:

- Brands;
- Manufacturers;
- Availability within Australia and distribution arrangements;
- History of use;
- Typical application as it applies to the project;
- Other dependant infrastructure requirements;
- Water use efficiency statistics;
- Operating costs;
- Life span;
- Maintenance requirements and cost;
- Recent technological advancements;
- Current research;
- Operational procedures;
- Ability to perform to specification;
- Case study examples of performance;
- Existing user comments;
- Identified problems or faults;
- Shelf price;
- Indicative cost of replacement parts or routine maintenance;
- Capacity for expansion or limiting factors;
- Energy use; and
- Associated carbon emissions for whole of life cycle and operation.

A list of product types of interest was provided by JIL as follows:

- Alternative pipes;
- Alternative liners;
- Pivot;
- Lateral move;
- Drip irrigation;
- Gating systems;
- Telemetry systems;
- Meters;
- Pumps; and
- Fencing.

Where possible, these products were included within the assessed Irrigation Product Review.

In some cases products have been grouped into classification of equipment such as water meters and channel liners. For product groups (equipment), a summary was provided with identifying characteristics to assist with individual brand or type selection. In cases where strong characteristics prevail for individual product types or brands, these products were summarised in a standard format. In cases where many product types and brands exist, a summary of selection and predominant characteristics have been provided to assist in individual product selection. The standard format utilised to summarise individual product types or brands is shown in the following table.

Table 1. Standard Product Summary Table.

1	Equipment:	
2	Types:	
3	Components:	
4	Dependant infrastructure requirements:	
5	Typical application:	
6	History of use:	
7	Water Use Efficiency statistics:	
8	Limiting factors:	
9	Recent technological advancements:	
10	Current research:	
11	Case study examples of performance:	
12	Recommended application:	
13	Establishment procedures:	
14	Operational procedures:	
15	Brands and manufactures:	
16	Availability in Australia:	
17	Market distribution:	
18	Life span:	
19	Indicative price:	
20	Case study establishment price:	
21	Case study operating costs:	
22	Repairs and maintenance requirements:	
23	Case study maintenance and repair costs:	
24	Part costs and availability:	
25	Case study energy use:	
26	Ability to perform to specifications:	
27	Identified problems or faults:	
28	User comments:	
29	Capacity for expansion:	
30	Associated carbon emissions:	

1.2. Review Interpretation

1.2.1. Interpretation of Information Provided

Information and data provided within this report should be considered a guide and summary of information only. Detailed information on individual products or brands should be sought directly from the supplier or manufacturer. Information independently assessed about different equipment has been included in the listed references where this information was readily available at the time of collating this report. The reference material presented within this review may not be comprehensive and thus it is strongly recommended to source additional material for further clarification on any particular identified topic.

The information collected from suppliers, manufactures and referenced source material was combined with the experience of the authors and interpreted to create this report and the individual product summaries.

The intention of this report is to provide a guide to various equipment, characteristics of selection and a summary of information on selected individual products. This must be used as a guide to seek further information that will assist the reader in selecting suitable equipment for scheme or on-farm modernisation.

1.2.2. Products Reviewed

Irrigation products have been reviewed either as a group, individually, as an individual branded product, or a combination of the above. The following list indicated the groups and items reviewed:

- Channel liners:
  - HDPE;
  - ITM;
  - PMC;
- Pipes:
  - Alternative gravity pipes:
    - Stormpro;
    - Plastream;
    - Greenpipe;
  - Pressurised pipes;
- Pumps;
- Control Gates;
- On-farm distribution:
  - Pipe and Risers;
    - Solid sub-surface;
    - Surface;
  - Pivots and Laterals;
  - Drip Irrigation;
    - Sub-surface;
    - Automation;
- Water Meters;
- Water Monitoring
  - Soil moisture monitoring;
  - Field water monitoring; and
- Automation.

This is not intended to be an exhaustive list of possible irrigation products that are suitable for modernisation of irrigation schemes and on-farm irrigation systems and delivery mechanisms. The list of equipment and individual products assessed only represents those considered as a possibility for the intended irrigation scheme and its members predominant farming practices.

1.2.3. Limitations

Information collected within this report is based on a combination of the authors' product knowledge, data supplied by suppliers and manufacturers, and reference material reviewed. Thus the identified references are not exhaustive and thus should be considered as a guide to the type of information readily available to be reviewed. Various State Departments of Primary Industries or Natural Resources provide reference material that could directly or indirectly relate to the topics reviewed. Only some of these references may have been included within this report.

Manufacturers or suppliers listed within this report may not reflect all manufactures or suppliers that may produce or sell these products in Australia. The listed manufacturers or suppliers are those identified by the authors with a history of supply within the irrigation industry. Other manufacturers may make similar products that are suitable alternatives to those identified within this report.

All prices within this report are GST exclusive unless otherwise stated. All costs are indicative only for the purpose of comparison between different products. These prices or costs may not be able to be used for comparison between different equipment types. The indicated prices may also represent list prices which may not reflect the actual cost of purchase by either a scheme or an individual irrigator. Within this industry, price is generally set on volume. Prices for actual products need to be considered *in situ* as different usage may incur significantly different overall costs. It is strongly recommended that if a comparison is to be made between different product options, it is done so on the basis of the intended purpose with competitive quotes obtained to reflect the particular details of the intended use.

Associated carbon emissions for whole of life cycle and operation has been included in the summary list as requested. However in the majority of cases, this section has not been fully completed because carbon emission data for the listed products is not readily available or in general publication. In many cases, carbon emissions are dependant upon the actual usage of the product as well.

2. EARTHEN CHANNEL REPLACEMENT

2.1. Channel Liners Selection Criteria

The greatest cause of water loss in transfers between water sources and irrigators is due to leaks and seepage in channels. Channel lining is a recognised method to upgrade and remediate deteriorated channel systems where seepage is a major issue. It is equally an important consideration in ensuring water delivery efficiency in the construction of new channel systems to minimise seepage losses.

There are important factors that require overall analysis to assess viability and arrive at an appropriate solution that include:

- The scope and cause of the seepage problem;
- Site specific conditions;
- The objectives of the remediation or new construction;
- Relevant criteria for the assessment of various techniques;
- Financial and Cost Benefit Analysis; and
- Comparative assessments of criteria to prioritise potential techniques.

The following points indicate fundamental criteria for initial investigation to identify suitable channel lining options prior to assessment and selection of the most appropriate technique(s).

Current and Future Supply Requirements – Ability of existing capacity to meet current and future supply requirements.

Channel Capacity – The selection of different techniques is influenced by channel size and capacity, e.g., pipelines can be effective for small channels but less practical for larger capacity channels. Space limitations for construction may also influence the remediation technique.

Operational Schedule – Most irrigation channels are emptied / drained only for a relatively short time in the off-season. The type and extent of remediation should consider construction opportunity and timeframes.

Impact of Seepage – Vertical or lateral seepage may be mitigated by different methods of remediation. The extent of seepage impact, negative or positive, may influence the scope and type of remediation.

Channel Dimensions and Site Conditions – Survey of the channel site is required to identify site features, limitations, preparatory works required and quantities of materials.

Soil Types and Subgrade Quality – Soil parameters such as permeability, dispersion and expansion / shrinkage potential, settlement, load bearing capacity, and texture of subgrade (e.g., smooth or rocky) may influence the selection of remediation techniques.

Topography/Flow Velocity – Flow velocities will influence selection of remediation methods depending on their ability to withstand them.

Climatic Conditions – Climatic conditions during the anticipated construction period often present a challenging working environment (usually wet and cold, but in some areas hot). This should be considered in both the selection of a technique and the method of installation.

Groundwater Levels – High groundwater levels can exert upward pressure on liners and dislodge them, which is an issue for both flexible and rigid surface liners. Compact earth liners have performed well in high groundwater conditions.

Adjacent Land Use – Adjacent land use and its value may influence the construction and final width of the channel and hence the remediation technique.

Operation and Maintenance – Existing O&M activities and requirements should be considered in remediation selection, e.g., fluctuating water levels and frequency of de-silting.

Potential for Damage and Exposure – An assessment of the risk and potential sources of damage should be undertaken and a liner chosen which is able to resist damage.

Structural Integrity of Channel Profile – If a channel and banks are not structurally sound, they may not support the installation of a liner without some remodelling work.

Occupational Health and Safety – Potential risks to public safety and authority staff should be considered in the selection of remediation techniques, e.g., flexible membrane liners can be slippery which makes it difficult for humans and animals to get out of the channel and the effort required to escape the channel usually results in puncture damage, particularly by clawed animals such as kangaroos. Extraction of trapped animals may pose similar hazards.

2.2. Liner Types

In selecting liners for channels, there are three main types to consider:

- Earthen
- Hard Surface
- Geomembrane

Within these categories, a large range of products and methods are available. Generally, the key success of the different types can be evaluated in terms of permeability performance as shown in Table 2. Indicative Liner Permeability below (as sourced from Lush G 2004 Guidelines for Channel Seepage Remediation). Compacted earth, bentonite lining, chemically stabilised soil and ordinary clay loam are all well established Earthen methods, whereas Geomembranes are representative of more recent technological advancements. The table clearly illustrates the superiority of Geomembranes over the other alternatives.

Table 2. Indicative Liner Permeability

Type of Lining	Expected Seepage Rate Reduction	Indicative Liner Permeability ($L/m^2/day$)
Compacted Earth	70-90%	0.5 – 2.0 but varies widely
Bentonite Lining	60 – 70%	0.5 – 1.0
Chemically Stabilised Soil	60 – 90%	0.5 – 1.0 but varies widely with material used
Concrete	70 – 90%	Below 0.5 if well constructed and maintained
Geomembrane	85 – 95%	0 – 0.5 but varies
Unlined - ordinary clay loam		5.0 – 25.0

Since 2003 when the above assessment was prepared, the performance of Geomembranes has improved towards the 100% seepage reduction goal, particularly as impermeable composite liners continue to demonstrate performance improvements in impermeability, resistance to puncture leaks and, in particular, the ability to seal to concrete headwall and canal structures.

2.2.1. Earth Lining

Earth lining is a method of channel construction or remediation where a property of an *in situ* or imported soil is employed as the main method of seepage reduction. With the advancements in soil engineering and earth moving equipment, earth lining is traditionally one of the most common types of channel remediation used in Australia. It has been widely employed for long-term usage and remediation and also has a longer performance history than other lining methods despite limitations in efficiency, particularly over time. Locally available material is usually considered first for channel remediation. Therefore, compacted earth linings are recognised as a relatively inexpensive and effective way of reducing seepage from a channel if required materials, machines and labour are readily available and the scale of the project is large enough to fully utilise heavy earthmoving equipment.

In recent times, the efficiency of earthen lining has fallen behind acceptable standards in reduction of seepage with the higher cost and scarcity of water in Australia. Also, earthen channels have maintenance costs relating to weed control, erosion and animal damage. In many circumstances, the cost of earthen lining may be less cost effective than lining with a flexible membrane, particularly over the long term. The majority of established earthen channels are highly suitable for improvement with flexible membrane liners. Table 3 below is a summary of the common methods used for Earthen liners.

Table 3. Common Methods used for Earthen Liners

Method	Key Selection and Installation Considerations	Seepage Rate[1]	Durability	Maintenance Requirements	Cost[2] ($/m²)
Compacted Earth Liners (in situ)	• Only suitable if in-situ soils exhibit properties that will result in reduced permeability under compaction. • Compaction of material on batters can be difficult. • Technique will be limited to channels of sufficient size to accommodate compaction plant. • Compaction equipment and experienced contractors widely available.	Expected seepage reduction is in the range of 70% to 90%	Estimated to have an effective life of up to 30 years. Greater durability can be achieved by covering with topsoil or crushed rock	Annual maintenance to check on integrity of liner. Mechanical de-silting methods not suitable due to potential damage to lining.	Generally a low cost lining option
Compacted Earth Liners (imported)	• Requires the availability of suitable borrow material close to the remediation site. • Clay lining is a standard and straightforward technique for channel remediation, in which water authorities and earthwork contractors have expertise and equipment. • Imported material can be blended with in-situ material to reduce haulage.	Expected seepage reduction is in the range of 70% to 90%	Estimated to have an effective life of up to 30 years. Greater durability can be achieved by covering with topsoil or crushed rock.	Annual maintenance to check on integrity of liner. Mechanical de-silting methods not suitable due to potential damage to lining.	Generally a low to medium cost lining option, especially if suitable materials are found nearby.

Method	Key Selection and Installation Considerations	Seepage Rate[1]	Durability	Maintenance Requirements	Cost[2] ($/m²)
	• Access for compaction equipment may be limited for small channels • Clay liner can be covered to improve longevity				
Bank Remodelling	• Mitigates lateral seepage only • Is a common technique, with good availability of equipment and resources	N/A	Remodelled/Reconstructed banks are estimated to last for 100 years	Inspections for erosion, piping due to dispersion and shrinkage cracks. Prevention/removal of tree growth.	Low
Loose Earth Liners	• Placement of a loose uncompacted layer of selected clay soils spread over the channel bed and batters up to 300 mm thick. • Ongoing treatment may decrease available waterway area.	N/A – One trial reported seepage rates through 150 mm loose earth blanket to be 4 times the rate through a 600 mm compacted liner using the same material.	Loose earth liners are expected to be effective for only a short time – up to 5 years. Some longer term benefits may result were the subgrade soil has pores into which the fine grained lining particles can penetrate and become entrapped.	Continuing placement of loose material may be required to maintain seepage reduction.	Low
Soil Modification	• Requires application of additives to soil substrate to improve material properties. Additives include lime, cement, resins, swelling clays and chemicals. • Following modification the liner is constructed similar to a compacted earth liner.	Expected seepage reduction varies considerably with materials used. It can be as high as 80% to 90% with concrete. A seepage rate reduction of 70% is expected with Bentonite.	Modified soil mixtures are estimated to have an effective life of 30 years, similar to compacted earth liners depending on the additives used.	Annual maintenance to check on integrity of liner. Mechanical desilting methods not suitable due to potential damage to lining.	Generally medium to high. Soil modification is an additional cost to a compacted clay liner. Bentonite is fairly expensive
Soil Sealants	• Soil sealants are generally applied either directly to the sub-grade or dispersed in flowing or standing water. • Materials include silts and clay, bentonite, resinous polymers, soda ash, and asphalt emulsions.	Seepage reductions vary from 65% to 90% but only for a short time after application.	Generally provide good seepage remediation during the first few seasons of service only.	Would require frequent reapplication to achieve long term success.	Medium Bentonite use is expensive

1. Seepage rates provided as a percentage are dependent on the initial seepage rate of the channel and are only provided to enable a general comparison of effectiveness.
2. The costs have been standardised to a rating of high, medium or low for comparison. Costs are highly dependent on a variety of site specific factors and costs of materials at the time and therefore quoting actual prices experienced at some sites may be misleading. A site specific economic evaluation should be performed to allow proper comparison of costs before selecting a method of seepage remediation

2.2.2. Hard Surface Lining

The construction of concrete channels has declined over time as more cost effective options have come into play. The greatest usage of this material occurs in porous sandy soil conditions or for the carriage of high velocity water. Of all options, concrete is by far the most expensive and is prone to cracking and seepage at the joints as the material ages.

Where a hard-surface channel lining is to be applied in an area where groundwater is likely to rise above the bottom of the lining, drains must be provided underneath or alongside the channel to relieve any hydrostatic pressure which might cause uplift and damage of the lining. Concrete linings are particularly susceptible to rupture by outside hydrostatic or other pressures.

Shotcrete is a cheaper option but requires skilled labour, is subject to cracking over time and is also very expensive. It is mainly used in sections of concrete channels where strata conditions and access issues cause difficulty in forming and pouring construction work.

For the purposes of lining channels, concrete is no longer considered an option generally for the purposes of irrigation unless special engineering conditions justify cost outlays. Of more importance is the growing need to line existing structures where leakage is a serious issue. Maintenance of a deteriorating concrete liner is very expensive. Materials used to reline concrete channels include Butyl Rubber and EPDM, asphaltic compounds and ITM Liner.

2.2.3. Flexible Membrane Materials

As the increasing cost of water, scarcity of supply and regulated efficiency requirements influence management practices, the minimisation of water losses to greater levels becomes more cost effective. Materials and methods will continue to develop with greater efficiencies and flexible membrane materials used as a composite are becoming the prominent technological area of advancement. The aim of composite materials is to amalgamate the strengths of various materials to overcome their inherent weaknesses. Generally the problem is that the most flexible and impermeable geomembranes are readily degraded by UV sunlight exposure and become too hard when additives are used to give UV protection. They are also easily ruptured and punctured and become too inflexible as a thicker material with poor surface adhesion quality necessitating gently sloped batters. By sandwiching the most flexible geomembrane between higher tensile geotextiles such as polypropylene with UV coatings, spray on-cementitious layers or other combinations, puncturing and UV degradation can be greatly reduced.

The range of flexible membrane/geotextile materials continues to grow with new products appearing regularly on the market, and it should be noted that the following list is by no means exhaustive.

PVC - Polyvinyl chloride (PVC) when used as a geomembrane contains additives known as plasticisers that enable it to become a soft flexible structure suitable to be used to line channels. It is the presence of these additives that make the PVC material susceptible to contact with various chemicals and exposure to UV radiation, which then causes the material to become brittle. The susceptibility to UV radiation means that some form of cover is usually required when this material is used.

HDPE - High Density Polyethylene (HDPE) is a common material used as a geomembrane and is similar to the material used in black polyethylene pipes. It has a broad chemical resistance and excellent UV resistance, but has a lack of flexibility and can develop brittle stress cracking at low stresses if not properly formulated. Since HDPE is a very stiff material, it cannot be pre-fabricated into panels. Instead it is delivered to the job site in rolls up to 6 metres wide and all the seaming is done on-site.

VLDPE & LLDPE - Very Low Density Polyethylene (VLDPE) and Linear Low Density Polyethylene (LLDPE) have been introduced in more recent times to address the shortcomings of HDPE in terms of flexibility. These are less crystalline forms of polyethylene which result in increased flexibility and a membrane less conducive to brittle stress cracking. However some degree of chemical and UV exposure resistance is sacrificed as a result and these materials are generally not recommended for exposed applications, although UV stabilised products are becoming available. While more flexible than HDPE, these LDPE materials are still not as flexible as PVC for ease in handling during installation.

FPP - Flexible Polypropylene (FPP) is a relatively new material and is produced in both unreinforced (**PPU**) and reinforced (**PPR**) forms to provide a choice in terms of tensile behaviour. The unreinforced membrane is typically very flexible with excellent elongation capabilities, however the reinforced membrane has low thermal expansion properties. FPP has quite a good resistance to common chemical exposures, excellent mechanical properties and excellent UV performance when the polymer is properly stabilised. This is sometimes referred to as FPA (Flexible Polypropylene Alloy).

CSPE - Chlorosulphonated Polyethylene (CSPE or Hypalon) is a geomembrane that is based on the use of chlorine and sulphur to modify and soften the polyethylene structure in order to make the material more flexible to facilitate seaming. CSPE membranes are always scrim reinforced for strength and dimensional stability. CSPE provides very good chemical resistance, excellent UV exposure performance and are not subject to cracking and embrittlement with long term exposure.

CPER - Reinforced Chlorinated Polyethylene is a product similar to CSPE.

EIA - Ethylene Interpolymer Alloy (EIA) geomembranes are an alloy of PVC resin with a special ethylene interpolymer that results in a flexible plastic free material. EIA geomembranes maintain the advantages of PVC but have a high degree of durability and chemical resistance, especially in relation to hydrocarbons and extreme temperatures. They are typically fabricated with a high strength reinforcing scrim. This product is typically used for speciality applications and is quite expensive.

EPDM and Butyl Rubber - Butyl rubber is a highly weather resistant, highly flexible, high elongation and durable membrane. EPDM (Ethylene Propylene Diene Monomer) was developed from butyl rubber and is installed as liners, caps and covers in containment applications worldwide, but is relatively new to the channel remediation industry. It exhibits excellent elongation characteristics and does not require a soil cover. Also, it exhibits high tensile strength and excellent resistance to punctures, UV radiation, weathering and microbial attack.

Dam Seal - The Dam Seal concept involves the in-situ application of a mineral filled, rubberised bitumen emulsion to a geotextile fabric liner. The DamSeal emulsion impregnates the geotextile and forms a waterproof lining of the channel floors and batters.

Liquid Boot is another product similar to Dam Seal.

Asphalt - Asphalt is a material which is used in several different lining methods. The thinner asphalt layers which are more common in today's climate of high oil prices are generally regarded as a flexible membrane liner. Types of flexible membrane asphalt liners include sprayed in place asphalt and hot-rolled asphalts, and polymer-modified asphalt roll goods (geomembranes).

Geosynthetic Clay Liner - Geo-synthetic clay liners (GCL) consist of clay material, usually bentonite, woven into the middle of two geotextile layers. This lining mechanism uses the beneficial properties of bentonite clay, and the material to which it is bonded holds the clay in place. GCLs require at least 0.3 m cover of soil ballast over the GCL to provide sufficient force to confine the expansion of the Bentonite core layer.

Polyurethane Coated Geotextile – Similar to the Dam Seal concept, but with the application of a UV resistant 1.5 mm thick Polyurethane cover over a geotextile fabric.

On-site fabricated plastic - On-site fabricated plastic is an emerging technology that is not yet commercially available. The technology will enable production of a continuous plastic film, without the need for seams. The manufacturer anticipates that the product will be of appropriate strength, competitively priced compared to 0.75 mm HDPE, and require less subgrade preparation than standard flexible plastic sheeting.

Polyester - A category of polymers which contain the ester functional group in their main chain. Polyester is either used as a woven or matted fibre material. It has high tensile strength and flexibility, low water absorption and minimal shrinkage characteristics particularly well suited to performance as a geotextile.

Acrylic Seal – Essentially an acrylic paint with UV stabilisers and other additives used as a protective coating and moisture barrier normally impregnated into an exposed geotextile layer.

ECC – Engineered Cementitious Composite, also called bendable concrete, is an easily moulded and shaped mortar-based composite reinforced with specially selected short random fibres, usually polymer fibres. This concrete composite is stronger than regular concrete and unlike regular concrete, can bend without breaking when strained with ductile behavioural properties like sheet-metal. Additionally, the material can self-repair hairline cracks. After a light rain or inundation, dry material exposed by the cracks reacts with water and carbon dioxide to form "scars" of calcium carbonate that make the healed concrete as strong as before.

ITM Liner – Composite Geomembrane Geotextile. Consists of a woven polyester membrane saturated with an acrylic paint on top of a geomembrane of flexible polypropylene with a bottom layer of a non-woven polyester geotextile.

PMC Liner – Polymer Modified Cementitious Composite or Flexible Cement Imbedded Membrane. A polymer modified cementitious composite (ECC) imbedded into a woven geotextile consisting of fibreglass reinforced polypropylene. Impervious, extremely strong and puncture resistant but flexible. Considered UV stable.

Table 4 below represents a practical comparison between the product solutions considered to be commonly available and in use over a period of time. HDPE is the most commonly used product in channel linings.

Table 4. A Quick Comparison of Flexible Membrane Materials

Material	Advantages	Disadvantages	Application	Properties
PVC	• Resists acids and bases • Flexible • Most workable of all geomembranes • Offers superior puncture resistance	• Susceptible to damage from burrowing freshwater life • Susceptible to stiffness with aging • Becomes brittle at 0°C, making it difficult to handle in cold seasons • Not UV resistant, susceptible to damage from the sun	• Where off site fabrication is possible. • Surface preparation is less than ideal • To increase the service life and reduce installation problems a thicker liner of 0.51mm (0.25mm originally) • Doubling the thickness increases construction cost by 15%	• Available gauges 0.2–0.85mm • Available widths 1.2–19m • Joining by heat, solvent or adhesive
HDPE	• Cost effective over large areas	• Inflexible. • Requires specialist welding equipment • Requires well prepared surfaces • Low resistance to vertical stress	• Cost effective over large areas • Industry standards for the installation of HDPE liners have been released by the International Association of Geosynthetic Installers (IAGI) • Most common material used	• Wide range of chemical resistance • Joining by welding • Available gauges 0.4mm to >2mm • Available widths <6m
FPP	• Flexible	• Some problems with fuel immersion • Requires specialist welding equipment	• Where long life in harsh conditions is required • Especially suited to situations where soil movement is expected	• Good UV damage resistance • Wide range of chemical resistance
VLDPE & LLDPE	• Puncture resistance has improved	• Very susceptible to sun damage	• Short term application < 2 years if not covered	• Available gauges 0.15 – 0.5mm

Material	Advantages	Disadvantages	Application	Properties
	• Resistant to biological deterioration and chemical attack • Resistant to root penetration • Becomes brittle at -15°C rather than zero, allowing installation in cold season		• Long term application if covered and installed correctly >50years, general expectation of 20 to 30 years • Has been applied in Australia as woven polyethylene at 0.2 mm thickness generally	• Available widths 5.0 –12 m • Joining by heat, tape or adhesive
GCL	• High puncture resistance • High friction capabilities with adjacent soils • Reduce or replaces clay liner component of composite liners	• Generally more expensive • Requires protection from exposure damage	• Bentonite is placed in between two geomembranes that are then stitched together to form a geotextile • Applied the same as other geomembranes	• Installations is complicated by the laying of multiple layers including 0.3m cover of ballast soil to confine expansion of Bentonite layer • Geotextile layers are joined by overlap
Butyl & EPDM	• Suitable for relining old concrete channels • Good weathering properties • Flexibility, toughness and good ageing properties • Resistance to most chemicals and abrasion • Can withstand extreme temperature changes • Resistant to sun damage	• Requires protection from mechanical damage and vandalism if exposed • Relatively high cost • Can suffer from ozone depletion and poor shrinkage • Service life dependent on careful & consistent fabrication which is difficult for large projects	• Special attention required to ensure adequate bonding and anchoring • Has been in service for 10 years both covered & uncovered with essentially no change • Can be reinforced with nylon • Can be used to meet specific service requirements that are not possible with less costly membrane	• Available gauges 0.8–3. 0mm • Available widths 8.5 – 14 m • Joining by adhesive

2.2.4. In-Depth Comparison of Selected Liners

The irrigation industry now requires cost effective means to find greater efficiencies in water usage and there is obvious potential for major savings to be made by eliminating seepage and leaks from delivery canals. For this to occur, new materials will need to reach aspirational goals of being:

- Totally impervious in practice, not being prone to hidden installation damage;
- Efficient in sealing to off-takes, sumps, headwall and control structures;
- Strong enough to resist punctures and mechanical damage from animal habitation, animal and vehicular traffic and bushfire;
- Inhospitable to weed and pest infestation;
- More durable if not permanent;
- Easier and cheaper to install requiring minimal subgrade preparation;
- Easier and cheaper to maintain, clean and remediate;
- Be competitive in relation to initial investment cost outlays; and
- Be more affordable from the perspective of total investment cost outlays required for the life of the asset, demonstrating a clear Cost Benefit Advantage.

Earthen and concrete liners by and large do not meet standards required from the perspective of permeability and/or cost. Subsequently, the industry standard has been heavily dominated by the use of HDPE liners for many years. However, new advances should generate a shift towards the use of Composite materials. The products chosen for this comparison are based on what is currently being used as well as new materials that are readily available in Australia backed by technical support, trials and analysis that demonstrate an ability or claim to meet the aspirational criteria identified above. Covered membranes are generally not ideal for channel linings since they introduce other problems such as weed infestation, crustacean damage and cover erosion, increasing maintenance requirements and are therefore not considered. Covered membranes are generally more suited to deep water storages.

In the following comparison two relatively new composite materials have been selected that demonstrate aspects that can be considered an advantage over HDPE (Table 5). ITM liner, (Table 6) is a composite liner designed to compete as a direct alternative to HDPE. PMC liner, (Table 7) is a relatively new Cementitious Composite Product. Cementitious products have the potential to supersede HDPE and much research and development is currently being undertaken with this technology in Australia and on an international scale.

Table 5. Flexible Membrane

1	Material:	**HDPE High Density Polyethylene**
2	Type	FLEXIBLE MEMBRANE
3	Components:	A common material used as a geomembrane and is similar to the material used in black polyethylene pipes. It has a broad chemical resistance and excellent UV resistance, but has a lack of flexibility and can develop brittle stress cracking at low stresses if not properly formulated. Since HDPE is a very stiff material, it cannot be pre-fabricated into panels. Instead it is delivered to the job-site in rolls, usually up to six metres wide sometimes more and all the seaming is done on-site. The HDPE liner is rolled out and laid across the channel with overlapping pieces to enable weld joining. The thicker product is more suited to exposed environmental conditions such as channels being more resistant to UV and animal damage
4	Dependant infrastructure requirements:	Subgrade preparation is critical to prevent punctures by hard surface objects such as rocks & clods. Special equipment required to weld seams. Appropriate fencing required to prevent damage from animal traffic.
5	Typical application:	Channels and dams
6	History of use:	At least 40 years. Well established as a channel liner
7	Water Use Efficiency Statistics:	Down to 2% leakage rate best case scenario. Joins are the weakest point for leakage. Sealing to headwalls and control structures is a major point of weakness. Seals poorly to control structures and headwalls allowing subgrade yabbie infestation and subsequent employment of compromising ameliorating techniques that leak
8	Limiting factors:	Short life 10 to 20 years without protective surface materials & subjected to UV exposure, has to be replaced once weakest part such as the most exposed bank to sunlight becomes brittle and fails. HDPE is imported from a number of countries and quality is variable and dependant on the type of manufacturing technique and quality of additives used. Expensive to repair, requires specialised equipment and skilled labour. Can only be installed in dry conditions. Fencing required, barrier coupled with electric in kangaroo and goat areas. Susceptible to animal damage particularly to kangaroo claw penetration. Channel liner is slippery trapping animals causing blockages and is an

		OH&S hazard requiring ladders to be installed along length. Batter slope limited by adhesion properties. Leakages can cause damage to subgrade requiring remediation. Susceptibility to bushfire damage
9	Recent technological advancements:	The use of new UV stabilisers can prolong life expectancy but is usually more expensive
10	Current Research:	UV stabilisers and incorporation as a composite material. Other research has been undertaken at Trangie Research Station
11	Case study examples of performance:	Wimmera Mallee Water Donald Main Channel, Trangie Research Station
12	Recommended application:	Lining channel where 10-20yr life spans versus cost is applicable. As a covered liner where long life spans are desirable and higher establishment costs are acceptable
13	Establishment Procedures:	Channel remediation to specifications, i.e. smooth even surface devoid of hard objects, dry conditions no wind. Roll out and lay in channel with overlaps, clean areas to be joined and seal with weld, test, anchor sides over batters with backfill method with 400mm cover, compact and backfill.
14	Operational procedures:	
15	Brands and Manufactures:	GSE, Solmax & others. Manufactured in many countries. 1.5 to 2.0mm thickness for UV exposed channels. Lower thickness to 0.4mm can be used where UV is excluded by coverings including water and geophysical damage or vertical penetration is excluded.
16	Availability in Aust.:	Widely available from specialised wholesalers
17	Market Distribution:	Manufactured overseas and imported into Australia from various sources
18	Life Span:	10 to 20years uncovered, indefinite when adequately covered and protected from vertical damage
19	Indicative price:	Current \$16.00 / m^2 installed
20	Case study establishment price:	Added costs channel remediation costs up to \$16.00/m^2 plus fencing costs @\$14.00 per channel metre (more cost effective on larger channels)
21	Case study Operating Costs:	Operating costs are very minimal where effective animal control infrastructure is established
22	Repairs and maintenance requirements:	Puncture repairs, fencing repairs, removal of blockages caused by animals, monitoring and remediation of soil anchors
23	Case study maintenance and Repair costs:	Maintenance & repairs are very minimal where effective animal control infrastructure is established
24	Part costs and availability:	Repairers sometimes difficult to find for small jobs
25	Case study Energy use:	Petroleum Oil based product, passive energy requirements when established. Electric fencing where required well serviced by solar solutions. Water transfers mainly rely on gravitation rather than pumping.
26	Ability to perform to specifications:	Well established and documented
27	Identified problems or faults:	Leakage at joins and channel structures

28	User Comments:	Cost effective over large areas
29	Capacity for expansion:	May be limited by cost of welding long joins where width is required
30	Associated carbon emissions:	Entirely Petroleum based product that has environmental benefits by reducing energy usage associated increased pumping transfers associated with wasted water resources

Table 6. Flexible Membrane/ Geotextile Composite

1	Material:	**ITM Liner**
2	Types:	FLEXIBLE MEMBRANE COMPOSITE ACRYLIC MEMBRANE
3	Components:	Top layer consists of a woven polyester membrane saturated with an acrylic paint Middle Layer is a geomembrane of flexible Polypropylene Bottom Layer is a non woven polyester geotextile
4	Dependant infrastructure requirements:	For earthen channels this product readily meets the strata environmental conditions. For solid channel structures, apply adhesion flashing to concrete on edges and drainage cells underneath liner
5	Typical application:	Channels and dams
6	History of use:	Melbourne & Barwon Water, in use up to 4 years with good results
7	Water Use Efficiency Statistics:	Hypothetically nil leakage given no leaks are present. Seals extremely well to control structures and headwalls preventing subgrade yabbie infestation and subsequent employment of compromising ameliorating techniques that leak. Good adhesion properties allow for steeper channel banks and deeper channels than HDPE therefore lower evaporation.
8	Limiting factors:	Comparable product investment outlay to HDPE offset by savings in installation costs. High resistance to damage from animal traffic removes the cost associated with fencing channels. Not as strong as PMC, similar to HDPE but animal resistant particularly to kangaroos. Requires resurfacing acrylic layer every12-18yrs to maintain life expectations
9	Recent technological advancements:	This product in itself is a recent technological advancement. Improvements to spray on acrylic layer
10	Current Research:	Trangie, Melbourne Water, Trials.
11	Case study examples of performance:	Melbourne Water, resolved massive leakage issue in concrete channel. Earthen irrigation channels, Condamine Irrigation Scheme, Toowoomba, QLD Bunded Containment Area, Transpacific Bituminous Products, Revesby NSW Channel lining over porous terrain, Kogarah Golf Club

12	Recommended application:	Earthen and concrete Channels and dams
13	Establishment Procedures:	Minimal. Shape and form channel. Can be damp, no compaction of subgrade required. Prepare anchor trench and bury. To join to concrete structures, clean and join with flashing.
14	Operational procedures:	Lay in trench, stretch & weld, spray on acrylic layer
15	Brands and Manufactures:	Infrastructure Technologies Ltd
16	Availability in Aust.:	Infrastructure Technologies Ltd
17	Market Distribution:	Infrastructure Technologies Ltd
18	Life Span:	With maintenance, up to 50yrs +
19	Indicative price:	$16.00 m^2 installed
20	Case study establishment price:	As a concrete liner worst case scenario, $35.00 m^2
21	Case study Operating Costs:	Resurface acrylic layer $16.00 m^2 for remediation of exposed area.
22	Repairs and maintenance requirements:	Cleaning and spraying of acrylic liner, repair mechanical damage.
23	Case study maintenance and Repair costs:	na
24	Part costs and availability:	Easy to use repair kits can be performed by unskilled labour in situ without expensive machinery. Minimal
25	Case study Energy use:	Excellent flow rates similar to pipe. Water transfers mainly rely on gravitation rather than pumping.
26	Ability to perform to specifications:	Meets and exceeds
27	Identified problems or faults:	Periodic remediation required to maintain asset
28	User Comments:	Easy to work with, has great conformability and durability
29	Capacity for expansion:	Unlimited due to easy integration and joining techniques
30	Associated carbon emissions:	Not highly dependant on petroleum products during manufacture

Table 7. Flexible Cementitious Membrane/ Geotextile Composite

1	Material:	**PMC LINER. Polymer Modified Cementitious Composite**
2	Types:	FLEXIBLE CEMENT IMBEDDED MEMBRANE
3	Components:	Polymer modified cementitious composite imbedded into a woven geotextile consisting of fibreglass reinforced polypropylene. Will not crack
4	Dependant infrastructure requirements:	This product readily meets the strata environmental conditions
5	Typical application:	Channels & Dams, erosion & flood mitigation & control

6	History of use:	New product recent use, Maroondah Aquaduct, Healesville, Melbourne Water Authority. Trials to be conducted at Trangie Ag Research Station
7	Water Use Efficiency Statistics:	Hypothetically nil leakage given no leaks are present. Seals extremely well to control structures and headwalls preventing subgrade yabbie infestation and subsequent employment of compromising ameliorating techniques that leak. Good adhesion properties allow for steeper channel banks and deeper channels than HDPE therefore lower evaporation.
8	Limiting factors:	Higher initial investment outlay offset by savings in installation costs compared to HDPE. High resistance to damage from animal and vehicular traffic removes the cost associated with fencing channels
9	Recent technological advancements:	This product in itself is a recent technological advancement. The recent development of incorporating stabilising polymers into the cementitious layer is designed to minimise chalking i.e. leaching of binding material from cementitious layer
10	Current Research:	Trangie Nevertire Irrigation Scheme at Trangie Research Station in initial phase. Development and Research is ongoing relating to EEC products at University of Michigan, US of A and Japan in particular as well as Asia and Europe in general.
11	Case study examples of performance:	Melbourne Water
12	Recommended application:	All channel linings earthen and rigid (remediation)
13	Establishment Procedures:	Minimal. Shape and form channel. Can be damp, no compaction of subgrade required. Prepare anchor trench and bury. To join to concrete structures, clean and join with flashing, lay geofabric and spray on cementitious layer
14	Operational procedures:	Lay in trench, stretch & weld. Spray on cementitious layer.
15	Brands and Manufactures:	Infrastructure Technologies Ltd
16	Availability in Aust.:	Manufactured in Sydney NSW
17	Market Distribution:	Infrastructure Technologies Ltd. Other Cementitious Liners have been manufactured and tested in the U.S and Japan
18	Life Span:	30years+ anticipated. Indefinite below waterline or when maintained above
19	Indicative price:	$\$18.75m^2$ + \$2.50 installation cost
20	Case study establishment price:	$\$18.50m^2$ + \$4.50 initial installation cost $\$18.75m^2$ + \$2.50 installation cost Maroondah Aquaduct
21	Case study Operating Costs:	N/A. Expected to be minimal
22	Repairs and maintenance requirements:	Remediation for exposed surfaces particularly in the event of mechanical damage from eg fallen trees or branches. High resistance to animal damage and blockages, particularly kangaroos and other livestock reduces maintenance costs.
23	Case study maintenance and Repair costs:	Not yet available but expected to be minimal
24	Part costs and availability:	Easy to use repair kits can be performed by unskilled labour in

		situ without expensive machinery. Minimal
25	Case study Energy use:	Reduced channel friction losses result in fast water flows. Water transfers mainly rely on gravitation rather than pumping.
26	Ability to perform to specifications:	Shown so far to exceed expectations and meet set standards
27	Identified problems or faults:	Setting and curing of cementitious layer in cold damp environment requires more time
28	User Comments:	Whole of life channel solution. Solid asset
29	Capacity for expansion:	Unlimited due to easy integration and joining techniques
30	Associated carbon emissions:	Can use recycled material eg glass, aluminium silica to reduce carbon emissions at manufacture stage

2.2.5. Channel Liners References and Acknowledgements

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Irrigation Australia Website Links

Channel Seepage Remediation Techniques
http://www.irrigation.org.au/seepage/4_2_techniques.html

How much will it cost to do nothing or fix it, is it worth it?
http://irrigation.org.au/seepage/5_remediationCosts.html

How to identify and quantify channel seepage
http://irrigation.org.au/seepage/3_identMeasure.html

How to reduce channel seepage http://irrigation.org.au/seepage/4_remediation.html

What is the preferred method for each site? In what order should works be undertaken?
http://irrigation.org.au/seepage/6_prioritisation.html

What is the regional risk or potential for seepage?
http://irrigation.org.au/seepage/2_seepageRisk.html

General Website Links

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2.3. Pipes

2.3.1. Gravity Supply

Gravity supply is defined as a system where in flow and / or pressure are caused by the force of gravity. Two types of gravity systems exist:

1. Pressurised gravity system, where the pipeline operates full; and
2. Non-pressurised gravity system, where the pipeline operates partially full.

(Source: Water Supply Code of Australia Version 2.3 Water Services Association of Australia).

Non-pressurised pipes have been utilised successfully in underground drainage systems for many years. The development of new processes and cheaper production methods allows non-pressurised pipe systems to become viable alternatives for pressure pipe and channel systems where gravitational delivery and topography are suitable. Non-pressurised pipe delivery systems are suited to low velocity loads and gravitational transfers particularly in situations where channels are normally used.

Comparisons to open channel and pressure pipe systems:

- Virtually nil leak, seepage and evaporative losses, highly dependant upon quality of installation work;
- Permanent solution in so far as anticipated lifetimes exceed 50 years or more with reduced maintenance costs (not including control structures). Installation costs are generally higher than Flexible Membrane lined channels. Demonstrably more affordable from the perspective of total investment cost outlays required amortised over the life of the asset, with a clear Cost Benefit Advantage;
- Efficient gravitational transfers mean pumping costs/energy consumption and supporting infrastructure is very minimal if any;
- Can integrate readily into holistic systems where combinations of pressure pipe delivery and open channel sections are also appropriate or required to maximise efficiency;
- Passive to the above ground environment and underground protection ameliorates water contamination, mechanical and solar damage. Where above ground delivery systems are an undesirable obstruction to agricultural and transport activities, underground pipe is an advantage; and
- Where pressure pipe systems have been installed to reduce seepage, evaporation and leakage and gravitational supply is a viable alternative from an engineering perspective, the installation, running and maintenance costs of non pressurised pipe systems is far cheaper.

2.3.2. Non-pressurised Pipe Product Comparisons

Non-pressurised pipe delivery systems of alternative pipes can be considered a emerging technology insofar as they are established drainage products being adapted to irrigation purposes. A number of suitable products are manufactured in Australia and suppliers are researching, investing and promoting the irrigation potential to varying degrees. These products are compared in the following tables.

Table 8. Plastream

1	Equipment:	**Plastream**
2	Types:	UNDERGROUND GRAVITATIONAL DELIVERY PIPELINE- PIPES & FITTINGS DESIGNED TO COMBINE THE PROPERTIES OF SMOOTH BORE PIPE WITH THE STRUCTURAL STRENGTH OF STEEL
3	Components:	Pipes and fittings are manufactured with a smooth polyethylene material on the inside reinforced with steel reinforced spiral ribbing on the outside. The product is designed to combine the properties of smooth bore pipe with the structural strength of steel. Effective strength is a function of the flexibility of the pipe and the resistance to the deflection of load by the surrounding embedment. Diameter sizes are 225-2250mm. Fittings such as bends, reducers, junctions and tees can be installed on-site to provide sumps off-takes and vents. Pipe can easily be joined to poured concrete headwalls, detention systems & control structures
4	Dependant infrastructure requirements:	Gentle fall, firm foundation, trenching, embedment and backfill. Bedding provides firm support for the pipe to maintain its correct line and level. Suitable bedding materials include: • Aggregate • Blue metal • Crushed rock • Coarse sand • Stabilised cement sand
5	Typical application:	Long term solution to refurbishment of inefficient channel systems where seepage losses are prevalent and challenge economic viability. Particularly suited to large distance transfers where evaporation losses are also an issue. Passive to the above ground environment where underground protection ameliorates contamination, mechanical and solar damage. Where above ground delivery systems are an undesirable obstruction to agricultural and transport activities, underground pipe is an advantage
6	History of use:	Flexible pipes have been in use for drainage purposes for decades, often under heavy load conditions. Product data indicate that due to steel strengthening Plastream can be expected to have higher long term stiffness compared to polyethylene alone
7	Water Use Efficiency Statistics:	With correct installation this technique can prevent losses due to both seepage and evaporation with the added benefit of savings from negligible or nil pumping costs
8	Limiting factors:	Initial cost outlays. Both flexible and rigid pipes require proper placement and backfill technique. Unsuitable backfill material include: Fine soil, heavy or sticky clay, 'brickies sand. Grades exceeding 15% require extra support with anchor blocks cast around the pipe. Where changes in flow direction occur at high velocity, thrust blocks may be needed. Pressure rating of joins is an unknown quantity requiring specification to establish parameters for purposes of supplying water to above ground for gravitational delivery.
9	Recent technological advancements:	Improvements have been made to the materials used in manufacture and the range of fittings extended to reflect demand

1	Equipment:	**Plastream**
10	Current Research:	As above
11	Case study examples of performance:	Not yet available. Case studies where used in the area of drainage would by and large mirror uses in irrigation.
12	Recommended application:	Long term remediation solution to existing channel systems where gravitational delivery methods are currently used and wastage from seepage and/or evaporation compromises efficiency
13	Establishment Procedures:	Laying in the trench on the compacted embedment should start at the downhill end of the tank with the spigot end facing downhill. Pipe diameters greater than 900 mm are welded, for smaller pipe rubber ring gaskets are used. Trenches are backfilled and compacted around haunching (underside of pipe) then backfilled and compacted to required depth
14	Operational procedures:	Water would be supplied to the head of the pipe by means of a control structure and delivered by gravitation. Water is then extracted along the length from flooded sump, off-takes or supplied storages.
15	Brands and Manufactures:	Caliber Plastream, manufactured by Rocla Australia
16	Availability in Aust.:	Can be supplied direct from Sydney factory or manufactured from a site depot to reduce transport costs
17	Market Distribution:	Rocla product centres are established throughout Australia
18	Life Span:	50 years+ usually guaranteed, may well last 100 years or more based on the known properties and use of polyethylene and steel
19	Indicative price: GST Exclusive Large Project wholesale supply including delivery	• 450mm diameter $72.64/m del. 6m lengths • 900mm diameter $267.98/m del. 6m lengths • 2250mm diameter $922.40/m del. 6m lengths
20	Case study establishment price:	Not yet readily available, particularly as establishment price is very site specific. Quotes are readily obtainable
21	Case study Operating Costs:	None yet available but expected to be negligible particularly as transfer is by gravitation rather than mechanical pumping methods requiring energy inputs. Lift pumping from sumps and storages can be factored in based on known case studies applicable to system capacities required
22	Repairs and maintenance requirements:	System should require nil repair costs unless subject to avoidable mechanical damage. Depending on design, methods and conditions some systems may require de-silting in areas such as off-take sumps, otherwise no other maintenance costs are anticipated. Control structures if imbedded into the system may in themselves require regular maintenance.
23	Case study maintenance and Repair costs:	Well established drainage systems indicate maintenance and repair costs are virtually nil unless avoidable mechanical damage has occurred
24	Part costs and availability:	Small quantity parts for repair are readily available. Costs are higher based on volume price structures and transport costs.
25	Case study Energy use:	Since established systems rely on gravitation energy studies have not been relevant
26	Ability to perform to specifications:	Well tested and confirmed

1	Equipment:	Plastream
27	Identified problems or faults:	Work needs to be undertaken to establish pressure ratings of pipe and joins particularly as applied to head requirements allowing gravitational feed above ground. Hidden installation damage to the pipe exposing steel ribbing can lead to corrosion and early failure. Compaction process of backfill at the base of the pipe can cause pipe to move upwards due to it being lightweight.
28	User Comments:	Pipe is lightweight making it quick and easy to handle and install
29	Capacity for expansion:	Probably predetermined by engineered-in capacity, however extending and joining is otherwise relatively easy in dry pipe situations and where topography, gradients and substrata allow

Table 9. Ribbed PE pipe with smooth bore

1	Equipment:	Ribbed PE non pressurised pipe i.e., Stormpro
2	Types:	LIGHTWEIGHT UNDERGROUND GRAVITATIONAL DELIVERY PIPELINE- TWIN WALL POLYETHYLENE PIPES & INBUILT FITTINGS, SMOOTH ON THE INSIDE WITH STRENGTHENING RINGS ON THE OUTSIDE
3	Components:	Pipes and fittings are manufactured with a smooth polyethylene material on the inside reinforced with polyethylene rings on the outside. Effective strength is a function of the flexibility of the pipe and the resistance to the deflection of load by the surrounding embedment. Diameter sizes are 225-900mm. Structures such as bends, reducers, junctions and tees are incorporated into pipe at manufacture to provide sumps off-takes and vents. Pipe can easily be joined to poured concrete headwalls, detention systems & control structures
4	Dependant infrastructure requirements:	Gentle fall, firm foundation, trenching, embedment and backfill. Bedding provides firm support for the pipe to maintain its correct line and level. Suitable bedding materials to the same standard as Plastream
5	Typical application:	Long term solution to refurbishment of inefficient channel systems where seepage losses are prevalent and challenge economic viability. Particularly suited to large distance transfers where evaporation losses are also an issue. Passive to the above ground environment where underground protection ameliorates contamination, mechanical and solar damage. Where above ground delivery systems are an undesirable obstruction to agricultural and transport activities, underground pipe is an advantage. Can be used above ground with support structures
6	History of use:	20 years in Australia, mainly for drainage. Work has been undertaken for use in irrigation on a commercial scale
7	Water Use Efficiency Statistics:	With correct installation this technique can prevent losses due to both seepage and evaporation with the added benefit of savings from negligible or nil pumping costs
8	Limiting factors:	Initial cost outlays. Both flexible and rigid pipes require proper placement and backfill technique. Suitable embedment and backfill material must be used. Pipe diameters are limited to 900mm although the manufacture of larger sizes is feasible

1	Equipment:	**Ribbed PE non pressurised pipe i.e., Stormpro**
9	Recent technological advancements:	Testing in the field indicates that wall thickness for irrigation circumstances can be less than that required for sewerage grade systems
10	Current Research:	Application of Stormpro and Sewerpro products for irrigation purposes are being trialled in the field. Research is continuing to investigate light and reduced structural strength versions of these products to reduce costs.
11	Case study examples of performance:	Has been applied to a commercial enterprise with success
12	Recommended application: (Same as Plastream)	Long term remediation solution to existing channel systems where gravitational delivery methods are currently used and wastage from seepage and/or evaporation compromises efficiency
13	Establishment Procedures: (Similar to Plastream)	Laying in the trench on the compacted embedment. Rubber ring gaskets are used for joining. Trenches are backfilled and compacted around haunching (underside of pipe) then backfilled and compacted to required depth
14	Operational procedures:	Water would be supplied to the head of the pipe by means of a control structure and delivered by gravitation. Water is then extracted along the length from flooded sump, off-takes or supplied storages. Sufficient pressure head can be applied to the pipeline to raise water above surface level to accommodate gravitational off-take up to 85 kpa without causing leaks at the joints
15	Brands and Manufactures:	Vinidex “Stormpro & Sewerpro” And Iplex “BlackMAX & SewerMAX”
16	Availability in Aust.:	Statewide with multiple manufacturing plants
17	Market Distribution:	Australia Wide
18	Life Span:	A+ rating expected to last well beyond 50 years
19	Indicative price: GST Exclusive Large Project wholesale supply including delivery	• 450mm diameter $116.33/m delivered. 6m lengths • 900mm diameter $411.66/m delivered. 6m lengths
20	Case study establishment price:	Not yet readily available, particularly as establishment price is very site specific. Quotes are readily obtainable
21	Case study Operating Costs:	None yet available but expected to be negligible particularly as transfer is by gravitation rather than mechanical pumping methods requiring energy inputs. Lift pumping from sumps and storages can be factored in based on known case studies applicable to system capacities required, however this piping can deliver water to the surface for gravitational supply
22	Repairs and maintenance requirements:	System should require nil repair costs unless subject to avoidable mechanical damage. Depending on design, methods and conditions some systems may require de-silting in areas such as off-take sumps, otherwise no other maintenance costs are anticipated. Control structures if imbedded into the system may in themselves require regular maintenance.
23	Case study maintenance and Repair costs:	Well established drainage systems indicate maintenance and repair costs are virtually nil unless avoidable mechanical damage has occurred

1	Equipment:	Ribbed PE non pressurised pipe i.e., Stormpro
24	Part costs and availability:	Small quantity parts for repair are readily available. Costs are higher based on volume price structures and transport costs.
25	Case study Energy use:	Since established systems rely on gravitation energy studies have not been relevant
26	Ability to perform to specifications:	Well tested and confirmed
27	Identified problems or faults:	Costs could be lowered by incorporating lower wall thicknesses and specifications.
28	User Comments:	Pipe is lightweight making it quick and easy to handle and install
29	Capacity for expansion:	Probably predetermined by engineered-in capacity, however extending and joining is otherwise relatively easy in dry pipe situations and where topography, gradients and substrata allow

Table 10. The Green Pipe

1	Equipment:	The Green Pipe
2	Types:	RECYCLED HDPE FLEXIBLE PIPE
3	Components:	It is formed using a newly developed manufacturing technique and made out of 100% recycled / kerbside collection of HDPE containers (mainly milk bottles). Many fittings including headwalls and Ts are available Being flexible, The Green Pipe™ relies upon the surrounding embedment material to absorb and transfer vertical loads to the surrounding support zone.
4	Dependant infrastructure requirements:	Firm foundation, trenching, embedment and backfill. Bedding provides firm support for the pipe to maintain its correct line and level. Suitable bedding materials to the same standard as Plastream
5	Typical application:	Long term solution to refurbishment of inefficient channel systems where seepage losses are prevalent and challenge economic viability. Particularly suited to large distance transfers where evaporation losses are also an issue. Passive to the above ground environment where underground protection ameliorates contamination, mechanical and solar damage. Where above ground delivery systems are an undesirable obstruction to agricultural and transport activities, underground pipe is an advantage. Can be used above ground with support structures
6	History of use:	Established widely as a stormwater product during the late 1990s particularly in Civil applications. The Green Pipe has been CSIRO tested and rated for stormwater and has proven ideal for all low pressure water transfer, stormwater drainage and flood irrigation applications.
7	Water Use Efficiency Statistics	With correct installation this technique can prevent losses due to both seepage and evaporation with the added benefit of savings from negligible or nil pumping costs
8	Limiting factors:	Both flexible and rigid pipes require proper placement and backfill technique. Suitable embedment and backfill material must be used. Pipe diameters are incremental in size from

1	Equipment:	**The Green Pipe**
		250mm to an upper limit of 600mm
9	Recent technological advancements:	• Rubber ring joined Spigot and Socket joining systems • Tidal flaps for one way flow control • Heavy Duty Recycled Plastic Headwalls • Slidegates and • A full range of custom designed fittings.
10	Current Research:	Areas flagged for future improvement include joins, pipe smoothness and fittings
11	Case study examples of performance:	Has been tested and approved for use by Government Authorities under roads etc. Also used in flood and on farm irrigation, marine and extensively in the forestry industry
12	Recommended application:	Long term remediation solution to existing channel systems where gravitational delivery methods are currently used and wastage from seepage and/or evaporation compromises efficiency.
13	Establishment Procedures:	Laying in the trench on the compacted embedment. Joints are established by joining bell mouths by welding for higher pressure heads or by system with rubber O rings for pressures heads up to 1 metre. Trenches are backfilled and compacted around haunching (underside of pipe) then backfilled and compacted to required depth.
14	Operational procedures:	Water would be supplied to the head of the pipe by means of a control structure and delivered by gravitation. Water is then extracted along the length from flooded sump, off-takes or supplied storages. Sufficient pressure head can be applied to the pipeline to raise water above surface level to accommodate gravitational off-take up to10kpa without causing leaks at the joints with O ring rubber seals or up to 10mtres with welding. Load ratings are similar to PVC pipe of the same diameter and wall thickness
15	Brands and Manufactures:	The Green Pipe manufactured by Recycled Plastic Technology Pty Ltd in Moamma NSW
16	Availability in Aust.:	Australia wide
17	Market Distribution:	300 Resellers throughout Australia
18	Life Span:	Can be expected to be similar to Plastream and Storm pro based on known properties of HDPE
19	Indicative price: GST Exclusive Large Project wholesale supply including delivery	• 450mm diameter $65.55/m del. 6m lengths • 600mm diameter $118/m del. 6m lengths
20	Case study establishment price:	Not yet readily available, particularly as establishment price is very site specific. Quotes are readily obtainable. Pipe manufactured from recycled material is considerably cheaper than products made from virgin material.
21	Case study Operating Costs:	None yet available but expected to be negligible particularly as transfer is by gravitation rather than mechanical pumping methods requiring energy inputs. Lift pumping from sumps and storages can be factored in based on known case studies applicable to system capacities required, however this piping can deliver water to the surface for gravitational supply
22	Repairs and maintenance requirements:	System should require nil repair costs unless subject to avoidable mechanical damage. Depending on design, methods

1	Equipment:	The Green Pipe
		and conditions some systems may require de-silting in areas such as off-take sumps, otherwise no other maintenance
23	Case study maintenance and Repair costs:	Well established drainage systems indicate maintenance and repair costs are virtually nil unless avoidable mechanical damage has occurred
24	Part costs and availability:	Small quantity parts for repair are readily available through comprehensive reseller network. Costs are higher based on volume price structures and transport costs.
25	Case study Energy use:	Where established systems rely on gravitation energy studies are not relevant
26	Ability to perform to specifications:	Well tested and confirmed
27	Identified problems or faults:	Pipe quality has been improved particularly internal smoothness to deliver better flows
28	User Comments:	Pipe is lightweight making it quick and easy to handle and install
29	Capacity for expansion:	Probably predetermined by engineered-in capacity, however extending and joining is otherwise relatively easy in dry pipe situations and where topography, gradients and substrata allow

2.3.3. Non-pressurised Pipe References and Acknowledgements

Caliber Plastream. Pipes that work, Technical Guide. Rocla NSW

s 22(1)(a)(ii) Vinidex. Smithfield. Tel. s 22(1)(a)(ii)

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s 22(1)(a)(ii) . The Green Pipe Pty Ltd. Tel. s 22(1)(a)(ii)

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s 22(1)(a)(ii) e. Rocla. Brisbane. Tel. s 22(1)(a)(ii)

StormPRO & SewerPRO. Twin-Walled Corrugated Polypropylene, Pipe and Fittings for Non-Pressure Applications. Vinidex Pty Ltd NSW

StormPRO & SewerPRO. Installation Guide. Vinidex Pty Ltd NSW

StormPRO. For Culverts, channel replacement and any stormwater applications. Vinidex Pty Ltd NSW.

The Green Pipe, Installation Guide for the Green Pipe

The Green Pipe. Minimum Requirement for Private Property, Installation for the Green Pipe

The Green Pipe. Swinburne Results

Website Links

Caliber Plastream. Rocla. http://www.caliberpipelines.com.aul

StormPRO. Vinidex. http://www.vinidex.com.au

The Green Pipe. The Green Pipe Pty Ltd. http://rptgreenpipe.com

2.2.3 Pressurised Supply

Pressurised pipes are generally required when a pipe line is pressurised via pumping or due to elevational head. Pressurised pipes should meet the Australia Water Services Code of materials for pipeline construction. While installation should be based upon installation requirements established in the Australian Water Services Code of pipeline installation. Material selection is generally based upon route location, site characteristics including geotechnical evaluation, hydraulic limitation and requirements and capital costs.

Pipeline materials considered are those commonly and economically available from national suppliers including Iplex, Vinidex, Tyco, and others, including:

- Poly Vinyl Chloride (PVC) Series 1 and Series 2;
- Polyethylene (PE);
- Ductile Iron (DI);
- Glass Reinforced Plastic (GRP); and,
- Mild Steel (MS).

A summary of the properties advantages and disadvantages of each material is summarised below. Within irrigation schemes and on-farm systems PE and PVC are the dominate pipe selections, generally due to costs.

Table 11. Comparison of Pipeline Materials

	Advantages	Disadvantages
Polyethylene (PE)	• Can be laid above and below ground easily • No thrust blocks required to restrain welded joints • Flexible, allows a 33 x OD curvature radius • Economically competitive for smaller diameter (< 375 mm) pipelines • Low roughness coefficient • Available in large and small diameters (16 – 1000 mm) • Easy to alter after installation • Light compared to DI • Reduces effect of water hammer • Corrosion resistant • Suitable for directional drilling • Can be welded to resist end load • Available in long coils for fewer joints in pipe sizes smaller than <DN 125 • Compression coupling and fitting resist end long for smaller diameters are available	• Economical competitive for larger diameters (>375 mm) pipelines must be assessed based on pressure rating • Welding/fusion of joints is time consuming and required specialised equipment, • Out of trench jointing may be required • Lower pressure ratings than GRP and DI • Valve arrangement requires restraint to ensure pipelines are not damaged during valve operation • Fusion repair methods are more difficult • Retrospective installation of fitting and repairs for larger pipe sizes are more complicated • Can be difficult to trace in ground • Not suited to above ground use

	Advantages	Disadvantages
Poly vinyl chloride (PVC)	• Rubber ring joints allow for fast installation • Low roughness coefficient • Cost effective over DI for low pressure applications • More flexible than DI and GRP • Joints are flexible by 3° • Readily available pipe material • Use standard DI fittings for Series 2 PVC • Light compared to DI • Reduces effect of water hammer • Corrosion resistant	• Thrust restraint required at all rubber ring joints, bends and crossings • Not as flexible as PE with a 250 x OD curvature radius • Not available in large diameters (>630 mm ID) • Lower pressure ratings than GRP and DI • Series 1 PVC pipes need adaptor bands to fit standard DI fittings • Can be difficult to trace in ground • Suffers from degradation with prolong sunlight exposure
Glass Reinforced Plastic (GRP)	• Rubber ring joints and sleeves allow quick installation • Joints are flexible by 2° • Available in large and small diameters (80 mm – 3000 mm) • Use standard DI fittings • Corrosion resistant • High wall stiffness • UV resistant	• Very rigid, no curvature possible along pipe length • Higher cost than PVC • Not easily available • Thrust restraint required at all rubber ring joints, bends and crossings • Susceptible to damage • Can be difficult to trace in ground
Steel (MS)	• Comes in various forms - cement mortar lined (with PE coating) or PE lined. • Can be Welded or RRJ (Rubber ring joint) • High mechanical strength • Available in long lengths • Can be welded for end load resistance • Customer – made • UV resistant • Impact resist and vandal proof	• Welded joints require specialised equipment and skilled operators • Welding joints required reinstatement of protection systems onsite • Corrosion
Ductile Iron (DI)	• High pressure ratings • High mechanical strength and toughness • UV resistant, vandal proof and impact resistant • Off the shelf fittings readily available (DI) • Rubber ring joints allow for fast assembling • Lower cover and bedding requirements, hence excavation costs reduced • Reserve strength allows future boosting • Easy to trace • Can be PE lined	• Requires PE protection from corrosion • 4 times heavier than plastic counterparts • Sensitive to water hammer • Thrust restraint required at all rubber ring joints, bends and crossings • PE sleeving can be easily damaged • Not suitable in aggressive ground water areas

3. CONTROL AND DELIVERY MECHANISMS

3.1. Pumps

Many pump manufactures provide a range of irrigation suitable pumps. Pumps may be required to divert water in an irrigation scheme or on-farm to:

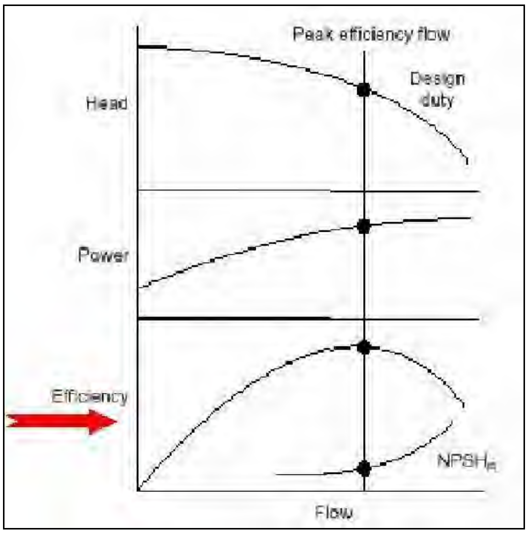
- Divert water from a river or main supply channel into a channel system or gravity system, especially when the land does not favour gravity diversion ;
- Supply water from a river or main supply channel into pressurised supply pipeline;
- Raising surface drainage water to a higher level into a drainage or irrigation system;
- Supply ground water to a gravity distribution system;
- Supply ground water to pressurised system;
- Raise drainage water for subsurface drains; or
- Supply Stock and Domestic water from a river or main supply channel into a pressurised pipe line network.

Different pump types are used to provide the desired outcome for each of the above diversion requirements. Each pumping situation has particular requirements and poor pump selection can result in poor pump performance and increased operating costs. Pump selection is one of the final processes in an irrigation system design. The aim is to obtain the best performance for the least cost. Consideration in the selection of a suitable pump needs to be provided to the following:

- Suction conditions, such as:
  - bank position;
  - water quality;
  - water level;
- Maximum discharge and total head (pressure) requirement;
- Variability of supply;
- Frequency of operation;
- Power availability;
- Existing physical limitation;
- Maintenance capacities;
- Supply availability;
- Service, repairs and parts availability;
- Capital cost (pump and works);
- Part and repair costs; and
- Operating cost.

It is important to select a pump that meets actual requirements and not to take a conservative approach and oversize the pump. Pump selection should be based upon actual requirements to optimise pump efficiencies and minimise ongoing operating costs. The following graph provides an indication where the require flow rate and total system head should match the pumps peak operating efficiency.

Figure 1. Pump Selection Curves



Source: http://promot.cres.gr/promot_plone/pumps/overview/pump-choice-management.

Pump efficiency is the ratio of water power produced by the pump to the power delivered to the pump by the motor. A typical pump efficiency from 70% to 95% is generally targeted in pump selection. In systems with variable delivery, operations may require multiple pumps, multi speed or variable speed drives to maintain system efficiency. In many cases, a pump is selected to meet the maximum delivery requirement which may be oversized for normal operating loads and will create operating inefficiencies and increase operating costs.

3.1.1 Pump Manufacturers

The following major manufactures provide suppliers with various types of irrigated related pumps. Details on the types of pumps available from each manufacturer are readily available from their web sites.

- AJAX;
- Caprarci;
- Davey;
- Grundfos;
- Lowara;
- ITT – Flygt;
- Mono;
- Southern Cross; and
- TFL – Flowserve;

3.1.1. Pump References

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3.2. Water Channel Control Gates

3.2.1. Overview

The objective of channel control gates is to regulate and deliver water supply in an accurate and timely fashion whilst minimising losses to the system. Regulating delivery is complicated by the number of clients moving in and out of the system drawing water from a channel network during any given timeframe and the time and distance requirements of supply relative to its source. This raises a number of issues and objectives for consideration

- Minimal Channel level fluctuations and Gate actions to extend working life of equipment and improve demand response
- Monitoring. Water loss minimized through precision control and loss Detection Technology
- Detection of leaks for repair or lining
- On Demand water supplied when required
- Crop needs matched with precision water supply flow rates
- On-farm efficiency and improved production is a function of supply control
- Accurate billing and regulatory compliance through precision volumetric measurement
- Technological improvements for management and scheduling e.g. internet and phone ordering and confirmation
- Benchmarking of customer service
- OH & S Issues. Safety in operating equipment
- Improvement in environmental outcomes for salinity and water loss, reduction of leachate and end-channel wastage or outfalls.

3.2.2. Selection of Control Gates

From a function viewpoint, control gates can be described as overshot or undershot or a combination of the two. Usually a combination of overshot and undershot gates is selected for modernised channel systems and different configurations are engineered to specific performance requirements depending on type and size of channel. Backbone channel requirements are different to downstream off-take channels. The selection of a specific gate type may be influenced by:

- Required size and economy, cost and type of dependant infrastructure requirements
- Engineering considerations related to size, materials (timber, steel, stainless steel, aluminium), orifice shape, design and quality
- Service Life, i.e. wear and tear characteristics related to load over time
- Functionality or performance of discharge and control relating to changes in channel height
- Fully or partially open operational requirements
- Continuous or discontinuous flow, e.g. ability to drain channel to empty state if required
- Precision in Volume Control
- Sealing ability on shut-off
- High or low head requirements
- Water quality and resistance to blockages (trash racks may need to be installed)

- Impact of discharge turbulence on channel erosion and wear.
- Design structure integration into new or existing control structures or flumes
- Available labour and expertise
- Accessibility for maintenance and / or control
- Method of monitoring control used
- Control Mechanisms. Manual or Automated
- Commercial viability. Initial costs versus long term cost and maintenance costs.
- Operational Health & Safety issues
- Statutory requirements

The following sections describe design and function aspects of common Control Gates.

1. Overshot Gates

Overshot gates are raised or lowered fully or partially such that water is decanted over the top of the gate.

Figure 2. Layflat (Tilt) Gate (source AWMA)

Design: Bottom hinge gate lowered downwards and forward of flow direction or upwards against flow direction. Can be designed as a fully open, fully shut gate or incrementally controlled from fully open to fully shut.

Function: Flow or level control from full to empty channel levels. Manual or automated control capability.

2. Downward Slide Gates

Figure 3. Downward Slide Gate (source AWMA)

Design: A vertical gate that slides downward incrementally from the position of the full water level in the channel. It may either:

- with the top edge designed to lower to the bottom level of the channel with 100% opening, particularly suited to drop structures. In this case the entire gate lowers to a position below the bottom of the channel, or
- or usually be a slide gate that lowers down in parallel to a fixed weir gate of the same size sitting at the bottom of the channel. Opening size is restricted by the slide with the

greatest height. Usually, all slides are of the same height. Multiple slides are used to achieve greater opening sizes.

Function. Flow or level control with some designed to drain as in the first example above. Manual or automated control capability.

3. Stopboards

Figure 4. Stopboard (source AWMA)

Design: A vertical gate system with a series of boards that lay or stack on top of each other laid horizontally across the channel opening and slide and lock into a flume structure by means of a vertical U shape recess on each side of the channel opening. There are fixed points of incremental control determined by the height and length of the boards.

Function: Commonly used on older systems, stopboards are particularly useful as a cheap on-farm level control mechanism for gravitational off-take and is also used for flow control. It is a manual control mechanism.

4. Undershot (Sluice) Gates

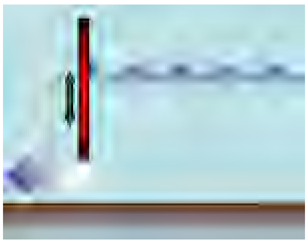

Figure 5. Undershot (Sluice) Gate (source AWMA)

Undershot gates are raised or lowered fully or partially above the channel such that water is discharged from the bottom of the channel underneath the gate.

Design: A vertical gate that slides upwards incrementally from the position of the full water level in the channel.

Function: Flow or level control from full to empty channel levels. Fast flow response, manual or automated control capability. Silt and debris at the bottom of the channel can cause interference to operations.

5. Combination Gates

Figure 6. Combination Gate type 1 (source AWMA)

Figure 7. Combination Gate type 2 (source AWMA)

Design: A series of two parallel vertical gates that can slide upward or downward independently and incrementally from above the position of the full water level to sitting on the base of the channel.

Function: Flow or level control from full to empty channel levels. Can perform undershot or overshot delivery and minimise movements to reduce wear and tear in response to full or partial discharge demand. Fast flow response, automated control capability.

3.2.3. Gate Differences

- Water discharge rates of undershot delivery are influenced less by changes in head water levels when compared to overshot discharge requiring less gate travel to regulate flow.
- Undershot discharges have a higher discharge rate when partially opened compared to overshot gates.
- The operating head of an overshot gate is lower than an undershot type.

3.2.4. Gate Drive Control Systems

Control systems vary from visual and mechanical control to fully automated. The components that are common to these control systems are listed below (not including stopboards).

Mechanical Drives

- Hand-wheel with rising or non rising spindle
- Crank handle fixed or removable with non rising spindle
- Reduction gearbox with hand-wheel and with rising and non-rising spindle
- Rack and pinion
- Hydraulic/Pneumatic piston
- Electric driven spindle with manual override
- Linear electric motor

Monitoring

- Water level sensors
- Flow measurement sensors (see Water Meters Section 3.2.6)

Automated Actuation

- Switchgear and cabling
- Solar power with battery backup or mains powered
- Telemetry equipment & base control station, equipment and infrastructure
- Management and scheduling software

3.2.5. System Flow Control & Measurement

Control systems using a mixture of automated and manual control from source supply to 'farmgate' off-takes are commonplace. Mechanical Dethridge Wheels have been the traditional method of measuring on farm deliveries and are being replaced by more accurate methods, normally a combination of ultrasonic meters, electromagnetic meters and flumegate meters utilising hydraulic calculation based on flow rates relating to water level measurements over time. Some of these meters are commonly used in pressure piped water systems and have been described in greater detail in Section 5.1.

3.2.6. Meter Types and Usage

Dethridge Meters are a positive displacement meters and have been used extensively by most major irrigation water providers in Australia. Up until recently the Dethridge meter has had widespread use with over 40,000 meters installed throughout Australia. The Dethridge meter is both a meter and a flow control device with the Victorian version of the design having an upstream gate with which to control flow and flared downstream sidewalls to minimise downstream impedances to flow. These meters are subject to wear and tear over time and become inaccurate and flow rates have limited measurement ranges based on size.

Magnetic Flow Meters are a volumetric flow device based on Faradays Law of Magnetic Induction. As water flows through the pipe it acts as a conductor, inducing a voltage which is proportional to the average flow velocity, the higher the flow rate, the higher the voltage. Magnetic Flow meters are now in widespread use across Australia by Irrigation Water Providers and are generally used for the metering of the supply of irrigation water. They are available in flanged, end of pipe and flangeless design and may be powered by solar panels. The benefits of these in-pipe meters are that they demonstrate a high degree of accuracy $< \pm 0.5\%$, feature no moving parts, have a wide flow range of 0.5 ML/day to 300 ML/day using different diameter meters bodies, have little Occupational, Health and Safety risk and low maintenance costs. Best accuracies are achieved when velocities are greater than 1m/s. See Section 5.1

Ultrasonic Meters. There are two types amply described in Section 5.1. Both use different methods to measure the passage of ultrasonic waves through the water flow. The main type in use works on the Doppler principle whereas the alternative operates on the transit time principle. Transit Time Meters are gaining prominence as they technically have greater capability with the preference for one of the other type usually determined by cost. Both these meters can be mounted externally to pipe and can measure an extremely high flow range of 0.5ML/day to 6000ML/day are robust and require minimal maintenance and can be powered by solar panels, does not pose a Operational Health and Safety risk and can be very accurate $< \pm 1\%$.

FlumeGate™ Meters manufactured by Rubicon Systems are a control and measuring device and comprise a downward pivoting radial gate or a form of overshot tilt gate with sensors to measure the upstream, water level, the downstream water level and the position of the gate. A mathematical algorithm then uses each of these positional measurements to calculate the flow rate thence the volume passed. Flow range is specified up to 55 ML/day. The gate is powered by a solar-charged battery system which is managed by power regulation hardware and software. The FlumeGate™ uses radio telemetry to communicate farmer requirements to the gate and report flow rates and real-time usage through the internet. This information is accessible to farmers and water authorities. The radio telemetry also provides a gateway to monitor and control on-farm automation equipment.

3.2.7. Summary

Automated mechanical control systems tend to become prohibitively expensive from a cost benefit perspective at end-channel locations.

The traditional upstream method of maintaining control of channel systems has largely been established on pre-emptive logistical control whereby water is forward ordered and calculations are made to release and control water transfers based on time and volumes attenuated by system capacities, losses and multiple demand logistics. Delivery is mostly measured at the channel system exit point to on-farm destinations.

New technological advances in software development and monitoring and control systems now allows on-demand or downstream control systems whereby sections of channel are divided into supply pools from which transfers and off-take supply can be accommodated and upstream adjustments can be effected along the pool chain to regulate and meet flow requirements. The system typically uses automated FlumeGates™ that measure upstream and downstream water levels and accurately compute flows. This system works somewhat like a synchronised traffic light system delivering greater and more constant flow with less blockage points. The system saves time, increases overall flow volumes and becomes more responsive to on-demand ordering.

3.2.8. Indicative Prices and Suppliers

Amongst others, the main manufacturers and suppliers of prefabricated channel control gate systems in Australia are AWMA Water Control Solutions and Rubicon Systems Australia Pty Ltd. Numerous other manufactures provide various gate to order.

In most situations, an integrated range of Overshot and Undershot or Combination gates are usually selected for modernised channel systems and different configurations are engineered to specific performance requirements depending on type and size of channel.

In a comparative analysis, two automated gate types were selected to adequately service a particular control structure with the specifications as listed. AWMA Water Control Solutions were then requested to provide indicative pricing with the following results:

Gate Size

- 2100mm CW
- 1200mm OL
- 1500mm TOC

Electrical components including:

- Large enclosure
- Solar panel mast – 6m
- Solar panel mounting frame
- Solar panels
- Batteries Level sensors
- Solar regulator for PL20
- Ultrasonic enclosure
- RTU

- HMI – touch screen
- Solid State Actuator Drive
- MPI – stand alone
- Battery charger
- Lightning protection
- Change over switch

Item indicative price of $26,700.00

1 x Walkway – 4.5 metres indicative price of $2,400.00

Option 1: Overshot Gate

1 x Aluminium LayFlat gate fitted with a SA57 actuator $11,900.00

Total Investment **$41,000.00**

Option 2: Overshot - Undershot Gate

1 x Aluminium Combination gate fitted with a Maxon actuator $17,240.00

Total Investment **$46,340.00**

All Prices are GST Exclusive.

The above comparison illustrates the relative high costs associated with automation and the cost of automation greater than that of the gates alone. The difference in prices between the gate types is not huge despite the Combination Gate setup being more refined in control capability and design than the Layflat type. In addition to this cost a control structure would need to be added. Typically, this would be in the region of an additional $8,000.00 to $12,000.00 depending on channel size and structure design.

3.2.9. References and Acknowledgements

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Website Links

AWMA Links to Australian Water Industry, Govt organisations, Water Suppliers, resources. http://www.awma.au.com/gates/

AWMA. Water Control Solutions. Design, Manufacture Install. http://www.awma.au.com/userfiles/file/awmacatalogue.pdf

Channel Automation and people. Oakes A. Luscombe C. http://www.irrigation.org.au/assets/pages/75D4C8BD-1708-51EB-A6816CD6992AC045/52%20-%20Oakes%20Paper.pdf

Environmental Best Practices Guidelines Environmental Best Practices. 5.0 Efficient Irrigation. http://www.agric.wa.gov.au/content/AAP/DC/5_EfficientIrrigation.pdf

Flowmeters – ultrasonic flowmeters. http://www.flowmeters.f2s.com/article.htm

Future of the Dethridge Meter. Goulburn Murray Water . http://www.udvnorth.org.au/downloads/41-future%20of%20the%20dethridge%20meter%20_final_.pdf

Irrigation Australia. http://www.irrigation.org.au

Know the Flow Flowmetering Training Manual. http://www.irrigation.org.au/assets/pages/6E9E6203-1708-51EB-A65470E3F41123EB/Know%20The%20Flow%20Training%20Manual.pdf

Omega Flow and Level Products. http://www.omega.com/green/flow-level.html

Omega Ultrasonic/Doppler Flowmeters. http://www.omega.com/toc_asp/subsectionSC.asp?subsection=E&book=green&all=1

Rubicon. Scada Application, Total Channel Control Brochure Gates Brochure, Flumegate Brochures, Water Savings. http://www.rubicon.com.au/downloadDoc/downloadDoc.asp

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4. ON-FARM FIELD APPLICATION

4.1. Centre Pivots and Lateral Irrigators

4.1.1. Selection Criteria Overview

When selecting a travelling sprinkler irrigation system, the most important physical parameters to consider are:

- Soil infiltration rates;
- The shape and size (hectares) of the field;
- The topography of the field. Hilly with steep slopes or flat;
- The amount of time and labour required to operate the system; and
- Availability of labour.

A Centre Pivot system is very adaptable but doesn't work very well on irregularly shaped fields, long narrow fields and areas that contain some type of obstruction (trees, buildings, etc.). In these situations, lateral sprinkler systems may be more effective. Generally, Centre Pivots are more suited to undulating fields and smaller coverage areas whereas Lateral Irrigators are more suited to larger, flat coverage areas. However, many other factors need to be considered, such as

- Peak and total crop water requirements during the growing season;
- Factoring in operational efficiencies driven by factors such as meteorological conditions;
- Effective crop root zone depth;
- Soil conditions;
- The soil water holding capacity;
- Pumping capacity from channels, storages, bores or wells (if they are the primary water source) and losses e.g., seepage and evaporation;
- Viability of earthen channel; and
- Cropping type and methods.

A moving sprinkler system must be designed to apply water uniformly without runoff or erosion. The benchmark value for uniformity is 90%. The application rate of the sprinkler system must be matched to the soil infiltration rate of the most restrictive soil in the field. If the application rate exceeds the infiltration rate, the water will run off the field or relocate within the field resulting in over and under-watered areas.

4.1.2. Evaluation of Irrigator Types

The evaluation of the best irrigator option is a very site-dependant exercise. Therefore a detailed study needs to be undertaken to establish all the parameters and requirements to arrive at the most efficient engineering and economic solution based on a sound business plan. The following highlight the many differences in capabilities and circumstance that need to be factored into the selection process in relation to centre and lateral move pivots. Each option should be evaluated against the other and costed for final evaluation where one or the other is not immediately precluded.

Table 12. Centre Pivot Travelling Irrigator

1	Equipment:	**Centre Pivot**
2	Type	CIRCULAR TRAVEL IRRIGATOR. CIRCULAR AREA

1	Equipment:	**Centre Pivot**
		COVERAGE. Centre pivots are typically less than 500m in length (circle radius). Towable options are available for multiple field irrigation.
3	Components:	•Travelling truss-supported pipeline on propelled wheels with sprinklers dispersing an even band of water coverage along its length moving in a circular motion from a fixed pivot pressurised by a pump and fed by a fixed pipeline from a water source. •Suitable sprinkler head selection and spacing, filters, pressure regulators, computer controls, electrical control wiring and alignment control system. •Construction materials may include various combinations of Polyethylene, Galvanised Steel, Stainless Steel, Cast Iron and aluminium.
4	Dependant infrastructure requirements:	Water pump and pipe infrastructure, supply pipeline, circular field, free of trees and other infrastructure such as buildings, reliable water supply to meet capacities required by crop at the correct time
5	Typical application:	Broadacre Cropping, Pasture, Dairy, Horticulture Winter & Summer Cropping. Most suited to high level of automation
6	History of use:	First Developed in 1955 in the US. Not utilised much in Australia until the late seventies
7	Water Use Efficiency Statistics:	Prone to high evaporation losses in hot windy conditions, more so than Laterals because of emitter variation requirements. Distribution Uniformity to 85-95%. Water use efficiency is at between 85 - 90% Prone to high evaporation losses in hot windy conditions. Sprinkler heads can operate on lower throws when meeting infiltration rate reducing evaporative losses and more even application in hot windy conditions. Large droplet applications to reduce evaporation losses are more achievable compared to centre pivots due to maximum operating groundspeeds requirements being lower, therefore lower soil sealing, compaction and runoff issues. Environmental conditions will have an equal effect on the application rate along the whole length of the application band resulting in even application rate and coverage regardless. Application rates can be corrected to account for evaporative losses by adjusting groundspeed. Thus actual infield water use efficiency in practise can vary significantly during actual use and thus overall efficiency can be reduced.
8	Limiting factors:	Terminal span instantaneous application rate is the limiting factor to design size of pivot due to matching soil infiltration rates. Spreading the water application over a greater area (widening the target band at the fastest end) increases wind drift and evaporative losses due to reduction in droplet size. High application rates and large droplets can lead to compaction and soil sealing, reducing infiltration rates particularly in heavier soils. This can also lead to uneven water application resulting in either deep percolation losses, insufficient water penetration or both. The biggest setups with travelling arms of around 400m long, cover about the same area as laterals of the same size with long runs, but can take up to 1.6 times longer to traverse the same area. Water quality can lead to corrosion issues.
9	Recent technological advancements:	Improvements in Controls and development of Telemetry & Reporting to GPS & Web Based Control & Monitoring

1	Equipment:	**Centre Pivot**
		Software, Cell Phone Controls & SMS Text Monitoring
10	Current Research:	State Departments Of Agriculture
11	Case study examples of:	• 395m (49ha) Towable Centre Pivot – including all establishing infrastructures • Bogging and rutting can be a big problem in half circle setups. Boombacks and half spray nozzles alleviate the problem in full circle • Good emitter selection is vital to application performance /uniformity. Low Energy Precision Applicators (LEPA) in use on modern machines reduce evaporative losses dramatically • Well managed scheduling is vital to maximise application efficiency and crop yields. • Many of the older systems do not meet capacity requirements • Planting in line with a centre pivot is made easier with suitable GPS guidance equipment.”
12	Recommended application:	Suited to smaller undulating fields with slopes up to15%. Any intensive pasture or horticultural crop application where efficient irrigation is required to minimise water wastage and maximise efficiency with even applications and the correct quantity at the right time. Where a high degree of automation is desirable.
13	Establishment Procedures:	Evaluate field area to establish suitability of irrigator type to crop demands, soil type topography, shape, irrigation demand, water capacity, availability and application rates. Evaluate dependant infrastructure requirements and availability. Analyse crop modelling, costs and returns, management, maintenance and labour requirements. Construct dependant infrastructure required and install pump, footings, pump reservoir, thrust blocks, pipeworks and centre pivot. Test and commission
14	Operational procedures:	Start Diesel Pump Unit, Engage Clutch & Pump, Fill System to desired Operating Pressure, Centre Pivot will “Walk Off” once Correct Operating Pressure is reached 3G Phone Module will activate under Alarm or Safety situation Alerting Operator of Problem or Shut Down
15	Brands and Manufactures:	Zimmatic, Lindsay Manufacturing Company, Reinke, Valley, T & L. Valmont Components. Nelson
16	Availability in Aust.:	No Domestic Manufacturer in Australia (Mainly USA Based Manufacturers)
17	Market Distribution:	Australia Wide
18	Life Span:	20-30 years Depending on Water Quality and resistance of construction materials to corrosion
19	Indicative price:	No Indicative Pricing Available – Pricing Dependent on Fluctuations in Steel, Copper Pricing, O/S Freight Rates & $USD/AUD Exchange Rate Main determination is size of unit
20	Case study establishment price: (GST	$AUD 357,900.00

1	Equipment:	**Centre Pivot**
	Exclusive)	
21	Case study Operating Costs: (GST Exclusive)	Pumping Costs: 30-35Ltr Diesel/Hr @ ~ $1.10+Ltr for On Farm Diesel variable. Electric power if available is considerably cheaper with greater price stability. Big savings with off peak/ shoulder rates particularly on weekends
22	Repairs and maintenance requirements: (GST Exclusive)	Initial Service Main Service at 1000hrs
23	Case study maintenance and Repair costs:	$120.00 Per Span & $135.00 for Centre Point x 8 = $1,095.00 + Consumables, Oils etc. Annual Service: Costs = $1,000.00⁺ Cheaper where electricity is used to power pump
24	Part costs and availability:	Normally available from distributor
25	Case study Energy use:	30-35Ltr Diesel Fuel Hour, Mains Electrical supply cheaper if available
26	Ability to perform to specifications:	Well established within realistic parameters. Under ideal conditions perform well within targeted parameters if well maintained. Performance may vary dramatically under adverse conditions.
27	Identified problems or faults:	Application uniformity. Application rates can exceed Infiltration rates on the outside span area leading to soil sealing and runoff. High evaporation conditions can cause higher water losses. Poor sprinkler selection and maintenance and inefficient pressure regulators compromise application uniformity. Systems operating at higher than necessary pressure heads incur higher pumping costs per unit area. Outside spans prone to bogging and deep tracking in heavier soil types.
28	User Comments:	Older machines with lower application rates such as 8-10mm day do not meet crop irrigation requirements during demand periods. Farming in circles can be difficult. Part farming a pivot can be even more difficult.
29	Capacity for expansion:	Systems can be duplicated if capacity allows. Towable systems can be moved to additional fields, spans can be extended, corner spans can be added. Spray nozzles (guns) can be added to reach targets outside of the span area but are not generally efficient. Sprinkler heads can be repositioned and set for coverage behind pipeline tower wheels on the end spans to prevent bogging and deep tracking.

Table 13. Lateral Travelling Irrigator

1	Material:	**Lateral Move Irrigators**
2	Type:	LINEAR TRAVEL IRRIGATOR - SQUARE OR RECTANGULAR AREA COVERAGE. Lateral moves are not uncommon in Australia and typically range between 50-1000m in length. Smaller laterals are reasonably common. Can be towable for multiple field irrigation. Multiple types such as channel end suction, drag hose and looper connections.
3	Components:	Travelling truss-supported pipeline on propelled wheels with sprinklers dispersing an even band of water coverage along its length moving forward in a single or linear direction at the same rate along the span length. The pumping station (non electric particularly if channel supplied) moves with the irrigator either in the centre or at the end. Water can be supplied to the lateral system either through a canal, by dragging a supply hose which is connected to a mainline, or by connecting and disconnecting from hydrants as the system moves down the field. Other components include a water source such as a storage or bore, suitable sprinkler selection and spacing, filters, pressure regulators, computer controls, electrical control wiring, steerage and alignment control system. Lateral moves, rely on more complex guidance systems and require additional management when compared to centre pivot systems. Electricity generator to operate electrical drive and control systems. Construction materials may include various combinations of Polyethylene, Galvanised Steel, Stainless Steel, Cast Iron and aluminium
4	Dependant infrastructure requirements:	Require integral travelling power plant and pump (usually diesel) and an electric generator to supply power to motorised drive wheels (usually electric) Other infrastructure includes a supply canal or movable hose and/or coupling uncoupling hydrants storage / bore / supply pipeline, square or rectangular field. Can be designed to travel between tree lines and other infrastructure such as buildings, reliable water supply to meet capacities required by crop at the correct time
5	Typical application:	High value Broadacre Cropping, Pasture, Dairy, Horticulture. Winter & Summer Cropping.
6	History of use:	Developed in the 1950s in the US.
7	Water Use Efficiency Statistics:	Sprinkler Distribution Uniformity to 85-95%. Water use efficiency has been quoted up to 90% for non channel suction machines and may be down to 75% for channel end suction systems. Prone to high evaporation losses in hot windy conditions. Sprinkler heads can operate on lower throws when meeting infiltration rate reducing evaporative losses and more even application in hot windy conditions. Large droplet applications to reduce evaporation losses are more achievable compared to centre pivots due to maximum operating groundspeeds requirements being lower, therefore lower soil sealing, compaction and runoff issues. Environmental conditions will have an equal effect on the application rate along the whole length of the application band resulting in even application rate and coverage regardless. Application rates can be corrected to account for evaporative losses by adjusting groundspeed. Thus actual infield water use efficiency in practice can vary significantly during actual use and thus overall efficiency can be

1	Material:	**Lateral Move Irrigators**
		reduced.
8	Limiting factors:	Traverse time/coverage rate advantage diminishes over longer distances. Not suited to pumping with electricity for direct channel supply. Labour intensive when hoses need to be moved. Requires greater management and control systems. Water quality can lead to corrosion issues. Channel supply feed can cause system blockage issues throughout system requiring constant maintenance. Channels can limit access and reduce land utilisation.
9	Recent technological advancements:	Improvements in Controls and development of Telemetry & Reporting to GPS & Web Based Control & Monitoring Software, Cell Phone Controls & SMS Text Monitoring. Fast speed motors to return lateral to start of run. Swing over laterals which allow 1 machine to irrigation an oval shape and finish irrigating at the start position.
10	Current Research:	As above
11	Case study examples of performance:	395 m span Lateral on 1 km run Good emitter selection is vital to application performance /uniformity. Low Energy Precision Applicators (LEPA) in use on modern machines reduce evaporative losses dramatically Well managed scheduling is vital to maximise efficiency and crop yields. ½ sprinklers and extra long LEPA hoses should be used near towers to reduce the potential for wheel rutting. Many of the older systems do not meet crop peak demand requirements.
12	Recommended application:	Relatively flat fields, soil types where infiltration rates preclude use of or suitability of centre pivots. Any intensive pasture or horticultural crop application. Particularly suited to fields where temporary water logging would occur if for example surface irrigation was used instead. Good in low water holding soils with small fields.
13	Establishment Procedures:	Evaluate field area to establish suitability of irrigator type to crop demands, soil type topography, shape, irrigation demand, water capacity, availability and application rates. Evaluate dependant infrastructure requirements and availability. Analyse crop modelling, costs and returns, management, maintenance and labour requirements. Construct dependant infrastructure required and install pumps and supply mechanism, centre pivot. Test and commission
14	Operational procedures:	Start Diesel Pump Unit, Engage Clutch & Pump, Fill System to desired Operating Pressure, Lateral will "Walk Off" once Correct Operating Pressure is reached. Moving and connection and reconnection of hose supply lines required in cycle. Otherwise, monitoring of supply channel for checking and cleaning filters required 3G Phone Module will activate under Alarm or Safety situation Alerting Operator of Problem or Shut Down
15	Brands and Manufactures:	Zimmatic, Lindsay Manufacturing Company, Reinke, Valley, T & L, Nelson components. Components. Nelson
16	Availability in Aust.:	No domestic manufacturer in Australia (Mainly USA-based

1	Material:	Lateral Move Irrigators
		manufacturers)
17	Market Distribution:	Australia wide
18	Life Span: (Same as Centre pivots)	20-30 years Depending on Water Quality and resistance of construction materials to corrosion
19	Indicative price: (Same as Centre pivots)	No Indicative Pricing Available – Pricing Dependent on Fluctuations in Steel, Copper Pricing, O/S Freight Rates & $USD/AUD Exchange Rate Main determination is size of unit
20	Case study establishment price: (GST Exclusive)	$AUD 450,000.00 395 metre lateral on 1000metres channel.
21	Case study Operating Costs: (GST Exclusive)	Pumping Costs: 30-35Ltr Diesel/Hr @ ~ $1.10+Ltr for On Farm Diesel variable. Electric power if able to be utilised and available is considerably cheaper with greater price stability. Big savings with off peak/ shoulder rates particularly on weekends. Labour costs in moving supply lines or servicing channel supply
22	Repairs and maintenance requirements: (GST Exclusive)	Same as pivots
23	Case study maintenance and Repair costs:	Initial Service Main Service at 1000hrs $120.00 Per Span & $135.00 for Centre Point x 8 = $1,095.00 + Consumables, Oils etc. Annual Service: Costs = $1,000.00 + Supply channel systems require supply system and maintenance
24	Part costs and availability:	Normally available from distributor
25	Case study Energy use:	30-35Ltr Diesel Fuel Hour
26	Ability to perform to specifications:	Well established within realistic parameters. Under ideal conditions perform well within targeted parameters if well maintained. Performance may vary dramatically under adverse conditions.
27	Identified problems or faults:	Poor sprinkler selection and maintenance and inefficient pressure regulators compromise application uniformity. Systems operating at higher than necessary head pressures incur higher pumping costs per unit area. Larger span systems normally have higher pumping costs due to greater frictional head losses but can be reduced with larger diameter pipe lines at greater initial cost. Laterals with end rather than centre supply incur higher pumping and pipe costs but are less manoeuvrable for towing purposes. Channel supply systems are subject to inefficiencies due to seepage, leaks and evaporative losses.
28	User Comments:	N/A
29	Capacity for expansion:	Systems can be duplicated if capacity allows. Towable systems can be moved to additional fields, spans can be extended, corner spans can be added. Spray nozzles (guns) can be added to reach targets outside of the span area but are not generally efficient. Systems can be designed to travel laterally up the long sides of a field and pivot at the headlands particularly where channel

1	Material:	Lateral Move Irrigators
		supply is used. In this case the size limitations to span length applying to pivoting motion and efficiencies come into play

4.1.3. Pivot and Lateral References and Acknowledgements

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Rural Water use Efficiency Initiative. Irrigation for profit

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General Website Links

Irrigation Australia http://irrigation.org.au/index.cfm?/resources/irrigation-information-and-links

Irrigation Futures. http://www.irrigationfutures.org.au/news.asp?catID=14&ID=463

NDSU North Dakota State University http://www.ag.ndsu.edu/pubs/ageng/irrigate/ae91w.htm

Team Irrigation. Dubbo, NSW. http://www.teamirrigation.com.au

University of Southern Queensland – Steven Raine Publications. http://www.usq.edu.au/users/raine/#Publications

4.2. Drip Irrigation

Drip irrigation also known as trickle irrigation can be split into surface or above ground drip and subsurface drip irrigation (SDI). This review focuses upon SDI which is summarised in the following tables.

Table 14. Drip Irrigation

1	Equipment	Integrated Inline drip products
2	Types	A variety of emitter flow rates and spacings are available from approximately 0.4 – 4 litres per hour (LPH) and spacings down to 100mm. **Horticulture** = 0.9 to 1.1mm wall thickness; non pressure compensated, pressure compensated (PC), pressure compensated non drain (PCND, CNL), pressure compensated high closing non leakage (HCNL) **Subsurface/Vegetable** = 0.1mm – 0.5mm wall thickness; non pressure compensated, pressure compensated (PC), pressure compensated non drain (PCND, CNL). Some products are manufactured with a seam or seamless. Most of these products are also available wrapped in a geofabric and poly material to assist in lateral spread under the ground. Note some heavier walled products are being used in subsurface to increase the life expectancy and in vegetables where the product is retrieved post harvest. Some products are impregnated with trifluralin to inhibit root intrusion.
3	Components	Polyethylene, silicon and EPDM type polymers.
4	Dependent Infrastructure requirements	Pumps, filtration, pipelines, valves and controllers.
5	Typical Applications	As above.
6	History of Use	Inline drip has been used in Horticulture and vegetables in Australia and throughout the world since the early 1980's
7	Water Use Efficiency	Up to 95%
8	Limiting Factors	Experience in scheduling is crucial, Should be installed by an experienced installer when used in sub surface installations. Irrigation design must be carried out by a suitably experienced body.
9	Recent technological advancements	HCNL, High close non leakage emitters, and anti suck back emitters.
10	Current Research	Ongoing, developments of smaller emitters to reduce manufacturing costs. Also research into the use of more recycled product.
11	Case Study Examples of performance	Vineyards and Horticulture in the right soils excellent results. Very sandy soils mixed results. Subsurface installations mixed results depending on design.
12	Recommended application	As above
13	Establishment procedures	Particular care is need in scheduling the irrigation and monitoring soil moisture throughout the profile.
14	Operational procedures	As above
15	Brands and Manufacturers	Metzerplas, Netafim, Plastro, PPI, Toro. Plus many more imported types.
16	Availability in Australia	Five manufacturers above all manufacture in Australia.
17	Market Distribution	Excellent, distributed through irrigation dealers and some stock corporate rural merchandise facilities.
18	Life Span	Some manufacturers have quoted 10 year warranties on the product. Low density polyethylene and on line (old style drippers) were first installed in Adelaide in the late 1960's and are still there today. Subsurface products probably around 10 to 15 years.
19	Indicative Price	30c to $1.50 per metre pending on product diameter, emitter type, emitter spacing and

1	Equipment	Integrated Inline drip products
		additives.
20	Case Study establishment price	Vineyards/ Horticulture $6,000 -$9,000. per Ha, Subsurface Lucerne $5,000 -$7,000 per Ha
21	Case study operating costs	Pumping costs depending on area, crop type outlet quantity.
22	Repairs and Maintenance	Minimal. Regular monitoring, flushing and service of equipment is essential
23	Case study maintenance and repair cost	Allow on 0-100 Ha approximately $5,000-$10,000 for chemical injection and regular maintenance duties including labor
24	Part Costs and availability	Readily available. Replacement tube of as purchase price.
25	Case study energy cost	Pending crop type and size.
26	Ability to perform to specifications	Excellent providing the system has been correctly deign and the producer follows a strict monitoring and maintenance program
27	Identified problems or faults	Blockages, non uniform application, vermin attack (insect and animals), mechanical damage.
28	User Comments	Water more area at once, savings between 40 to 70% compared to flood irrigation. Massive reduction in labor costs allowing producer to work in other fields or develop more area
29	Capacity for expansion	Depending on initial design of mainline and infrastructure
30	Associated Carbon emissions	Pump energy costs only. Electric/Diesel/LPG

Table 15. Pressurised Drip Line Automation

1	Equipment	Irrigation Controllers for Drip Systems
2	Types	Most controllers in this group include the following features; 1. Sequential control 2. Grouping control 3. AC/DC operation 4. Multiple start and run times 5. Multiple cycle programming. 6. Filtration and chemical injection programs 7. Extensive reporting features 8. Auto program starts i.e. frost, high temperature programs 9. Inputs for weather control shut down or start up. 10. Access via PC. 11. Fault finding features
3	Components	Electronics
4	Dependent Infrastructure requirements	240VAC or 12 VDC. Solenoid valves and coils in 24VAC or 12 VDC
5	Typical Applications	All pressurised and non pressurised irrigation systems that have a valve or actuator that can be connected.
6	History of Use	The more featured types have been around for about 15 years
7	Water Use Efficiency	Excellent providing the operator has a good understanding of the controller and soil moisture requirements in the paddock.
8	Limiting Factors	Education, reliable power supply, well installed wiring/hydraulic tube and electrics.
9	Recent technological advancements	More so in the products/sensors that hang off the controllers like soil moisture wind speed/direction, fertigation/chemical injection units.
10	Current Research	Mainly new sensor development in monitoring plant growth, sap flow, soil moisture/salinity

1	Equipment	Irrigation Controllers for Drip Systems
		and temperature
11	Case Study Examples of performance	Vineyards and Horticulture Subsurface installations excellent depending on the operator having a good understanding of the controller and soil moisture requirements in the paddock.
12	Recommended application	All pressurised and non pressurised irrigation systems that have a valve or actuator that can be connected. Very important when pulse or cyclic watering is required.
13	Establishment procedures	nil
14	Operational procedures	Operator requires to be well educated in the use of the controller
15	Brands and Manufacturers	Metzerplas, Netafim, Plastro, PPI, Toro. Plus many more imported types.
16	Availability in Australia	Five manufacturers above all manufacture in Australia.
17	Market Distribution	Excellent, distributed through irrigation dealers and some stock corporate rural merchandise facilities.
18	Life Span	Some manufacturers have quoted 2 year warranties on the product. Life span up to 20 years
19	Indicative Price	$150,000 -$250,000
20	Case Study establishment price	Basic 20 Ha vineyard or subsurface designed block $3,000 -$20,000 pending on PC access requirement.
21	Case study operating costs	Minimal power only
22	Repairs and Maintenance	Minimal. Regular monitoring for moisture and/or insect intrusion.
23	Case study maintenance and repair cost	Nil proving there is no mechanical or electrical burn out.
24	Part Costs and availability	Parts usually readily available 2-20days
25	Case study energy cost	Minimal
26	Ability to perform to specifications	Excellent providing correct installation and operation
27	Identified problems or faults	Minimal, power surges may affect the operation of the controller. Highly recommend installation of Uninterrupted Power Supply (UPS) equipment
28	User Comments	Some controllers are very difficult to understand and use. Very dependent on the ability of the producer to understand the operation of the product. Ongoing support would greatly assist.
29	Capacity for expansion	Some controllers re limited whilst others have extra modules and/or can operate up to 999 valves.
30	Associated Carbon emissions	Power costs only. Minimal.

4.2.1. Dripline References

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www.npsi.gov.au

4.3. Pipe and Risers

Pipe and riser technology is the replacement of channel systems. Supply channels are replaced with pipes and head ditches with pipe and risers for outlets. Pipe and risers are buried pipes either pressurised or gravity depending upon the hydraulic limitations, requirements and design along the head of an irrigation field. One riser / outlet is required for every 2.5 hectares with a maximum distance of 90 meters between outlets with paddock grades around 1 in 600. Hydraulic design should focus on minimising ongoing pumping costs. A standard system would be designed with a maximum system head of 10 meters to minimise pipe grades and pumping costs. Bay outlets are sized at 315 mm to maximise delivery capacity and minimise head loss. Automation of pipe and riser systems can be easily achieved through telemetry controlled outlets as the figure below illustrates.

Figure 8. Telemetry Controlled Riser Outlet (Source: Archards Irrigation)

Table 16. Pipe and Risers Equipment Profile

1	Equipment:	Pipe and Risers
2	Types:	Solid PVC, PE pipe or modified system with Flexiflume ideal for cropping situations
3	Components:	Pumps, supply pipelines, outlets, valves
4	Dependant infrastructure requirements:	Pumps
5	Typical application:	Surface irrigation on crops and pasture
6	History of use:	Developed over 15 years
7	Water Use Efficiency Statistics:	Typical saving channel losses of 15% saving and by greater flow rates on bays typically 10% (see below)
8	Limiting factors:	Running pumps, Risers management
9	Recent technological advancements:	Automation of outlets, using products such as Stormpro to delivery water reducing infrastructure costs.
10	Current Research:	Nil
11	Case study examples of performance:	See below comments.
12	Recommended application:	All surface irrigation applications.
13	Establishment Procedures:	On farm design by experienced designer. Removal of old channels, installation of pumps, supply lines and pipe and risers.
14	Operational procedures:	As per normal flood practises.
15	Brands and Manufactures:	All suppliers of pvc, PE pipe, Bartlett and pumps.
16	Availability in Aust.:	Yes
17	Market Distribution:	Australia wide
18	Life Span:	50 plus years as long as no pvc is used above ground all above ground risers must be HDPE or other UV stable products.
19	Indicative price:	$2,500 per hectare (pressurised) including overheads
20	Case study establishment price:	N/A
21	Case study Operating Costs:	$5.00 per megalitre on power $10.00 per megalitre of diesel pumps
22	Repairs and maintenance requirements:	Routine pump and valve maintenance and repairs
23	Case study maintenance and Repair costs:	N/A
24	Part costs and availability:	N/A
25	Case study Energy use:	Related to pumping requirements and thus crop production.
26	Ability to perform to specifications:	High, comparative to the condition of the system replaced.
27	Identified problems or faults:	Maintenance of outlets can cause issues in the head land

1	Equipment:	Pipe and Risers
28	User Comments:	See below for details.
29	Capacity for expansion:	Unlimited – depending upon pump capacity and hydraulic design limitations.
30	Associated carbon emissions:	N/a

4.3.1. Case Study Performance

Investigations into pipe and risers systems indicate little to no research or completed case studies on this technology by Australian Departments of Primary Industries or associated government bodies. In Victoria, the Department of Natural Resources and Environment and North Central Catchment Management Authority did provide an incentive scheme between 2001 and 2004, based upon a 25% rebate on the cost to upgrade on-farm irrigation scheme supply channels to pipe and risers. A survey completed in 2007 with 17 respondents of the 42 recipients provided feed back as follows:

- **Water use:** Water use was reduced on all but 2 properties (10 to 20% reduction);
- **Pasture quality:** Pasture quality improved on most properties, with no change on 4;
- **Pasture quantity:** Pasture quantity improved on most properties (10 to 20% increase);
- **Irrigation preparation time:** Reduced irrigation preparation time on all properties;
- **Time required to irrigate:** Reduced irrigation time on all but 3 properties (up to 50% reduction in irrigation time).
- **Ease of irrigation:** Ease of irrigation improved on all properties.
- **Irrigation system maintenance time:** Reduced irrigation system maintenance time on all properties (due to no requirement for channel structural repairs, channel maintenance and channel weed control).

Estimated water savings calculations based on the above anecdotal responses are:

Assumptions:

- Water use on light soils is 10 ML/ha/year.
- 15% water savings on properties with pipes and risers irrigation systems.

Reduced water use on light soil types to an average of 8.5 Megalitres per hectare from 10.0 Megalitres per hectare.

Note that this was not conducted as a scientific trial. These are anecdotal observations by 17 irrigators and are not necessarily the views of the Victorian DPI.

User Comments:

- No more channel maintenance;
- Makes control of surface irrigation simple;
- We obviously lost more water in open channels than we thought because we now irrigation more area with the same water;
- The extra cost of pumping is more than repaid by no channel maintenance costs;
- We can irrigate any part of the farm without filling channels;

- On my new layout the pipeline only doubled the cost, if I would have had to put in channels, channel crossings and bay outlets and these would have cost ½ as much as the pipe did;
- I now grow pasture on the hectare that was channel;
- The water table was always high along my channel because of the loamy nature of the soil. Since piping the water table in this area has gone back to normal.

4.3.2. References

Personal communication with s 22(1)(a)(ii) – Archards Irrigation Cohuna s 22(1)(a)(ii)

Personal communication with s 22(1)(a)(ii) Loddon Campaspe Irrigation Area DPI Echuca s 22(1)(a)(ii)

5. WATER MONITORING

5.1. Water meters

Many types and forms of water meters are available:

- Dethridge meter;
- Propeller;
- Paddle wheel;
- Turbine;
- Ultrasonic;
- Electromagnetic;
- Venturi and Orifice;
- Flumes and Weirs.

Water meters are generally suited to either:

- Metering of water in open water flows; or
- Metering of water in full pipes and or partially full piped.

5.1.1. Selection Criteria Overview

The following list of criteria should be used to determine the most practical water meter for the intended circumstance.

- Site accessibility for installation & maintenance - Insertion or Inline type;
- Water flow type measuring – open bodies or piped water;
- Volumes – pressure, velocity, or pipe sizes;
- Pipe material;
- Water quality – assess abrasive wear from sand particles, blockages from weeds, turbidity;
- Workload versus Service Life;
- Service Life requirements – scheduling requirements, ease of repair and calibration, product support, quality of maintenance service provider;
- Ancillary equipment requirement – power availability or generating equipment, e.g., solar panel;
- Monitoring and reporting requirements – mechanical versus electronic, linkage to control mechanisms, remote automated network system linkage eg. telemetric reportage, data logging;
- Accuracy and reliability;
- Initial costs;
- Maintenance costs and part availability and costs;
- Lifetime cost;
- Security of equipment, e.g., solar power units, ability to be manipulated;
- Environmental protection; and

- Statutory requirements such as maximum permissible error, water requirements, Occupational Health and Safety.

Water meters measuring from an open channel to on-farm should have the following characteristics and features:

- Provide a consistent level of accuracy commensurate with the value of the water resource being delivered;
- The desirable accuracy level is of the true flow throughout the required flow range. In some applications, an accuracy variation no greater than ± 5%;
- Be able to measure flows accurately over a wide range of channel water levels;
- Be vandal proof or, where unauthorised interference occurs, be easily detectable;
- Be simple to operate and read, provide flow data as both instantaneous flow rates and totalised volume with provision for remote interrogation and/or transmittal of data;
- Use robust technology and construction with non-intrusive mechanism so as not to be affected by blockages, fouling or poor water quality;
- Have moderate capital cost with low operation and maintenance costs to result in low overall life cycle costs. Spare parts and support services should be readily available;
- Pose minimal risk to operators and the general public; and
- Provide minimum impedance to access along channel banks for operation and maintenance purposes.

This review focuses upon products that are best suited for metering water in full or partially full pipes which can be used for metering in either pressurised or gravity piped systems or channel systems with piped outlets. Flumes and Weir metering is covered within the topis of control gates, as automation of these style gates can allow for calculations that provide water flows.

5.1.2. Equipment Review

Types to Consider:

- Mechanical - Propeller, Turbine, Paddle;
- Electric – Electromagnetic, Ultrasonic (Doppler or transit time measurement).

Comparative Advantages Summary

<u>Mechanical Types</u>

- Simple to install and operate in basic form;
- Low setup and installation cost;
- Accurate performance when maintained;
- Does not require dependant infrastructure to operate;
- Commonly available off the shelf;
- Some interchangeable with pipe sizes (propeller types).

<u>Electronic Types</u>

- Much more durable than mechanical, lower wear particularly with turbid water;
- Higher setup and installation cost but cheaper long term (NPV basis);
- Lower maintenance / greater reliability;
- Most accurate and consistent;

- Less intrusive to pipeline flows;
- Better suited to automated and quality data collection;
- Can be interchangeable with pipe sizes;
- Higher water velocity range, accurate at very high and low velocities.

Price indications in the following tables are indicative indicators only. Depending upon the intended metering application additional support infrastructure may also be required. To obtain a true indication of price comparisons between meter types, brands and supplier the actual application must be fully costed. Actual prices need to be sourced from local suppliers to obtain a true comparison of price between different meter types. Metering prices can vary significantly between manufacturers and suppliers for the same type of meter.

The following tables provide a breakdown of various types of water meters suited to full pipe situations.

Table 17. Inline Paddle Meter

1	Equipment:	PADDLE METER (INLINE)
2	Types:	MECHANICAL - FULL FLOW
3	Components:	Small paddle that spins on bearings perpendicular to the flow of water
4	Dependant infrastructure requirements:	None if data output is solely mechanical. Otherwise electricity, electronic data loggers and/or transmitters
5	Typical application:	Basic pump systems, relatively clean water where ease of service, use and low establishment costs are preferred to long term cost efficiency and consistent accuracy
6	History of use:	One of the earliest metering devices used in piped systems evolving from Dethridge Wheel
7	Water Use Efficiency Statistics:	High Headloss up to 0.4m although part flow types much less. Less accurate than electric types typically to 2-5% or higher as wear progresses with age
8	Limiting factors:	High wear factor in turbid water particularly with sand particles, low service life, cannot be buried, inaccurate at low flows, unsuited to high flows, easily fouled or tampered with. Limited flow range size dependant from 9:1 to 15:1. Requires full pipe water volume
9	Recent technological advancements:	Modernised with electronic data collection, processing and linkage to telemetry
10	Current Research:	Efficiency studies indicate that these meters in practice tend to be more inaccurate than expected due to poor maintenance and monitoring of performance and continued usage beyond service life
11	Case study examples of performance:	N/A
12	Recommended application:	Low initial cost systems where backup infrastructure such as power generation are not easily deployable or where product service backup is basic and meter accuracy is less critical. User friendly meter reading.
13	Establishment Procedures:	Conduct selection criteria overview. Select most efficient meter specification to match pump line operating design characteristics and statutory requirements. Select appropriate location along

1	Equipment:	PADDLE METER (INLINE)
		pipeline with reference to laminar flow and away from components generating turbulence[1] and with appropriate access
14	Operational procedures:	Initial calibration is factory set. Timeline meter recording manual or auto. Manage maintenance program based on periodic checks for efficiency repair and replacement
15	Brands and Manufactures:	Multiple – US, Europe and China manufactured
16	Availability in Aust.:	Commonly available
17	Market Distribution:	Widely distributed
18	Life Span:	4 years depending on water quality
19	Indicative price:	Size dependant
20	Case study establishment price:	N/A
21	Case study Operating Costs:	N/A
22	Repairs and maintenance requirements:	Specialised skills to repair. Easily serviced in the field as a modular device that can be swapped over to reduce delay
23	Case study maintenance and Repair costs:	N/A
24	Part costs and availability:	Readily available
25	Case study Energy use:	N/A
26	Ability to perform to specifications:	Deteriorates with age
27	Identified problems or faults:	Subject to fouled or damaged vanes, wear to bearings and vanes and progressive inaccurate measurement
28	User Comments:	N/A
29	Capacity for expansion:	Available in many pipe sizes
30	Associated carbon emissions:	N/A

Table 18. Insertion paddle meter

1	Equipment:	PADDLE METER (INSERTION)
2	Types:	MECHANICAL - PART FLOW
3	Components:	Small paddle that spins on bearings perpendicular to water flow
4	Dependant infrastructure requirements:	None if data output is solely mechanical. Otherwise electricity, electronic data loggers and/or transmitters
5	Typical application:	Basic pump systems, relatively clean water where ease of service, use and low establishment costs are preferred to long term cost efficiency and consistent accuracy. Capable of higher flows than inline version

1	Equipment:	**PADDLE METER (INSERTION)**
6	History of use:	A refinement of earliest metering devices used in piped systems evolving from Dethridge Wheel
7	Water Use Efficiency Statistics:	High Headloss up to 0.2m i.e. less than in-line full flow types. Less accurate than full flow paddle meters and electric types. Accuracy typically to higher end of 2-5% of rate or higher as wear progresses with age
8	Limiting factors:	High wear factor in turbid water particularly with sand particles, low service life, cannot be buried, inaccurate at low flows, unsuited to high flows, easily fouled or tampered with. Limited flow range size dependant from 9:1 to 15:1. Requires full pipe water volume. Less accurate than inline version due to partial measurement disruption to laminar flow and generation of turbulence.
9	Recent technological advancements:	Modernised with electronic data collection, processing and linkage to telemetry
10	Current Research:	Efficiency studies indicate that these tend to be more inaccurate than expected due to poor maintenance and monitoring of performance and continued usage beyond service life.
11	Case study examples of performance:	N/A
12	Recommended application:	Low initial cost systems where backup infrastructure such as power generation are not easily deployable or where product service backup is basic and meter accuracy is less critical. User friendly meter reading.
13	Establishment Procedures:	Conduct selection criteria overview. Select most efficient meter specification to match pumpline operating design characteristics and statutory requirements. Select appropriate location along pipeline and away from components generating turbulence and with appropriate access
14	Operational procedures:	Initial calibration is factory set. Timeline meter recording manual or auto. Manage maintenance program based on periodic checks for efficiency repair and replacement
15	Brands and Manufactures:	Multiple – US, Europe and China manufactured
16	Availability in Aust.:	Commonly available
17	Market Distribution:	Australia wide
18	Life Span:	4 years depending on water quality
19	Indicative price:	$750
20	Case study establishment price:	N/A
21	Case study Operating Costs:	N/A
22	Repairs and maintenance requirements:	Specialised skills to repair. Easily serviced in the field as a modular device that can be swapped over to reduce delay
23	Case study maintenance and Repair costs:	N/A
24	Part costs and availability:	Available
25	Case study Energy use:	N/A

1	Equipment:	PADDLE METER (INSERTION)
26	Ability to perform to specifications:	Deteriorates with age, must have full pipe.
27	Identified problems or faults:	Subject to fouled or damaged vanes, wear to bearings and vanes and progressive inaccurate measurement
28	User Comments:	Low level of accuracy, short term metering measure, easy to remove.
29	Capacity for expansion:	Available in many pipe sizes
30	Associated carbon emissions:	N/A

Table 19. Turbine Water Meter

1	Equipment:	TURBINE METER
2	Types:	MECHANICAL FULL FLOW (INLINE)
3	Components:	Flange-mounted turbine that spins on bearings in the full flow of water with axis parallel to water flow
4	Dependant infrastructure requirements:	None if data output is solely mechanical. Otherwise electricity, electronic data loggers and/or transmitters
5	Typical application:	Basic pump systems, relatively clean water where ease of service, use and low establishment costs are preferred to long term cost efficiency and consistent accuracy
6	History of use:	Evolved after Paddle type and is more energy efficient.
7	Water Use Efficiency Statistics:	High Headloss up to 0.2m. Less accurate than electric types typically to 2-5% of rate or higher as wear progresses with age
8	Limiting factors:	High wear factor in turbid water particularly with sand particles, low service life, cannot be buried, inaccurate at low flows, unsuited to very high flows, easily fouled or tampered with. Limited flow range 30:1. Requires full pipe water volume
9	Recent technological advancements:	Modernised with electronic data collection, processing and linkage to telemetry
10	Current Research:	N/A
11	Case study examples of performance:	N/A
12	Recommended application:	Low initial cost systems where backup infrastructure such as power generation are not easily deployable or where product service backup is basic and meter accuracy is less critical. User friendly meter reading. Suited to higher flow rates than other mechanical meters
13	Establishment Procedures:	Conduct selection criteria overview. Select most efficient meter specification to match pumpline operating design characteristics & statutory requirements. Select appropriate location along pipeline and away from components generating turbulence and with appropriate access
14	Operational procedures:	Initial calibration is factory set. Timeline meter recording manual or auto. Manage maintenance program based on periodic checks for efficiency repair and replacement

1	Equipment:	TURBINE METER
15	Brands and Manufactures:	Multiple – Waltman, Bermad and ARAD
16	Availability in Aust.:	Commonly available
17	Market Distribution:	Australia
18	Life Span:	4 years depending on water quality
19	Indicative price:	Size dependant
20	Case study establishment price:	200 mm - $2,000
21	Case study Operating Costs:	N/A
22	Repairs and maintenance requirements:	Specialised skills to repair. Easily serviced in the field as a modular device that can be swapped over to reduce delay
23	Case study maintenance and Repair costs:	N/A
24	Part costs and availability:	Available
25	Case study Energy use:	Headloss characteristics (up to 0.2m) need to be factored into pump design. Higher headloss devices require higher energy usage at the pump to meet delivery requirements
26	Ability to perform to specifications:	Deteriorates with age
27	Identified problems or faults:	Subject to fouled or damaged vanes, wear to bearings and vanes and progressive inaccurate measurement.
28	User Comments:	Issues related to wear Susceptible to debris
29	Capacity for expansion:	Available in many pipe sizes
30	Associated carbon emissions:	N/A

Table 20. Propeller Water Meter

1	Equipment:	PROPELLER METER
2	Types:	MECHANICAL
3	Components:	Propeller mounted inside pipe that spins on bearings on axis parallel to pipe
4	Dependant infrastructure requirements:	None if data output is solely mechanical. Otherwise electricity, electronic data loggers and/or transmitters
5	Typical application:	Basic pump systems, relatively clean water where ease of installation, service, use and low establishment costs are preferred to long term cost efficiency and consistent accuracy
6	History of use:	Evolved after Paddle type and is more energy efficient. Mainly used in pipes up to 100mm diameter and where ease of installation is desired.

1	Equipment:	**PROPELLER METER**
7	Water Use Efficiency Statistics:	High Headloss up to 0.12m. Less accurate than electric types typically to 2% of rate or higher as wear progresses with age
8	Limiting factors:	High wear factor in turbid water particularly with sand particles, low service life, cannot be buried, inaccurate at low flows, mostly unsuited to very high flows, easily fouled or tampered with. Limited flow range up to 16:1 Size dependant. Requires full pipe water volume
9	Recent technological advancements:	Modernised with electronic data collection, processing and linkage to telemetry
10	Current Research:	N/A
11	Case study examples of performance:	N/A
12	Recommended application:	Low initial cost systems where backup infrastructure such as power generation are not easily deployable or where product service backup is basic and meter accuracy is less critical. User friendly meter reading. Suited to higher flow rates than other mechanical meters
13	Establishment Procedures:	Conduct selection criteria overview. Select most efficient meter specification to match pumpline operating design characteristics & statutory requirements. Select appropriate location along pipeline with reference to laminar flow and away from components generating turbulence[1] and with appropriate access. Propeller should be located at the centrepoint of pipe radius for accuracy
14	Operational procedures:	Initial calibration is factory set. Timeline meter recording manual or auto. Manage maintenance program based on periodic checks for efficiency repair and replacement
15	Brands and Manufactures:	Multiple – Waltman, Bermad and ARAD
16	Availability in Aust.:	Commonly available
17	Market Distribution:	Australia
18	Life Span:	4 years depending on water quality
19	Indicative price:	Pipe size dependant
20	Case study establishment price:	200 mm - $ 1,950 and 600mm - $6,000
21	Case study Operating Costs:	N/A
22	Repairs and maintenance requirements:	Specialised skills to repair. Easily serviced in the field as a modular device that can be swapped over to reduce delay
23	Case study maintenance and Repair costs:	N/A
24	Part costs and availability:	available
25	Case study Energy use:	Headloss characteristics (up to 0.12m) need to be factored into pump design. Higher headloss devices require higher energy usage at the pump to meet delivery requirements
26	Ability to perform to specifications:	Deteriorates with age

1	Equipment:	**PROPELLER METER**
27	Identified problems or faults:	Subject to fouled or damaged vanes, wear to bearings and vanes and progressive inaccurate measurement
28	User Comments:	Correct placement at centre of pipe radius increases accuracy
29	Capacity for expansion:	Interchangeable between various pipe sizes
30	Associated carbon emissions:	N/A

Table 21. Electromagnetic Water Meter

1	Equipment:	**Electromagnetic METER**
2	Types:	FULL FLOW
3	Components:	An electric field is induced across the section of pipe and a measurement taken of the change in voltage relative to the flow of conductive fluid i.e. water. Electronic sensors measures voltage which increases with flow velocity and sends it to a transmitter which calculates the flow rate
4	Dependant infrastructure requirements:	Electrical power mains, solar and or battery powered AC or DC, electronic data loggers and/or transmitters
5	Typical application:	Accurate, high flow, long life, low maintenance meter. Good long term cost efficiency and consistent high accuracy. Low wear and nil fouling characteristics conducive to unclean water conditions. May be damaged by abrasive sand. Can be buried. Matches well when electronic data collection and analysis systems are preferred
6	History of use:	Gaining prominence as a measurement system in irrigation practice as the importance of water efficiency and management, value of water and the level of quantifiable volume for trading purposes increase due to long term consistency and high accuracy.
7	Water Use Efficiency Statistics:	Negligible Headloss. High accuracy 0.5% to2% of rate. Can measure a wide range of flow up 1000:1
8	Limiting factors:	Requires full pipe water volume. Availability of dependant infrastructure. Security and environmental protection of dependant infrastructure
9	Recent technological advancements:	Solar power systems for remote power supply
10	Current Research:	N/A
11	Case study examples of performance:	N/A
12	Recommended application:	Full pipe
13	Establishment Procedures:	Conduct selection criteria overview. Select most efficient meter specification to match pumpline operating design characteristics & statutory requirements. Select appropriate location along pipeline with reference to laminar flow and away from components generating turbulence[1] and with appropriate access. Assess location and or availability of dependant support infrastructure

1	Equipment:	**Electromagnetic METER**
14	Operational procedures:	Initial and subsequent calibration if required is field in-situ. Meter recording is automated. Manage maintenance program based on periodic checks for calibration accuracy
15	Brands and Manufactures:	Various: Emflux, ABB, Siemens, CMC technologies
16	Availability in Aust.:	Commonly available but not off the shelf. Normally manufactured and imported to order
17	Market Distribution:	Widely available in smaller sixes. Larges sizes made to order o/s Europe and US.
18	Life Span:	20 years
19	Indicative price:	Size dependant
20	Case study establishment price:	200 mm -$3450 600 mm - $11,250
21	Case study Operating Costs:	N/A
22	Repairs and maintenance requirements:	Specialised skills to re calibrate in field. Reliable product technical support is important. Maintenance requirements are very minimal
23	Case study maintenance and Repair costs:	N/A
24	Part costs and availability:	N/A
25	Case study Energy use:	Electrical energy use for operation and measurement is negligible and can be self sustainable (solar) No pump energy demand to overcome frictional head losses
26	Ability to perform to specifications:	Long term consistency and reliability
27	Identified problems or faults:	Can be affected by stray electrical energy flowing through the flow tube. Electronic components liable to lightning damage
28	User Comments:	See below
29	Capacity for expansion:	May be limited by initial cost of support infrastructure, power in particular
30	Associated carbon emissions:	N/A

Table 22. Ultrasonic - Transit Time Water Meter

1	Equipment:	**ULTRASONIC METER**
2	Types:	TRANSIT TIME (IN LINE)
3	Components:	Module calculates velocity based on the time difference for a sound impulse to pass between two sensors
4	Dependant infrastructure requirements:	Electrical power mains, solar and or battery powered, electronic data loggers and/or transmitters
5	Typical application:	Non-flooded pipe and high turbidity situations. Accurate, high

1	Equipment:	**ULTRASONIC METER**
		flow, long life, low to nil maintenance meter. Good long term cost efficiency and consistent high accuracy. Low wear and nil fouling characteristics conducive to unclean water conditions. May be damaged by abrasive sand. Can be buried. Matches well when electronic data collection and analysis systems are preferred. Can measure bi-directional flow
6	History of use:	Gaining importance as a measurement system in irrigation practice as the importance of water efficiency and management, value of water and the level of quantifiable volume for trading purposes increase due to long term consistently high accuracy. Has largely superseded Doppler type technically due to greater capability to measure cleaner water but is not widely used
7	Water Use Efficiency Statistics:	Negligible Headloss. High accuracy better than 2% of rate. Can measure a wide range of flow up 150:1
8	Limiting factors:	Availability of dependant infrastructure. Security and environmental protection of dependant infrastructure.
9	Recent technological advancements:	Solar power systems for remote power supply
10	Current Research:	Development and refinement of meters using transit time and Doppler effect
11	Case study examples of performance:	N/A
12	Recommended application:	Dirty water, non flooded pipelines
13	Establishment Procedures:	Conduct selection criteria overview. Select most efficient meter specification to match pumpline operating design characteristics & statutory requirements. Select appropriate location along pipeline and away from components generating turbulence and with appropriate access. Assess location and or availability of dependant support infrastructure
14	Operational procedures:	Initial and subsequent calibration if required is field in-situ. Meter recording is automated. Manage maintenance program based on periodic checks for calibration accuracy
15	Brands and Manufactures:	Various: Siemens
16	Availability in Aust.:	Not widely available
17	Market Distribution:	N/A
18	Life Span:	15 years
19	Indicative price:	$6,500 to $10,000 multiple pipe size capacity
20	Case study establishment price:	N/A
21	Case study Operating Costs:	N/A
22	Repairs and maintenance requirements:	Specialised skills to re calibrate in field. Reliable product technical support is important. Maintenance requirements are very minimal
23	Case study maintenance and Repair costs:	N/A
24	Part costs and availability:	N/A

1	Equipment:	ULTRASONIC METER
25	Case study Energy use:	Electrical energy use for operation and measurement is negligible and can be self sustainable (solar) No pump energy demand to overcome frictional head losses
26	Ability to perform to specifications:	Long term consistency and reliability
27	Identified problems or faults:	Can be affected by stray electrical energy flowing through the flow tube. Electronic components liable to lightning damage
28	User Comments:	Interchangeable with various pipe sizes
29	Capacity for expansion:	May be limited by initial cost of support infrastructure, power in particular
30	Associated carbon emissions:	N/A

Table 23. Ultrasonic - Doppler Water Meter

1	Equipment:	ULTRASONIC METER
2	Types:	DOPPLER (INSERTION MOSTLY)
3	Components:	Module calculates velocity from differences in frequency of sound waves reflected from sound waves sent and reflected off particles in the water
4	Dependant infrastructure requirements:	Electrical power mains, solar and or battery powered, electronic data loggers and/or transmitters
5	Typical application:	Non-flooded pipe and high turbidity situations. Accurate, high flow, long life, low to nil maintenance meter. Good long term cost efficiency and consistent high accuracy. Low wear and nil fouling characteristics conducive to unclean water conditions. May be damaged by abrasive sand. Can be buried. Matches well when electronic data collection and analysis systems are preferred. Can measure bi-directional flow
6	History of use:	This was the first type of Ultrasonic meter developed and is gaining prominence as a measurement system in irrigation practice with the importance of water efficiency and management, value of water and the level of quantifiable volume for trading purposes increase due to long term consistency and high accuracy
7	Water Use Efficiency Statistics:	Negligible Headloss. High accuracy better than 2% of rate. Can measure a wide range of flow up 150:1
8	Limiting factors:	Availability of dependant infrastructure. Security and environmental protection of dependant infrastructure. Not suitable for measurement of very clean water flows unless air particles are introduced. Insertion types more prone to wear than non insertion and transit time types
9	Recent technological advancements:	Solar power systems for remote power supply
10	Current Research:	Development and refinement of meters combining transit time and Doppler effect. Doppler meters can be more accurate with muddy water

1	Equipment:	**ULTRASONIC METER**
11	Case study examples of performance:	N/A
12	Recommended application:	Dirty water, non flooded pipelines
13	Establishment Procedures:	Conduct selection criteria overview. Select most efficient meter specification to match pumpline operating design characteristics & statutory requirements. Select appropriate location along pipeline and away from components generating turbulence and with appropriate access. Assess location and or availability of dependant support infrastructure
14	Operational procedures:	Initial and subsequent calibration if required is field in-situ. Meter recording is automated. Manage maintenance program based on periodic checks for calibration accuracy
15	Brands and Manufactures:	Various: MACE
16	Availability in Aust.:	Available from specialised stockists
17	Market Distribution:	Wide
18	Life Span:	15 years
19	Indicative price:	$4,000 to $7,500
20	Case study establishment price:	N/A
21	Case study Operating Costs:	N/A
22	Repairs and maintenance requirements:	Specialised skills to calibrate in field. Reliable product technical support is important. Maintenance requirements are very minimal if any
23	Case study maintenance and Repair costs:	N/A
24	Part costs and availability:	N/A
25	Case study Energy use:	Electrical energy use for operation and measurement is negligible and can be self sustainable (solar) No pump energy demand to overcome frictional head losses
26	Ability to perform to specifications:	Long term consistency and reliability
27	Identified problems or faults:	Electronic components liable to lightning damage
28	User Comments:	Interchangeable with various pipe sizes
29	Capacity for expansion:	May be limited by initial cost of support infrastructure, power in particular
30	Associated carbon emissions:	N/A

Overall grower comments indicate the following:

- Long term metering focus is for either Magflow, Ultrasonic Doppler or Transit time.
- An even distribution of positive comments between Magflows and Doppler Ultrasonic.

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5.2. Soil water monitoring

5.2.1. Overview

Proficient management and scheduling of water requirements for irrigated crops is essential to optimising yields and returns to all cost inputs and not just the cost of water. It also leads to sustainable water use, soil and environmental management. Tools for measuring and processing soil moisture are integral to the decision making process in efficient management and scheduling. Selecting the most suitable monitoring tool is essentially about maximising cost benefit.

In general, more intensive irrigation systems benefit in efficiency gains with more thorough management and scheduling practices and there are highly developed monitoring systems available to meet requirements. In less intensive situations, simpler, cheaper devices may well be the most practical and cost effective. There are many considerations in identifying the device best suited to the purpose.

5.2.2. Selecting a Soil Water Monitoring Device

Following is a summary of questions and points to consider in selecting a device:

- What information can I get from soil water monitoring device?
  - Wet/dry measurements;
  - Depth and amount of irrigation;
  - Root activity and development;
  - Extent of any water tables within or just below a crop root zone;
  - Irrigation Scheduling.

- How labour-intensive is the device?
  - Labour availability
  - Manually read devices versus automatic logging devices

- How usable is the information from the device?
  - Presentation & Interpretation, eg. Graphs, charts & software

- Support software, training & product support

- What level of accuracy do I need?
  - Device should have an accuracy level that matches the irrigation system and degree of control it allows
  - Calibration and reliability and consistency

- Does soil type affect my choice?
  - Certain soils can affect accuracy of particular meters eg gypsum blocks in sand and capacitance probes in cracking clays can give inaccurate results

- Does the irrigation system I use limit my choice?
  - Irrigation system can affect suitability of device and how it is installed

- Does crop type limit my choice of device?
  - Profile and placement of the device must match the requirements of the crop at the monitored site.
  - Annual crop rotations and operations may prevent permanent positioning

- What other site factors affect my choice?
  - Livestock traffic
  - Crop access
  - Powering the device

- How durable is the product?
  - Ability to withstand environmental conditions
  - Susceptibility to damage in transporting instruments
  - Ability to withstand machinery and livestock traffic

- How much maintenance will it need?
  - Ability to be maintained on farm without specialised services
  - Ability to manage
  - Off-farm, on-farm support

- Can I afford it?
  - Cost benefit
  - Initial Cost
  - Maintenance Cost
  - Opportunity Cost. Can you afford not to afford it?

For more detailed information refer to:

Reference section - Website Links, 'Soil water monitoring: choosing the right device.'

5.2.3. Soil Water Monitoring Devices Available by Type and Product

Available products have been listed by grouping type below. This list is by no means exhaustive and is not an endorsement of any particular product brand or type.

Porous media:

- Tensiometers measured by handheld transducer
- Gauge type tensiometers
- UMS tensiometer
- Gypsum blocks
- Granular matrix sensor
- Watermatic sensor
- Soil Matric Potential Thermal Heat Sensor (Campbell Scientific CS229)

Frequency domain reflectometry (capacitance):

- Sentek EnviroSCAN®, EnviroSMART™, TriSCAN®
- Sentek EasyAg®
- Sentek Diviner 2000®
- C-Probe™ and C-Probe III
- Gopher® and MicroGopher®
- GLRL™ - Odyssey
- ECH2O® Probe
- ThetaProbe and MP406
- WET Sensor
- PR2 Profile Probe
- EnviroPro®
- Diviner

Time domain reflectometry (TDR) and time delay transmission:

- TRASE System 1 and MiniTRASE TDR
- Campbell Scientific TDR100
- Water Content Reflectometer (Campbell 615)
- Aquaflex
- Gro-Point

Neutron moderation

- Neutron Moisture Meter

Wetting front detection

- FullStop

For further information on products available see the reference section below:

'A list of Soil Monitoring Devices. NSW Agriculture'

5.2.4. Selecting a System

The selection of a monitoring system is probably best undertaken with the assistance of a state agriculture department Irrigation Officer or independent consultant as a starting point. The background information provided in this article should additionally assist an irrigator to competently partake in the decision making process and knowledgeably negotiate with suppliers.

The purpose of the following tables is to illustrate what kind of differences exist and what to look for in examining a system to match an irrigators need. The following tables are random comparisons illustrating some types of water monitoring devices used commercially in Australia. It is not an endorsement of any particular product or brand or an indication one product is superior or inferior to another. References are made to other brands in the same category.

5.2.5. Suction Measurement Systems

Porous media instruments are made from materials that are porous to water, i.e. materials through which water can move and be stored in the pores. Water is drawn out of the porous medium in a dry soil, and from the soil into the medium in a wet soil. Porous media instruments measure soil water potential and take three forms:

- tensiometers
- resistance blocks
- combination volumetric SWC–porous material devices.

Table 24. Porous Media

1	Equipment:	TENSIOMETERS
2	Type	Porous media instrument directly measures soil moisture suction. • Gauge • Hand - held transducer
3	Components:	Porous ceramic tip, a sealed water-filled plastic tube and a vacuum gauge.
4	Dependant infrastructure requirements:	Can be handheld manual reading, handheld transducer device or transducer device installed in the device and connected to a logger/computer
5	Typical application:	Monitoring most annual vegetable crops, orchards, nuts and pastures
6	History of use:	Some of the earliest devices used
7	Water Use Efficiency Statistics:	The soil suction reading relates directly to the plant water tension, and hence is a more meaningful measure of plant stress than soil water content measurements.
8	Limiting factors:	Tensiometers cannot be used to measure soil water suction greater than 75 kPa. Removing the bung during refilling can lead to the tensiometer moving and problems caused by loss of soil contact.
9	Recent technological advancements:	Transducer instruments for manual reading, data logging for automated reporting, recording and scheduling
10	Current Research:	Not known
11	Case study examples of performance:	Field with 2 monitoring sites and 3 depths monitored at each site = 6 tubes + 1 Gauge
12	Recommended application:	Low cost, fixed depth. Monitoring most annual vegetable crops, orchards, nuts and pastures where the measurement range is suited to management and scheduling of irrigation
13	Establishment Procedures:	The tensiometer must be airtight. To test this fill the tensiometer with water, place it in the sun and read it every half a day. A reading from 70 to 80 kPa should be reached before air enters

1	Equipment:	TENSIOMETERS
		the tensiometer causing the reading to revert to zero. To install the tensiometer, a hole is augered to the desired depth. It is then inserted and the tip is surrounded by finely ground, tamped soil to ensure excellent contact. The rest of the hole is then filled with a mixture of bentonite and soil to ensure water doesn't flow down between the tensiometer and the soil.
14	Operational procedures:	**Calibration.** As tensiometers measure soil-water suction, calibration to soil type is not required. The transducer in the handheld meter is pre-calibrated to kPa. Gauge types are preset to sea level atmospheric pressure. If used at higher altitudes a screw re-zeroes the gauge. No further calibration is required. **Data handling**. Meters are available with and without internal memory. Manual readings can be either recorded using graph paper or entered into a computer spreadsheet. The computer gauge (SoilSpec) comes with custom software to allow downloading, viewing and storage of readings
15	Brands and Manufactures:	SoilSpec, MEA & others see reference: NSW Agriculture. 2002. Soil Water Monitoring; List of Devices and Distributors
16	Availability in Aust.:	Readily Available
17	Market Distribution:	Worldwide
18	Life Span:	Will last many years with regular maintenance and care in handling and with minimal handling
19	Indicative price:	Example: Soilspec Brand Tubes, short/long = \$35.00 - \$43.00 Gauge = \$500.00 - \$900.00
20	Case study establishment price:	\$982.00 + 2 hrs labour
21	Case study Operating Costs:	Allow say 1 hr labour for monitoring (depending how far apart monitors are stationed) X frequency of monitoring
22	Repairs and maintenance requirements:	In a dry soil, water will be drawn out of the tensiometer more quickly than in a wetter soil. If the level drops more than 2 cm from the top, readings become inaccurate. The water level in the viewing tube should be checked at least weekly and refilled if necessary. If located in a frost prone area, methylated spirits (50 mL/L water) can be added to the tube to stop freezing. The rubber septum, which perishes and degrades after being pierced many times by the meter needle, should be covered and replaced regularly. A vacuum pump is used to remove trapped air from gauge type tensiometers.
23	Case study maintenance and Repair costs:	Easy and cheap to repair and maintain
24	Part costs and availability:	Relatively cheap, readily available
25	Case study Energy use:	Not relevant, negligible to non energy use, however efficient monitoring and scheduling should translate to energy savings at the pump
26	Ability to perform to specifications:	Well established
27	Identified problems or faults:	High maintenance requirement to maintain data quality. Difficult to convert to soil water content (SWC). Makes calculating irrigation amount needed harder
28	User Comments:	A fairly labour intensive method
29	Capacity for expansion:	Can be completely modular and therefore readily expandable

Table 25. Porous Media - Gypsum Blocks

1	Equipment:	GRANULAR MATRIX SENSOR
2	Type	**Porous media Instrument** directly measures soil moisture by electrical resistance.
3	Components:	•Sensor consists of two concentric electrodes buried in a special reference matrix material (granular quartz) that is held in place by a stainless steel case. •The matrix material reflects the maximum change of electrical resistance over the growth range of production crops. Soil moisture is constantly being absorbed or released from the sensor. As the soil dries out the sensor moisture is reduced and the electrical resistance between the electrodes is increased. The measured resistance gives a read out of soil moisture water suction. The sensor includes internally installed gypsum which provides buffering against salinity effects
4	Dependant infrastructure requirements:	Requires AC excitation and a device to read AC output (Transducer). Optional: data logger, cable, computer for automated systems
5	Typical application:	Suited to fixed monitoring perennial crops
6	History of use:	This sensor type is well established and accepted for many years.
7	Water Use Efficiency Statistics:	Good measurement range, 10 - 200kpa. Allows accurate monitoring of water stress for a broad range of crops
8	Limiting factors:	Labour intensive when manually read. Measures soil water tension, which is good indication of **when** to irrigate not **how much.** Does not work well in sandy soils, where the moisture drains more quickly than the sensor can equilibrate. Difficult to convert to SWC. Makes calculating amount of irrigation required harder.
9	Recent technological advancements:	Design improvements include modular interface connectivity with up to 3 sensors per amplifier
10	Current Research:	No current research found
11	Case study examples of performance:	WaterMark. Field with 2 monitoring sites and 3 depths monitored at each site = 6 probes + Optional, 1 logger (manual reader) or battery logger + shuttle system + pc Or else telemetry system
12	Recommended application:	Low to high cost depending on configuration, usually fixed depth. Monitoring capability is suited to most crops. Small bore holes means easy installation suitable for annual crops
13	Establishment Procedures:	It is installed in an augered hole and should be surrounded by fine soil and backfilled with soil bentonite mix to stop preferential flow.
14	Operational procedures:	Data is recorded by a handheld meter and manually recorded or stored on a computer. Soil water tension data requires no further calculation and can be compared with target figures for the specific crop and growth stage
15	Brands and Manufactures:	Watermark, GBLite
16	Availability in Aust.:	Readily Available

1	Equipment:	GRANULAR MATRIX SENSOR
17	Market Distribution:	Worldwide
18	Life Span:	Life-span depends on soil acidity and water flow. Usually last 7 to 10 years (probes)
19	Indicative price:	•WaterMark. Field with 2 monitoring sites and 3 depths monitored at each site = •Probe = $60.00ea •Optional, 1 logger (manual reader) = $750.00 •or battery logger $550.00 + shuttle system $1100.00 = $1650.00 •Or else telemetry system + $1600.00 •+ PC + Installation costs
20	Case study establishment price:	$1,110.00 - $3,560.00 + PC + Installation costs Depending on manual or automated options
21	Case study Operating Costs:	Nil
22	Repairs and maintenance requirements:	Pre-calibrated Granular matrix sensors are maintenance free.
23	Case study maintenance and Repair costs:	None when correctly matched to instrument capabilities
24	Part costs and availability:	Can be expensive particularly as modules are considered replaceable not repairable, readily available
25	Case study Energy use:	Not relevant, negligible to non energy use, however efficient monitoring and scheduling should translate to energy savings at the pump
26	Ability to perform to specifications:	Well established
27	Identified problems or faults:	If it dries out too much the sensor must be removed and wet again.
28	User Comments:	Relatively cheap and reliable
29	Capacity for expansion:	Can be completely modular and therefore readily expandable

5.2.6. Wetting Front Detection

Table 26. Wetting Front Detection

1	Equipment:	WETTING FRONT DETECTION
2	Types:	Porous media instrument designed to suit the situation where the only information required is the time when the wetting front arrives at a set depth in the soil.
3	Components:	Wetting-front detectors are soil moisture switches either mechanical or electrical, that are buried at locations of interest. It is a funnel shaped object with a sand filter at its base allowing water to pass into a float chamber where it either activates a float switch or raises a float flag. When soil moisture increases above a set point the detector

1	Equipment:	**WETTING FRONT DETECTION**
		switches on; when the soil dries to below the set point the detector is activated, giving the signal water has reached a given depth.
4	Dependant infrastructure requirements:	Practically nil
5	Typical application:	The FullStop is designed to complement existing logged equipment or as an entry-level learning tool. It can detect wetting fronts in all soils, particularly with overhead and drip irrigation. **Warning signals.** If a wetting-front detector is placed near the bottom of the root zone it can act as a warning signal that over-irrigation is occurring. Irrigation beyond this depth is wasted because the crop cannot get access to this water. Farmers can use a wetting-front detector to reduce over-irrigation, fertiliser loss and water-logging and, as a consequence, to increase crop yield. **Regulating how much water is irrigated.** Wetting-front detectors placed within the root zone can be used to regulate the amount of irrigation to the crop's water demand by turning off the irrigation when the wetting front is detected. This regulation occurs because the wetting-front speed depends on how dry the soil is before irrigation. If the soil is relatively dry, the wetting front moves slowly into the soil. This occurs because the soil absorbs much of the water and slows the progress of the wetting front. Conversely, if the soil is already wet, the wetting front moves fast because the irrigation water finds little available space to occupy. **Collection of soil-water samples.** Wetting-front detectors can be designed to collect samples of soil water from the wetting front. These samples contain solutes such as salt and nitrate and, when analysed, can provide useful information about managing fertilisers and the leaching of salt from the root zone.
6	History of use:	From 2002 onwards.
7	Water Use Efficiency Statistics:	This instrument can be utilised to check real time irrigation times and penetration efficiency of soil water particularly to ensure field conditions match placement positions of existing monitor probes.
8	Limiting factors:	Does not measure or indicate gradients of SWC therefore not useful for automated scheduling. Will not detect wetting fronts moving at drier than 2 to 3 kPa and therefore may not account for weak fronts particularly attributable to light rain events or deep placement. Does not record history of soil moisture status in basic form.
9	Recent technological advancements:	Automatic indicator reset, electronic switch for logging and automated switch-off control of irrigation (in development), greater sensitivity to weak fronts
10	Current Research:	As above
11	Case study examples of performance:	Field with 2 monitoring sites and 3 depths monitored at each site = 6 detectors
12	Recommended application:	Where balance between simplicity, accuracy and cost is required. Also see section 5 above
13	Establishment Procedures:	The FullStop is large (20 cm diameter) and requires a hole of the same size to be dug during installation. Preferential flow though the disturbed soil may be an issue until the soil settles. When used with annual crops the sensor is installed after cultivation and when soil is already disturbed. No calibration.
14	Operational procedures:	The output from a FullStop is **visual** by a mechanical flag.

1	Equipment:	**WETTING FRONT DETECTION**
15	Brands and Manufactures:	FullStop™ - Australian invention manufactured in South Africa
16	Availability in Aust.:	Readily obtainable
17	Market Distribution:	Australia wide and some other countries
18	Life Span:	Long life
19	Indicative price:	$150.00 per pair + delivery
20	Case study establishment price:	$450.00 + delivery + minimal labour
21	Case study Operating Costs:	Labour requirement for monitoring and sampling activities unless switch activates an actuator to modulate equipment eg pump
22	Repairs and maintenance requirements:	FullStop requires no maintenance
23	Case study maintenance and Repair costs:	Components are cheap and replaceable. No maintenance unless mechanical damage is a problem
24	Part costs and availability:	Cheap and readily available
25	Case study Energy use:	Consumes nil power
26	Ability to perform to specifications:	Recently established
27	Identified problems or faults:	Basic flag system may not give timely alerts unless constantly observed
28	User Comments:	A good diagnostic tool for checking efficacy of fixed probe monitoring and scheduling as well as operational efficiency of irrigation systems. Also very useful system for collecting samples for monitoring nutrients and salt.
29	Capacity for expansion:	Modular units easily duplicated

5.2.7. Volumetric Water Content Systems

The dielectric constant is a measure of the capacity of a non-conducting material to transmit electromagnetic waves or pulses. Two approaches have been developed for measuring the dielectric constant of the soil water media and, through calibration, the SWC. These approaches are:

- time domain reflectometry
- frequency domain reflectometry

Table 27. Frequency Domain Reflectometry

1	Equipment:	**FREQUENCY DOMAIN REFLECTOMETRY (CAPACITANCE) Environpro**
2	Types:	**Volumetric water content systems** There are many products using different materials in construction see Brands Item 15. For example, the EnvironPro Probe commonly used in Australia is described
3	Components:	A series of capacitance sensors on a central spine. The spine is completely encapsulated and sealed inside a 35 mm diameter

1	Equipment:	**FREQUENCY DOMAIN REFLECTOMETRY (CAPACITANCE) Environpro**
		PVC tube which is inserted into the soil. The sensor measures soil moisture, electrical conductivity and temperature.
4	Dependant infrastructure requirements:	VHF base station radio to download data, PC, solar charger and antennae unit, logger with vhf radio. Interchangeable with other systems and configurations
5	Typical application:	Best suited to fixed monitoring perennial crops
6	History of use:	Use started in the mid to late 90's with significant expansion of supply over the past 6 to 8 years
7	Water Use Efficiency Statistics:	This is a sophisticated system designed to maximise management and scheduling efficiencies to gain maximum efficiency from intensive irrigation systems particularly.
8	Limiting factors:	Sensor failure requires complete replacement. Measurement is very sensitive to installation
9	Recent technological advancements:	Improvements to data logging systems and ability to interface via firmware updates. The TekSmart system packages the EnviroPro with a custom logger and integral VHF radio for remote communication.
10	Current Research:	CSIRO conducting case studies
11	Case study examples of performance:	Field with 2 monitoring sites and 3 depths (80 cm) Can do 8 sensors & measure temp, moisture, EC(salinity) + dependant infrastructure
12	Recommended application:	Fixed site monitoring used on wide range of crops
13	Establishment Procedures:	•Sensors are placed at standard 100 mm depth increments in 400 mm segments. Therefore, standard models consist of four, eight, twelve or sixteen sensors to 1600 mm depth (EP100A- 04 to EP100A-16). •**Calibration.** Two options are available: output probe data in uncalibrated form and any calibration equations are applied at the PC after download convert the raw data to standard units inside the probe. The salinity reading can also be used to adjust errors in the soil moisture reading
14	Operational procedures:	**Data handling.** The EnviroPro communication protocol (SDI-12, RS232, RS485 etc) can be changed by simple modification to the firmware. This allows linking to a range of logging facilities. The TekSmart system packages the EnviroPro with a custom logger and integral VHF radio for remote communication.
15	Brands and Manufactures:	Sentek EnviroSCAN, EnviroSMART, TriSCAN Sentek Diviner 2000, Sentek EasyAg, C-Probe and C-Probe III, Gopher and MicroGopher, GLRL – Odyssey ECH2O Probe, ThetaProbe and MP406, WET Sensor, PR2 Profile Probe, The EnviroPro soil probe (EP100A)
16	Availability in Aust.:	Readily available
17	Market Distribution:	Worldwide
18	Life Span:	Expected to be a long term solution
19	Indicative price: GST Exclusive	• 8 sensor - 80 cm probe = $1,490.00 • Star post + 3 mtr 40 mm aluminium pole to mount logger = $90.00 • 5 core cable allowing 10 metres at Base Station =

1	Equipment:	**FREQUENCY DOMAIN REFLECTOMETRY (CAPACITANCE) Environpro**
		$16.10 • Field Radio Complete - 2028 - with solar & 3dB antenna = $1,809.31 • Base station telemetry with iNTELLiLOGGER software = $2,078.73 • + PC + Installation costs
20	Case study establishment price: GST Exclusive	$9,760.80 + PC + Installation costs
21	Case study Operating Costs:	Very minimal due to automation
22	Repairs and maintenance requirements:	The EnviroPro soil probe is designed to be maintenance free.
23	Case study maintenance and Repair costs:	Equipment is sealed and modular, therefore physical damage or unit failure requires replacement
24	Part costs and availability:	Replace modular units rather than repair
25	Case study Energy use:	Very minimal, some instruments solar powered
26	Ability to perform to specifications:	Well established
27	Identified problems or faults:	Not readily moveable. Higher end establishment cost
28	User Comments:	Reliable and very stable
29	Capacity for expansion:	Can be completely modular and therefore readily expandable. Initial cost may be an impediment

5.2.8. Soil Water References and Acknowledgements

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APPENDIX D: ENGINEERING REPORT

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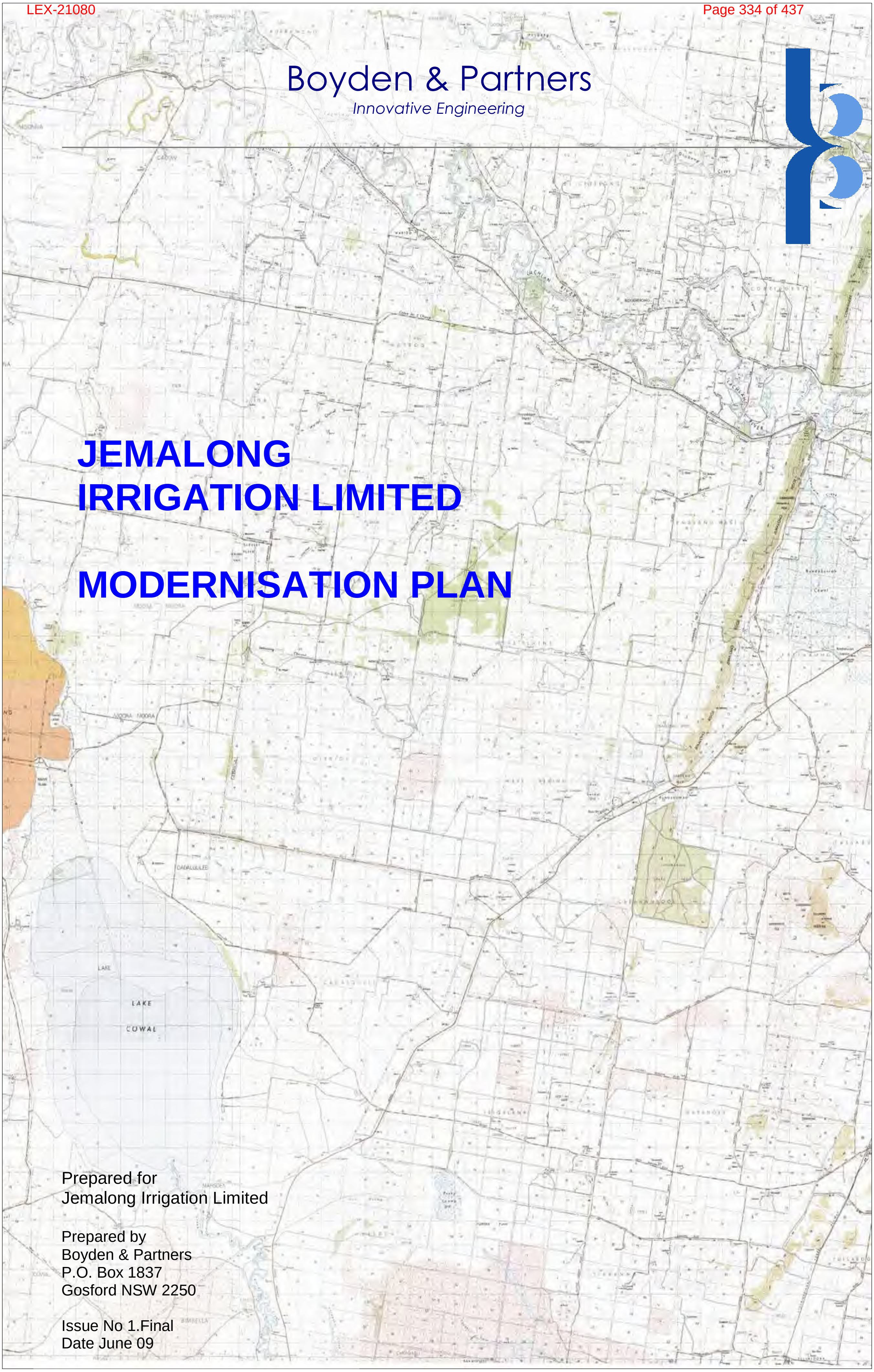

Boyden & Partners

Innovative Engineering

JEMALONG IRRIGATION LIMITED

MODERNISATION PLAN

Prepared for
Jemalong Irrigation Limited

Prepared by
Boyden & Partners
P.O. Box 1837
Gosford NSW 2250

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EXECUTIVE SUMMARY

This report has been prepared to provide engineering assistance and advice to Jemalong Irrigation Limited and to form and integral part of the Jemalong Irrigation Scheme Modernisation Plan. The preparation of the Plan has been funded by the Federal Government under part of the Water for the Future program to secure the long term water supply for all Australians.

This report has been undertaken as an investigation of the earthen channel water delivery systems that form the Jemalong Irrigation Scheme and which carry water from a pondage formed by the Jemalong Weir, located on the Lachlan River, to the farm gates of 119 properties.

The Jemalong Irrigation District is located in the Central West of NSW, approximately 387km west of Sydney. The eastern extent of the Jemalong Irrigation District and the offices of the Scheme managers, Jemalong Irrigation Limited (JIL), is located 24 km west of Forbes. Jemalong Irrigation Limited manages and maintains approximately 300km of open, earthen channels. The land area of the Jemalong Irrigation District totals 96,000ha (equal to an area of 31km x 31km). Of this area between 12,000ha and 20,000ha is irrigated from the Jemalong Irrigation Scheme. On average Jemalong Irrigation Limited diverts more than 80,000 mega litres (ML) of water from the Lachlan River each year to 119 shareholder members within the district.

This engineering investigation has focused upon identification and/or determination of the likely water losses that leak from the earthen channels to the channel surrounds and substrata during the operation of the channels as a water transport and delivery system. The anticipated channel system delivery losses were applied to separate water supply scenarios. These scenarios were then weighed against the anticipated channel system delivery losses should the Scheme remain unchanged until 2030. The burden that the reduced water allocation scenarios placed upon the Scheme was found to be significant. The proportion of water lost from the channel system was estimated to increase from 28% loss for a 75% Annual Allocation to 48% loss for an equivalent year under a reduced 43% Annual Allocation. The proportional increase of loss from the channel system is accentuated by an anticipated further reduction in water allocation as a result of the impact of forecast climate change.

This investigation has found that the Jemalong Irrigation District is characterised by two separate subsoil formations. In the northern districts of the Scheme (Division 1), particularly the Warroo Main channel, the Scheme channels are characterised by high and variable loss rates from both invert and bank leakage.

In the southern districts of the Scheme (Division 2), though still subject to some leakage, the soils within which the channels have been excavated show more regularity and are anecdotally less likely to leak the volumes or leak at the rate that the channels within Division 1 leak.

The predominant approach that has been adopted throughout this investigation has been to reduce channel transmission losses. Piping of anticipated reduced irrigation flows has been found to be the most efficient means of reducing transmission losses though the initial capital cost of piping the system or sections of it is significantly higher than synthetic lining the channels. In all cases where channel lining has been considered, the use of concrete, clay, synthetic liners and stabilised earth construction has been considered and comparatively priced as alternatives. In addition, costs for the provision of protection to the liner and maintenance of the liner has been considered and comparatively priced.

The Jemalong Irrigation Scheme presently operates a significant portion of the channels as ponded systems for an average 9 month operational period. The system is operated in this manner principally to satisfy irregular demands for supply and to facilitate the operation of the elevated Dethridge wheel meters; though keeping the channels with water in them also assists in reducing “wet-up’ losses and helps keep weed growth to a minimum. Jemalong Irrigation Limited is proactively eliminating the use of Dethridge wheels in favour of the more efficient Water Management Outlets (WMO). Because of the intricacies of the Jemalong Irrigation System it is however impossible to imagine any pipe system, other than a pressure pipe system, replacing the existing open channel system and check gates.

It is considered that lining of selected channels will increase the likelihood of the Scheme continuing to operate in its present manner though further advantage can be gained with regard to the minimisation of channel losses should a shorter operating period be able to be achieved.

It is estimated that high pressure piping of the peak demand flows within the Division 1 channels could reduce the channel losses to 2.3% at a cost of approximately $210M. Alternatively, high pressure piping of reduced flows and lining and utilisation of the existing channels within Division 1 could reduce the channel losses to 2.4% at a cost of approximately $125M. Finally, it has been estimated that synthetic lining of the existing channels within both Division 1 and Division 2 could reduce the channel transmission losses to 4.9% for a cost of approximately $100M.

INTRODUCTION

The Jemalong Irrigation District covers an area of approximately 96,000 ha, and is located in Central Western NSW between Forbes and Condobolin. It is bounded by the Lachlan River to the north, Lake Cowal to the south, Jemalong Range to the east and Bogandillon Mountain and Manna State Forest to the west (McGowen, Duff et al. 2001).

The Jemalong Irrigation District is located approximately 387 km west of Sydney. Jemalong Irrigation Limited holds an irrigation licence on the Lachlan River of 99,877ML (JIL 2004).

JEMALONG IRRIGATION LIMITED

In 1936 a weir was constructed on the Lachlan River at the point where the river breaks the Jemalong Range. This weir became the impetus of the Jemalong Irrigation District. The Jemalong-Wylde Plains Irrigation District was opened by the Water Conservation and Irrigation Commission of New South Wales. In 1941 the irrigation scheme made water available to 81 properties (JIL 2004).

During September 1951, subdivisions of approximately 565 hectares were made available by the War Service Land Settlement Board. The Jemalong-Wylde Plains Irrigation District was privatised in March 1995 to become Jemalong Irrigation District, managed by Jemalong Irrigation Limited. THE Jemalng Irrigation Limited is an unlisted public company controlled by a Board of Directors. Each irrigator landowner is a shareholder in the company. Shares are held in proportion to the water entitlements held by each member (JIL 2004).

Jemalong Irrigation Limited diverts, on average, more than 80,000 mega litres (ML) of water from the Lachlan River each year to 119 shareholders within the district. The district comprises more than 96,000 hectares of farming land of varying soil types capable of supporting a wide range of cropping and livestock enterprises (JIL 2004). At times there can be between 12,000ha and 20,000ha irrigated directly from the Jemalong Irrigation District.

METHODOLOGY

As part of Boyden and Partners engagement to examine the modernisation of the Jemalong Irrigation District, an in-depth analysis of the open-earthen channel delivery system has been undertaken. This analysis allows the estimation and forecast of measurable system losses under normal operational and forecasted conditions, including the effects of future climate change.

This analysis was undertaken in three stages. Each of these stages is designed to provide information to contribute to the next stage. A flow chart of the methodology employed in this report is indicated below, with a full description of each method shown in Appendix 1.

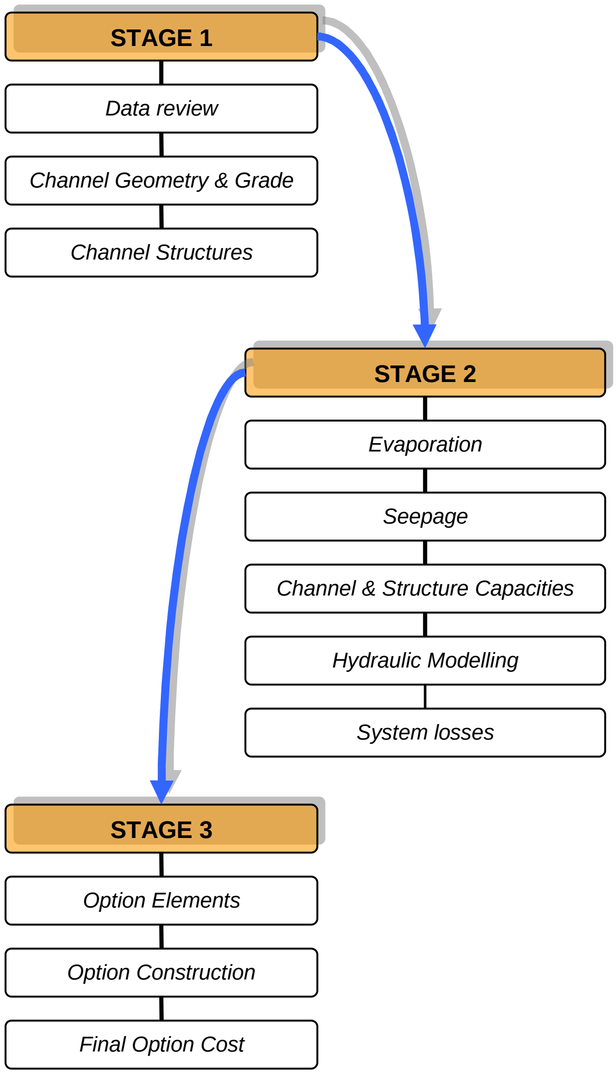


Figure 1, Flowchart of Methodology

JEMALONG IRRIGATION DISTRICT PHYSICAL CHARACTERISTICS

CHANNEL CHARACTERISTICS

The Jemalong Irrigation Limited's irrigation scheme consists of a network of open-earthen channels that total approximately 300km in length. A schematic map of the Jemalong Irrigation Limited scheme has been produced using data that was supplied by Jemalong Irrigation Limited (see Appendix 2).

An earthen channel is defined as an open channel excavated and shaped to a required cross section in natural earth or fill along a predetermined route and grade (LWRRDC 2001).

Earthen channels can be classed as lined or unlined depending on the treatment of the wetted perimeter (LWRRDC 2001). The typical channel cross-sectional shape within the Jemalong Irrigation District is trapezoidal. This shape is associated with stabilised natural streams and is easily maintained (LWRRDC 2001).

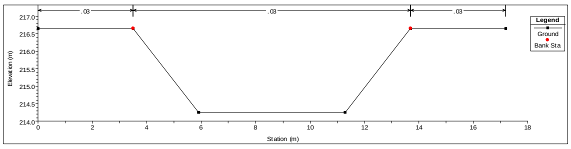


Figure 2, Typical cross section of the Jemalong Irrigation delivery system.

AGE AND CONDITION OF CHANNELS

Historic survey data supplied by Jemalong Irrigation Limited indicates that the majority of the channels in the system were constructed in the 1940's. Since this time there have been further works including the retirement of some channel reaches and excavation of others.

Image 1, Newly excavated channel (source B&P)

Channel construction and widening works were undertaken during the 1980's as part of a de-silting program. These works are ongoing and form part of the maintenance regime.

Channel dimensions vary significantly throughout the delivery system network. Channel sizes in the upper reach of the "Jemalong Main" channel have a maximum width of approximately 6 metres at the base and are 1.2 metres in depth from the top of bank level. In comparison, channel reaches further downstream in the system such as "Warroo No.5" measure approximately 0.9 metres wide and 0.46 metres in depth.

The condition of the channels observed during site visits by Boyden & Partners to the Jemalong Irrigation District was noted to be good along some parts of the channel system and fair along others.

Good channel conditions correlated with areas adjacent to paddocks used for cropping, or areas where the channel was fenced off from stock.

Fair channel conditions correlated with areas that appeared to have significant erosion in the banks, were often unfenced and in some areas appeared to have been damaged by stock access.

Significant vegetative growth was observed in many of the channels. This however will be removed before irrigating by a maintenance weed-control program.

Image 2, Typical channel showing extent of vegetation (source B&P)

Image 3, A typical channel in the Jemalong Irrigation District (source B&P)

GRADES

The longitudinal grade of an earthen channel is primarily dictated by the topography along the channel alignment. The steepest grades are determined by the maximum permissible flow velocities for the material of which the channels are primarily constructed. Longitudinal grade can be reduced if necessary using drops to restrict the grade and the velocity of the flow to the maximum allowable (LWRRDC 2001).

Grades for the Jemalong Irrigation District have been sourced from original survey maps of the irrigation scheme and Works as Executed drawings supplied by Jemalong Irrigation Limited.

From this information a grade analysis was performed on the entire scheme. The results of this analysis have been tabulated in Appendix 5 and a map has been produced (Appendix 4) outlining the relevant grades of each reach.

Grades throughout the Jemalong Irrigation District range from 0.01%-0.02% to 0.1%-0.2%. Results of the Grade Analyses have been tabulated in Appendix 4. The channels that do not appear in the table did not have any survey data provided.

From an engineering perspective, channel grades can primarily dictate what modernisation options would be viable for an irrigation scheme.

GEOLOGY

The geological characteristics of the Jemalong Irrigation District have been investigated by draping the channel schematic supplied by Jemalong Irrigation Limited, over a 1:250,000 Geological Series map for Forbes NSW sourced and geo-referenced from Geoscience Australia.

From this analysis it is evident that there are two main geological periods that contribute to the underlying geology of the Jemalong Irrigation District. These can be broken into the two distinct irrigation divisions that make up the Jemalong Irrigation District. Division 1, the northern sections, namely the Cadow and Warroo networks, and Division 2, the southern section, namely the Jemalong channels.

The material underlying Division 1 was predominately formed in the Quaternary Period up to 1.8 million years ago to as recent as 0.01 million years ago. The formations are typically alluvium deposits.

The material underlying Division 2 consists predominately of material from the Devonian Period approximately 400 million years ago. The deposits in this area are typically red sands and clay deposits.

The Jemalong Irrigation Districtcan be described as a fluviatile plain that is bounded by two prominent ranges on the east and to the west. The northern boundary of the Jemalong Irrigation District is the Lachlan River and to the south is a shallow lake called Lake Cowal.

SOILS

Surface soil information was sourced from soil maps provided by Jemalong Irrigation Limited, (Appendix 6). Indicative soil types listed throughout this area include Red Clay Loam, Red Loam, Sandy Loam, Grey Clay, Black Clay, Red Clay and Sand.

The soils map is a good indication of surface conditions. Many channel inverts have however been excavated below the surface layers and as such, there can be significant variability in soil type and, characteristics of the soil strata. Some delivery channels also have a significant layer of silt, up to 200mm in depth, in some channel locations.

Sampling of some of the soils within the channel base (invert) and batters determined that the surface soil map as supplied by Jemalong Irrigation Limited is not always an adequate representation of the actual field conditions.

AVERAGE ANNUAL GENERAL SECURITY AVAILIABLE WATER DETERMINATION

BACKGROUND

The Lachlan River extends from near Carcoar on the Belubula River in the east, and from Lake Wyangala to the south east to the Murrumbidgee River to the south west.

The region can be broken up into three zones – the upper, mid and lower catchments. The upper catchment is characterised by the elevated

undulating country of the western slopes of the Great Dividing Range. The mid-catchment is characterised

by its undulating landscape and fertile alluvial floodplains adjacent to the watercourses and includes the section of the Lachlan River between Wyangala Dam and Lake Brewster. Jemalong Irrigation Limited's area of operations is located within this section of the region. The lower catchment includes the area west of Lake Brewster and includes the broad alluvial floodplain that extends west to the Booligal Wetlands (CSIRO 2008).

The Lachlan River drains approximately 85,000 square kilometres. The Lachlan River is 1500km in length starting near Goulburn and travelling west to meet the Murrumbidgee River. Due to regulation of approximately 1300km's of the Lachlan River very little water actually reaches the Murrumbidgee. Most of the available water is used up or provides inflows to the wetlands in the lower Lachlan (DIPNR 2004).

Since the construction of the Wyangala Dam and the inclusion of two large off river storages (Lake Brewster, Lake Cargellico), and the inclusion of various other weirs and diversion structures the pattern and volume of the flows in the Lachlan River have been altered considerably (DIPNR 2004).

In 1997 the Lachlan River Management Committee was established to provide advice for the creation of environmental flow rules for the Lachlan River. The committee was made up from representatives from a wide range of stakeholder groups that included: the irrigation industry, indigenous communities, local government and state government agencies such as the Fisheries, and National Parks and Wildlife Service (DIPNR 2004).

In 2001 the Minister for Land and Water Conservation asked the Committee to make recommendations on water sharing rules for the Lachlan and as a result a draft Water Sharing Plan was prepared. In 2004 the statutory Water Sharing Plan for the Lachlan River took effect (DIPNR 2004).

Although the statutory Water Sharing Plan took effect in 2004, it has never enacted due to the Lachlan Valley being under the Drought Contingency Plan since 2003. The Drought Contingency Plan aims to conserve water by changing the traditional water delivery operations. This has allowed the Lachlan Valley to efficiently manage the low water resources (Water 2006).

WATER AVAILABILITY

An Available Water Determination (AWD) is:

"The water made available from time to time to water access licence holders. Expressed as ML/unit share (but still publicised to users as percentage allocations)" (NWC).

AWD's are determined for the different categories of access licence in each water source. An AWD is determined according to the rules set out in the water sharing plan and takes into account aspects such as climate, storage, flow levels and historic usage.

AWDs are generally announced at the start of the water year (1 July) and whenever there is an improvement in water availability. Announcements for general security licences are reviewed and updated regularly reflecting changes in the Department's assessment of available water (DWE 2009).

An Annual Average General Security Available Water Determination (AWD) has been calculated using information sourced from the statutory Water Sharing Plan for the Lachlan Regulated River Water Source 2003 - REG 31, (NSW and Government 2004).

The Lachlan Regulated River Source has the following access license categories and share components:

Water Sharing Plan Lachlan Regulated River Source		
SHARE TYPE	**PRIORITY**	**ENTITLEMENT ML/YR**
BASIC RIGHTS		
Stock & Domestic		None
Native Title		None
EXTRACTION		
Total Licensed Long term Extraction		305000
Local Water Utilities	High	15539
High security Access	High	26472 (shares)
Conveyance	High	999.4
	General	16911.6
Stock & Domestic	High	13100
General Security Access	Medium	592847 (shares)
ENVIRONMENTAL PROVISIONS		
Total Environmental share		907000*
Environmental Allocation	High	350000** (shares)

Table 1, Water Sharing Plan Components, Source (DIPNR 2004)

* By limiting long-term average annual extractions to an estimated 305,000 ML/y this plan ensures that approximately 75 percent of the long-term average annual flow in this water source (estimated to be 1,212,000 ML/y) will be preserved and will contribute to the maintenance of basic ecosystem health.

** An allowance for replenishment flows to be provided for the environment and unregulated river access licences if required, of up to 12,000 ML/y to Willandra Creek; 9,000 ML/y to Marrowie Creek; 9,000 ML/y to Torriganny/

Muggabah/Merrimajeel Creeks; and 12,500 ML/y to Booberoi Creek (DIPNR 2004).

An estimate of the long-term average annual extraction that would occur under the conditions specified under subclause (1) (a) of the statutory Water Sharing Plan for the Lachlan Regulated River Water Source 2003 Plan include:

The Long Term Average Annual Extraction Limit estimate made using the Lachlan IQQM computer model under the conditions as specified in the Water Sharing Plan indicated a long-term average annual extraction volume of approximately 305,000 ML/year.

The Maximum Average Long Term Extraction Limit set using the Lachlan IQQM computer using baseline conditions established under the Murray Darling Basin Agreement, indicate a Maximum Long-Term Average Annual Extraction volume of approximately 315,000 ML (DIPNR 2004).

The statutory Water Sharing Plan establishes that the long-term extraction limit for the Lachlan Regulated River water source is the lesser of the two above scenarios. By limiting long-term average extractions to an estimated 305,000 ML/year the Water Sharing Plan ensures that approximately 75% of the long-term average annual flow in the Lachlan River (estimated to be 1,212,000 ML/year) will be preserved and will contribute to the maintenance of basic ecosystem health (DIPNR 2004).

To calculate the average water availability or the Average Water Determination (AWD) for the Lachlan Regulated River Water Source, all access share components other than the General Security component are subtracted from the Total Licensed Average Long term Extraction Volume.

For the purpose of this estimate, with input from the State Water Operations Manager, we assume that the utilization of high security licenses is currently 100%. Local Water Utility & Stock & Domestic utilization is about 70%-80%. For the sake of our calculations we thought best to go middle range thus adopted 75%.

Conveyance water for Jemalong Irrigation Limited currently has a pseudo high security component of 999.4ML. When the general security allocation is zero this amount is still allocated. The remaining portion of Jemalong Irrigation Limited's conveyance volume (16911.6ML) is regarded as General Security.

Using the statutory Water Sharing Plan for the Lachlan Regulated Rivers limit on extractions for

General Security Access as being 1ML per unit share, gives a general security volume of 592,847ML/year.

By dividing the Total Licensed Average Long Term Extraction Volume less the high priority entitlements by the General Security Access component a percentage Average Annual General Security Volume is determined; the Average Annual Available General Security Allocation is **43%.**

Boyden & Partners

Jemalong Irrigation Limited Modernisation Plan

WATER AVAILABILITY IN THE YEAR 2030

PREDICTED EFFECTS OF CLIMATE CHANGE ON THE LACHLAN REGULATED RIVER SOURCE

The CSIRO Murray Darling Basin Sustainable Yields Project was convened by the Prime Minister on the 7th November 2006. The projects aim is to provide governments with a robust, basin wide estimate of water availability taking into account climate change predictions and other risks (CSIRO 2008).

Currently there are 18 Sustainable Yields project reports that cover a range of regions. Jemalong Irrigation Limited district falls into the Lachlan Regulated River Source which forms part of the Lachlan Region as defined in the Murray Darling Basin Sustainable Yields Project.

A summary of the key findings from the Lachlan River Region report is that currently the average surface water availability is 1139 GL/year and about 321 GL/year (28 percent) of this is used. This is a moderately high level of development and includes surface water diversions that total 292 GL/year and eventual stream flow loss that is induced by current groundwater use. Groundwater use is about 236 GL/year or 45 percent of total water use (CSIRO 2008).

Flows in the Lachlan River are highly regulated as Wyangala Dam regulates 68% of all inflows and General Security Water in the system is highly utilised at approximately 71% (CSIRO 2008).

Under the Best Estimate 2030 for the Future Climate, Future Development Model there would be a 10 percent reduction in total net diversions and a 15 percent reduction in end of system flows(CSIRO 2008).

Example of possible scenario under climate change

Water Product	Current ML/yr	% Forecasted Change	
Stock & domestic	13100	+7%	
High Security	26472 (shares)	+7%	
General Security	592847 (shares)	-9%	
Local water Utilities	15539	0	
Conveyance	17911	+7%	
Environmental Allocation	350000	-12%	
Total Licensed long term extraction	305000	-10%	271450

General Security Average Water Availability 2030	
Total Licensed long term extraction less High Security products	
Water Product	**2030 ML/yr**
Total Licensed long term extraction	305000
- 10%	274500
Stock & Domestic	13100
High Security	26472
Local water Utilities	15539
Conveyance	999.4
TOTAL	218390
General Security	592847
Conveyance general security	16911.6
Sub total	609759
TOTAL AWD %	**36%**

Table 2, Water Availability in 2030

PHYSICAL ASSETS OF JEMALONG IRRIGATION LIMITED

ASSET	AGE	CONDITION
Delivery system 300km	Approximately 69yrs old	Good
Jemalong Weir offtake	Approximately 69yrs old	Good
In channel structures	69 – 2 years old, (constantly upgrading)	Good
Scheme office	40yrs old	Good
AFFRA meter	8yrs old	Good
Work shop	50yrs old	Good
Vehicles and plant	10yrs old	Good
Dethridge wheels	Approximately 69yrs old	Good
Water Management Outlets	Approximately 3yrs old to new	Good

Table 3, physical asset age and condition

DELIVERY SYSTEM

The Jemalong Irrigation Scheme includes approximately 300km of open channel delivery system. The system is comprised of an off-take at the Jemalong Weir and a network of supply channels.

The Jemalong Weir off-take is located on the upstream side of the Jemalong Weir. The water ponds upstream of the weir, above the lip level of the off-take. In this way water can be transferred from the Lachlan River into the Jemalong channel network.

Flows through the system are regulated by check-gates. License holders receive their allocation when the water in the channel adjacent to their property has reached a level such that the Dethridge Wheel begins to function thus measuring the supply to their property.

The Jemalong Irrigation District has been divided into two divisions,

- Division 1 – The more northern channels **(Blue)**
- Division 2 – The more southern channels **(Red)**

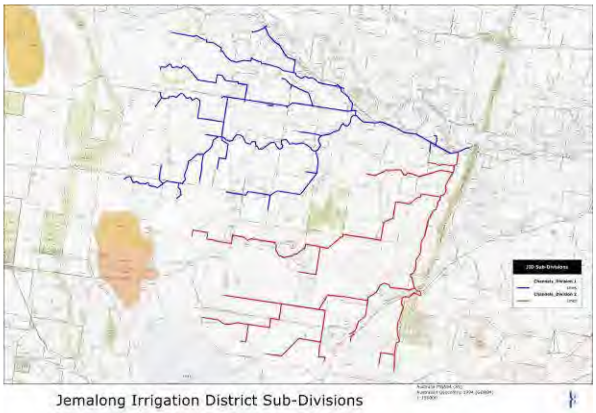


Image 4, Sub Divisions of the Jemalong Irrigation District

Simplified flow chart of the Jemalong Irrigation District delivery system

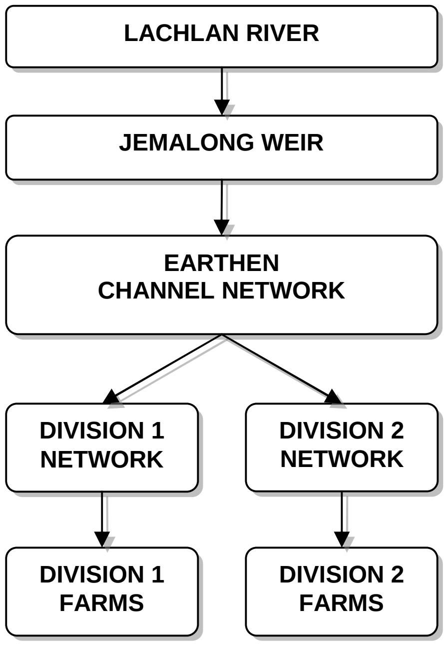


Figure 3, flow chart of the JEMALONG IRRIGATION LIMITED delivery system

JEMALONG WEIR

The Jemalong Weir is owned by State Water and is constructed of concrete and steel. It consists of 3 vertical lift gates, each measuring 12.2 m wide by 5 m in height. There are bypass gates located in each abutment that are 1.8m wide by 1.4m high.

Jemalong Irrigation system is a gravity fed system. An off-take is located on the left abutment of the Jemalong Weir and consists of a box culvert with a

4.1m wide by 1.5m high radial gate. The reported maximum capacity of the off-take supply is 800ML per day. The reported average off-take is approximately 450-600ML/day.

Image 5, Jemalong Weir

Image 6, Jemalong Irrigation Limited Offtake source B&P

A network of delivery channels transfer water from the Lachlan River to licensed irrigator properties.

STRUCTURES

Structures Data

A comprehensive record of the existing structures and their location has been recorded within a database that has been supplied to us by Jemalong Irrigation Limited. Structure locations in the channel network have been determined by chainages along the length of each channel reach.

A 'breakdown' of most of the structures has been created from the data provided to Boyden & Partners by the Jemalong Irrigation Limited and presented in Table 4 and in graphical form in Figure 4.

Type Of Structure	Qty
Road Bridge	99
Access Bridge	60
Road Culvert	79
Access Culvert	49
Access Bridge & Regulator	85
Road Bridge & Regulator	14
Access Culvert & Regulator	32
Regulator Check	260
Pipe Outlet	99
Siphon	14
Subway	64
Maintenance Culvert	3
Flood Escape	8
Other Structures	18
Inverted Siphon Metered Outlet	2
Abandoned / Removed Structure	1
Total	**887**

Table 4, Structure table

Records from the data base indicate that the majority of the structures were constructed around 1941; upgrades however have been on going up to the present day.

A breakdown of the types of structure that are present in the Jemalong Irrigation District is presented below in Figure 4.

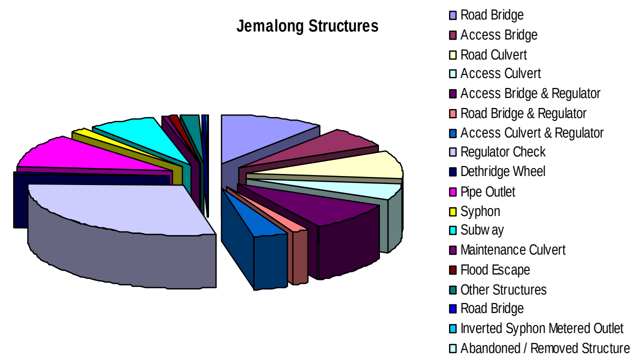


Figure 4, Breakdown of structures

From our analyses of the supplied data it is clear that the most common structure throughout the Jemalong Irrigation District is a regulator check gate. Pipe outlets are the second most common structure, followed by bridges.

Structure location data has been supplied in the form of chainages along reaches. These chainages have been manually converted to geographic locations and entered into a Geographical Information System

(GIS), thus giving each structure an approximate location coordinate.

These locations have been plotted on to a map and have formed part of the analysis of the system, (See Appendix 3).

Dethridge wheels

The Dethridge meter is a positive displacement meter and has been used by most major irrigation water providers in Australia (Hydro and Environmental 2007). The Dethridge wheel was invented in Australia in 1910 by John Dethridge, who was the commissioner of the Victorian State Rivers and Water Supply Commission at the time. Up until recently the Dethridge meter has had widespread use with over 40,000 meters installed throughout Australia. The general design and dimensions of the Dethridge wheel have remained unchanged for more than 90 years (Hydro and Environmental 2007).

The Dethridge meter reasonably accurately measures and records the volume of water delivered, under controlled laboratory conditions, given that:

- Clearances and settings of the wheel relative to the concrete emplacement are within tolerance.
- The upstream and downstream water levels are within acceptable limits.
- Flow rates are limited to between 3 ML/d and 10 ML/d.
- Water is not allowed to jet under the upstream control gate into the vanes on the wheel (Hydro and Environmental 2007).

Tests carried out in the field commissioned by Goulburn-Murray Water (Hydro and Environmental 2007), found that all Dethridge meters under measured the volume of water delivered. Volume inaccuracies were within a range of -24.1 % to -1.5%, with an average of -10% which exceeds the tolerance allowances of ± 5.0 % by a significant degree. Dethridge meters generally under measured more at lower flow rates (Hydro and Environmental 2007).

Image 7, Dethridge wheel, source B&P

The Jemalong Irrigation District uses Dethridge wheels to estimate water deliveries to the farm gate from the main delivery channels. In 2008 the accuracy of Dethridge wheel was the subject of another study completed in the Goulbourn Murray Irrigation District (Hydro and Environmental 2008). This later study found that Dethridge wheels have an average meter error of up to 6.9% in favour of the irrigator (Hydro and Environmental 2008). Although the results vary from the 2007 report to the 2008 it does highlight the level of inaccuracy that can be associated with the Dethridge wheel.

There are approximately 135 Dethridge wheels in Division 1 and 112 in Division 2 of the Jemalong Irrigation District. Dethridge wheel locations and their corresponding sizes have been located on a map in Appendix 7.

Water Management Outlets

Many Dethridge wheels in the Jemalong Irrigation District are being replaced with locally produced Water Management Outlets (WMO's). Water Management Outlets are locally constructed using HDPE pipe and come in 3 sizes, 600mm, 750mm, and 900mm. they consist of a length of HDPE pipe with a Vertical Rising Sluice gate fitted in the centre.

Image 8, WMO's locally manufactured by Jemalong Irrigation Limited

WMO's have the ability to be linked to a Supervisory Control and Data Acquisition, (SCADA) system. This would give the Jemalong Irrigation Limited greater control over its operations. The WMO can be fitted with a meter however its accuracy for water measurement is yet to be determined.

These outlets have the ability to deliver between 1-80ML a day which can increase an irrigator's efficiency by allowing the irrigator to irrigate a tract of land in less time.

Currently Jemalong Irrigation Limited has installed approximately 27 WMO's in Division 1 and 18 in Division 2. The location and relative sizes of which have been plotted on a map in Appendix 8.

METERS

The main off take at the Jemalong Weir calculates flow by using a differential system. Measurements are taken upstream and downstream of the gates and the gate opening and these are used to calculate the flow. The gates have been calibrated against hydrometric gauging.

Image 9, Jemalong Irrigation Limited offtake at Jemalong weir

In 2001-2002 Jemalong Irrigation Limited installed its own meter downstream from the Jemalong Weir off-take. The type of meter installed is an Acoustic Flow meter for Remote Areas (AFFRA). This meter is a Doppler Flow meter that continuously measures the velocity of flow.

Image 10, AFFRA meter installed by Jemalong Irrigation Limited

The Doppler Flow meter (or Ultrasonic meter) is a volumetric flow meter which measures the instantaneous and total water flow in channels and pipelines. The basic principle of it's operation employs the frequency shift (Doppler Effect) of an ultrasonic signal when it is reflected by suspended particles in motion in the water (Hydro and Environmental 2007).

Doppler Flow meters have an extremely wide flow range (0.5 ML/day to 6,000 ML/day), are robust and require minimal maintenance (Hydro and Environmental 2007). They can measure bi-

directional flow and are easy to Install (Hydro and Environmental 2007).

SCHEME LOSSES

HOTSPOTS ASSESSMENT PROJECT

The Irrigation Infrastructure Hotspots Assessment Project (Irrigation Hotspots Project) is a key component of the $5.8 billion *Sustainable Rural Water Use and Infrastructure* element of the Australian Government's *Water for the Future* initiative (DEWHA 2008).

The Hotspots Program is proposed to use a consistent and science-based approach to identify the nature, location and quantity of water losses (known as "hotspots") in existing channel and piped irrigation delivery systems across Australia (DEWHA 2008).

A hotspots assessment is initiated to identify water losses at a whole-of-system and sub-system level, by incorporating local knowledge with data from the irrigation district operators and detailed on-site investigations (DEWHA 2008).

To ensure a consistent and robust approach, the Australian Government commissioned the CSIRO to develop the *Technical Manual for Assessing Hotspots in Channel and Piped Irrigation Systems* (Technical Manual). The manual was developed through a series of workshops that involved National and International experts in irrigation and hydrology, along with Australian and state government representatives (DEWHA 2008).

The Technical Manual outlines a range of hotspot assessment methods including:

- Water balances
- Remote sensing
- Electromagnetic and airborne electromagnetic surveys
- Geo-electrical resistivity surveys
- Groundwater monitoring
- Inflow-outflow methods
- Pondage tests

A draft Hotspots desktop analysis and design report has been completed for the Jemalong Irrigation Scheme by GHD in February 2009. This draft report provides a desktop analysis of the Jemalong Irrigation District. The report uses information provided in seepage reports and the Jemalong Irrigation Limited database to estimate spatial water losses in the main delivery channel network. The draft report outlines the data gaps that exist within the system. The data gaps identified will provide the basis for the design of an on-ground Hotspot Assessment.

SCHEME LOSS ESTIMATION METHODOLOGY

Modelling of the operations of the Jemalong Irrigation Limited has been completed using a "Weir-Storage Model" for regular operations and a "Mass-Balance Loss Model" for open channel flows. The modelling procedures are detailed in Appendix 11 of this report.

MODEL OVERVIEW

Two types of model were prepared to estimate the operational losses associated with irrigation water diversions, in comparison with the losses determined from a historic water balance. Both of these models can be classified as physically-based (McKenzie 2007).

Physically based models have the ability to incorporate known physical properties such as soil percolation rates, evaporation rates and grade into the predictions of actual channel behaviour (McKenzie 2007). Physical models emphasize the generality of the subject being analysed thus are suitable for use in an ungauged area (McKenzie 2007).

WEIR-STORAGE LOSS MODEL

The Weir-Storage Loss Model is a spreadsheet-based model used to determine 'losses' associated with the storage of diversions, using a system of 'check-gates' within the existing channel network.

Depths of supply over a nominal nine-month historic operational period were assigned in this model as per operator experience and with regard to the 'Full Supply Level' on historic Works as Executed survey plans supplied by Jemalong Irrigation Limited.

The model calculates a continuous loss from both infiltration associated with the wetted perimeter area, as well as the evaporation loss from the top surface area of the regularly-operated channel reaches. The geometry and loss rates associated with the existing channel network form an integral component of loss-estimations.

The Weir-Storage Model is the best representation of the existing Jemalong Irrigation Limited operations.

MASS-BALANCE LOSS MODEL

The Mass-Balance Loss Model is also a spreadsheet-based model, similarly used to determine 'operational losses' via hydraulic distribution of diversions. This model is conceptual, such that flows are modelled as part of an 'open-channel' system, and are adjusted by a 'mass/water-balance' within each reach of the supplied channels.

The model is run by system capacities as per experienced operator advice, and by channel geometric characteristics as per historic survey plans. Hydraulic characteristics of the distributed flows such as depth are solved by the model's operation, and thereby allow an estimation of the associated losses, similar to the Weir-Storage Loss Model.

Although the Mass-Balance Loss Model is not a true representation of the regular operations of the Jemalong Irrigation network it was however, found to be particularly suitable in estimating losses associated with the open-channel diversions to the Barrick Mine. A summary of the operations of the mass balance Loss model is included in Appendix 11.

MODELLING PROCEDURES

Preliminary analysis of the Jemalong Irrigation Limited delivery system was conducted using historic Works as Executed survey plans. These plans provided the foundation data for the channel dimensions. These dimensions were also checked in the field by Boyden & Partners during field trips. Where there was found to be a significant difference between the historical data provided in the historic works-as-executed survey plans and the field surveyed data the field surveyed data was adopted.

Differences in the channel dimensions were probably associated years of use and desilting programs that were carried out in some reaches.

A nominal nine-month, averaged flow of the maximum existing allocation was adopted for the preliminary modeling. The system was initially modeled as an unrestricted hydraulic Mass-Balance Loss Model to quantify operational losses across all channel reaches. Losses were determined by the application of average seasonal evaporative rates and indicative soil type infiltration rates sourced from soil maps supplied Jemalong Irrigation Limited and from field testing by Boyden & Partners (field survey in Oct-2008). The results of this procedure tended to produce overall unrealistically high quantities of water lost.

Following a meeting with an experienced Jemalong Irrigation Limited operator in Mar-2009, the modeling procedure was modified to reflect the operator's experience, thus providing an anecdotal representation of losses from the existing delivery system.

Check-gates within the existing Jemalong Irrigation District are used to control the storage of water deliveries for later release to downstream irrigators. The system is required to be operated to the "Full Supply Level" in order to provide deliveries to the irrigator's Dethridge wheels or other lateral supply meters, often set high in the channel batters.

The Weir-Storage Model was trialled adopting system capacities from anecdotal information supplied by the scheme operator. System operation and total operational losses over 'representative years' were nominated by Jemalong Irrigation Limited. These representative years were nominated as they best represented normal operations. The years selected by Jemalong Irrigation Limited for model testing included 1995-96, 1998-99, 1999-2000, 2000-01, 2001-02 and 2002-03. Results showed that the model had a tendency to underestimate the losses that anecdotal estimations indicate are being experienced. This was considered a preliminary result.

In order to match historic water balance losses recorded, calibration of the preliminary Weir-Storage Model was conducted, by increasing infiltration rates in Division 1 uniformly. It is considered that this calibration of the model provided a good agreement with historic loss figures.

The Mass-Balance Loss Model was run for diversion supplies to the Barrick Gold Mine, downstream of "Jemalong No.2C" in Division 2. This model produced a very good correlation with the operator's knowledge of the losses that are experienced by the Barrick Mine delivery channel.

From the results achieved from the modeling the loss rates calculated were subsequently adopted for Division 2.

Due to the limited amount of physical data available the results are the best that could be established at this time. Further works are needed to quantify infiltration loss rates in all areas throughout the scheme.

Results of the models trialled are discussed in further detail in Scheme Loss Model Verification and Baseline Losses sections, in this report.

SYSTEM CAPACITIES

The delivery capacity of the Jemalong Irrigation District is constrained by the capacity of the existing channel network and the capacity of the structures within them. Preliminary estimates of the system capacities were obtained from hydraulic modelling, based upon historic and field collected survey data.

Variations in system capacities are possible and may result from:

- Channel conditions, such that the hydraulic roughness is inconsistent with previous design assumptions;
- Ongoing deterioration, erosion, and de-silting maintenance, significantly changing the cross-sectional area of the channels;
- In-line structures, which can constrain flows.

Due to the variability of the reported system capacity variations in capacity from the calculated system capacity and considering the age of the survey data, capacities of the Jemalong Irrigation District channel network were adopted as per anecdotal advice from an experienced operator.

The system capacities that were primarily derived from anecdotal advice have been plotted on a map for use in hydraulic modelling. These can be seen in Appendix 9.

ESTIMATED LOSSES

Literature Review

In undertaking our assessment of the Jemalong-Wyldes Plain Irrigation Scheme a literature review was undertaken to identify areas of the Jemalong Irrigation District that have documented evidence of seepage analysis.

Areas that have been identified in past literature are most notably the Warroo Main Channel area.

In a report titled Channel Seepage from Warroo Main Channel, Jemalong Irrigation District, published in

1993 by Water Resources (Lely 1993), investigations into seepage along the Warroo Main Channel of the Jemalong Irrigation District were carried out using an Idaho Seepage Meter test every 200m. Results were highly variable with seepage readings ranging from less than 1mm/day to over 300mm/day (Lely 1993). An estimated 50% of the Warroo Channels leakage was reported as taking place over as little as 17% of the channels total length (Lely 1993). Unfortunately this report does not indicate the location of the channel that the 17% losses are associated with. This extent of variability correlates with results from our own investigations using a simple single ring infiltrometer test. Results from two tests carried out in the Warroo Main Channel ranged from 72mm/day to 288mm/day.

Van der Lely identified that the presence or absence of deposited silts had an impact on the rate of seepage from the channel. This correlates with anecdotal information supplied by one of Jemalong Irrigation Limited's experienced operational staff who reported that there appeared to be a greater amount of seepage loss after the channels have been de-silted.

An investigation carried out by the NSW Department of Agriculture (Smith and Rose 1992), also found highly variable seepage rates along the length of the Warroo Main Channel. Tests were carried out using a method that involved the monitoring of 114 sites along the Warroo Main Channel for their Volumetric Soil Water % (VSW%) and Soil Water Content (SWC) mm. Soil salinity readings were also taken using an Electromagnetic Survey (EM31). The tests

found that seepage along the tested length of the Warroo Main Channel varied along the length of the

channel and identified that operational height of the water level and the different soil types along the channel had an impact on the soil moisture content both next to the channel and below the channel (Smith and Rose 1992).

The presence of silt deposits as identified in a later report (Lely 1993) was not identified as a contributing factor. Soil salinity results were carried out using an Electro Magnetic scan (EM31). The EM31 readings were not able to be used to quantify channel seepage but as found in other areas where they have been used they are a good indicative tool that allows for identification of areas that are likely to leak.

Adding further to the variability of seepage along the Warroo Main Channel is an investigation that was carried out by Theiss Environmental in 1995. Pondage testing was carried out and monitored over 4 reaches of the Warroo Main Channel and a total of 6.684km of channel. Results ranged from 0.24ML/day of loss to areas that recorded as high as 1.17ML/day loss (Theiss 1995).

A report into the Selection of Channel Seepage Management Options carried out by Kinhill Engineers (Kinhill 1995) also identified the highly variable nature of channel seepage within the Warroo Main Channel, quoting results from previous reports most notably (Lely 1993).

The above information has been confirmed in our own assessment of the entire Jemalong Irrigation District, in which we found loss rates from channels to be highly variable and to approximately correlate with the characteristics of the material of which they are constructed in. However in areas that were expected to be leaky we often found the contrary. This we expect is due to layers of deposited silts in some of the channel inverts and these may have contributed to skewed results.

Our best estimation of losses within the Jemalong Irrigation District has been quantified by dissemination of the data available and conservative assumptions accrued through member consultation. The elements required to make these estimations are:

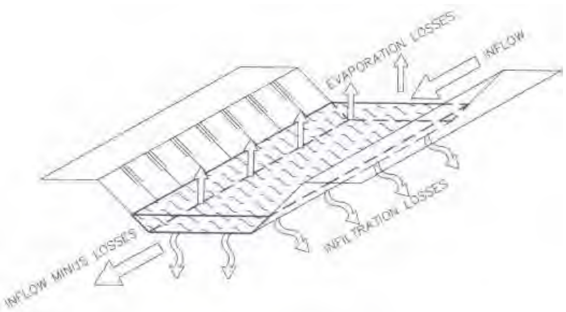


Figure 5, Elements of open-channel losses

- Channel seepage/infiltration rates
- Channel geometry
- Channel grades
- Evaporation rates
- Flow supply rates from Jemalong Weir or depths of regular operations
- Duration of flow supply
- Scheme operation information

Key elements used to quantify losses have been summarised below.

INFILTRATION/SEEPAGE

Earthen channels are rarely constructed through or made of a perfectly watertight material. In a rural area such as central NSW most schemes have been constructed in situ of local materials sourced on location (IAL 2004). Construction methods have often failed to achieve watertight barriers particularly in older channels (IAL 2004).

"Channel seepage" is defined as the diffuse movement of water through the bed and banks of irrigation channels into sub-surface layers (LWRRDC 2001).

"Channel leakage" is defined as the loss of water through a bank as a result of damage such as cracking of the bank, holes through the bank, cuts through the bank, voids around a structure, cracks, burrowing activity by aquatic biota and tree roots (LWRRDC 2001).

Channel seepage from open-earthen channels involves the relatively uniform passage of water through the wetted perimeter of the channel profile (bed and batters inclusive) due to poor-quality substrate material (IAL 2004). It does not refer to leakage that occurs due to localised cracks, holes or bank failures (IAL 2004).

Seepage processes are complex and interpretation of seepage results from a channel require knowledge of the factors affecting it. The rate of seepage from earthen channels is related to:

- The material lining the channel and material below the channel.
- Permeability of the channel bed and banks.
- Percentage of voids within the soil structure.
- Rate of capillary action and gravity.
- The chemical make up of the soil.
- The temperature of the soil.
- The channel geometry
- Depth of water within the channel.
- Shape of the channel and the wetted perimeter.
- Water quality.
- Amount of sediment carried.
- Water temperature.
- Length of time that water has been in the channel.
- Depth of water table.
- Slope of ground
- Microbiological activity.
- Barometric pressure and weather conditions.
- Surrounding vegetation.

Estimates of seepage losses are required for computing reliable water budgets, analysing system efficiencies, for sizing of planned channels and for input into hydraulic models (LWRRDC 2001). Due to the multiple factors influencing channel seepage, often closely related and acting simultaneously, it is very difficult if not practically impossible to determine the contributions each factor makes toward channel seepage (LWRRDC 2001).

Seepage rates from irrigation channels vary from site to site depending on local conditions. Studies have shown that unlined channels may lose about 150L/m2/day or 6.3mm/hr in clay loam, about 250L/m2/day or 10.4mm/hr in sandy loam, and 750L/m2/day or 31.3mm/hr or more in sandy or gravelly soil (IAL 2004). A review by the Victorian Rural Water Commission of channel seepage measurements taken between 1962 and 1983 across the Goulburn-Murray Water region found seepage ranged from 2.4 to 116L/m2/day (IAL 2004). A summary of seepage rates in various materials has been complied using information sourced from Irrigation Australia is provided in the table below.

Classification	Material	Seepage rates (L/m^2/d)
Clays and clay loams	Alluvium (unspecified)	82
	Cemented gravel and hardpan with clay loam	104
	Impervious clay loam	76-107
	Medium clay underlain with hardpan	107-152
	Clay and clay loam	125
	Ordinary clay loam, silt soil or lava ash loam	152-229
	Gravelly clay loam or sandy loam, sand and clay	229-305
Silts and silty loams	Silty loam	341
Sands and sandy loams	Sandy loam	201
	Volcanic ash	207
	Fine to medium sand	216
	Volcanic ash with some sand	299
	Sandy loam	305-457
	Sand and volcanic ash or clay	366
	Loose sandy soils	457-533
	Sandy soil with some rock	512
Gravels	Gravelly sandy soil	610-762
	Sandy and gravelly soil	671
	Very gravelly soil	914-1,829

Table 5, Seepage Rates for Unlined Channels source(IAL 2004)

JEMALONG IRRIGATION DISTRICT INFILTRATION/SEEPAGE RATES AND RESULTS

To obtain relevant loss values, a "Combined Approach" (IAL 2004), has been adopted. This entailed the use of Spatial Analysis using a GIS with geological maps, Remote Sensing using aerial photography, satellite images, topographic maps, results of indicative infiltration testing, review of seepage reports conducted by others, soil sampling, and observations reported by experienced scheme operators.

Using all the above-listed information, we were able determine for each soil type an indicative infiltration rate based upon sample infiltration testing conducted by Boyden & Partners and aligning these results with soil types taken from Jemalong Irrigation Limited soil maps (Appendix 5). These rates were compared to expected results taken from historical water balances and anecdotal evidence from experienced operation staff.

The results of the comparison showed that the indicative results were a reflection of the soil types. The results did not appear to correlate with the level of loss as indicated by anecdotal evidence in Division 2. The results however were comparable to the levels of loss associated in areas of Division 1. The skewed results of indicative testing was probably due to the state of the channel when tested being extremely dry whilst historical water balances have been recorded after the channel has been wetted up.

Image 11, Indicative infiltration testing carried out using an single ring infiltrometer source B&P

The anecdotal losses reported by Jemalong Irrigation Limited were equated to proportional infiltration/seepage rates, based upon 'regular operations'. These rates are simply coefficients that enable the models to approximately match the historic water balances, encompassing a variety of factors attributed to infiltration loss.

Infiltration loss rates adopted for recent models of representative years have been calibrated, as described in Modelling Procedures.

EVAPORATION

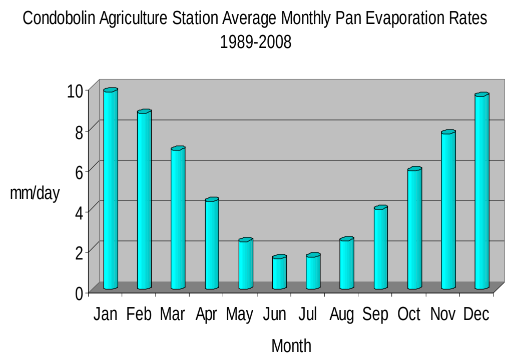
The historic evaporation loss rates used for the hydraulic modelling were derived from data provided by the Condobolin Agriculture Research Station (CARS). This data set was favoured over Forbes BOM data set as it contained 20 years of recent, continuous and complete records (Appendix 10).

An evaporation rate simulating the 'worst-case' scenario for the Jemalong Irrigation District has been used in the preliminary Mass-Balance Loss Models to simulate the potential maximum evaporation

'losses' that could be expected in the system. In this case, the 'average summer' evaporation rate of 9.4mm/day was adopted. Average evaporation rates have been sourced from pan evaporation results from CARS for all months are shown below. A summary of which has been included in Appendix 9. These were favourable as a complete data set for all 'representative years' tested.

MONTH	MM/DAY
Jan	10
Feb	9
Mar	7
Apr	4
May	2
Jun	2
Jul	2
Aug	2
Sep	4
Oct	6
Nov	8
Dec	10

Table 6, CARS, average monthly pan evaporation rates 1989-1008



Graph 1, CARS average monthly pan evaporation rate

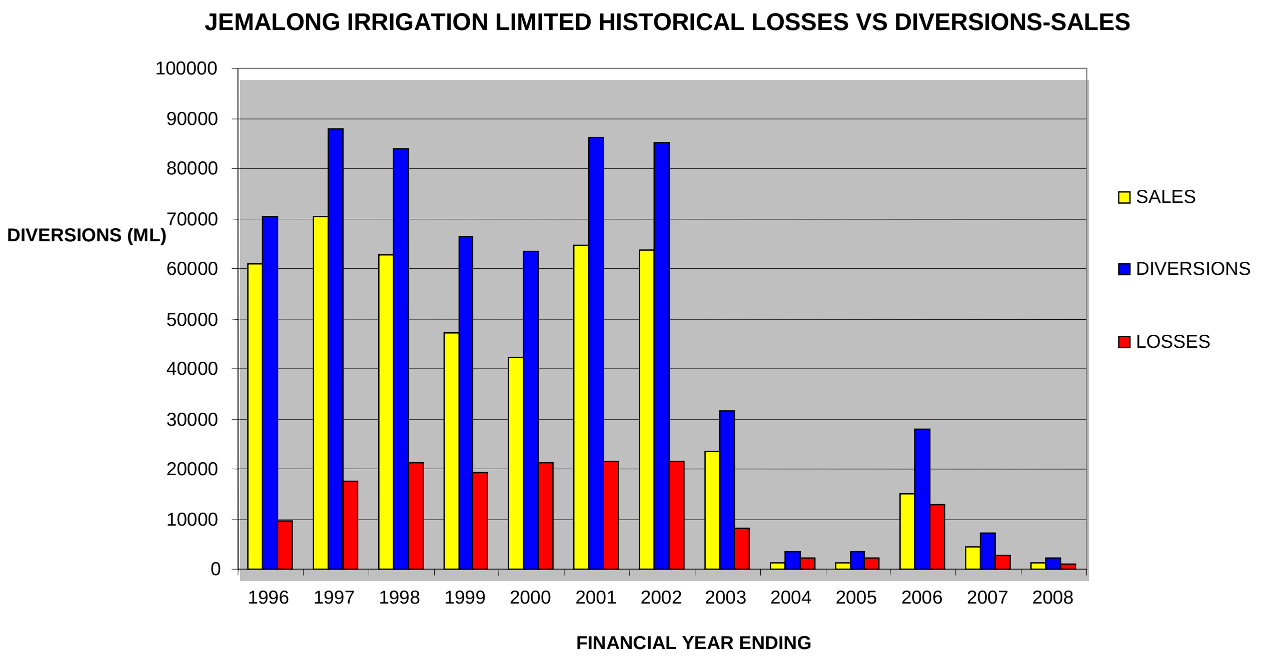
HISTORICAL LOSS DATA

A historical water balance has been compiled using diversion and sales information supplied by Jemalong Irrigation Limited for the period of financial years from 1996 to 2008, as set out in the table below. This period was chosen as it was the most complete, recent and confidently metered data set supplied to us for our analyses.

YEAR	SALES	DIVERSIONS	LOSSES
1996	60893	70465	9572
1997	70492	87953	17461
1998	62795	83952	21157
1999	47085	66376	19291
2000	42135	63358	21223
2001	64600	86134	21534
2002	63788	85191	21403
2003	23498	31687	8189
2004	1259	3385	2126
2005	1212	3470	2258
2006	15055	27786	12731
2007	4399	7180	2781
2008	1174	2184	1010

Table 7, Historical water balance data

The graphical representation below is an illustration of the above figures.



Graph 2, Water balance constructed from historical sales and diversions

SCHEME LOSS MODEL VERIFICATION

Preliminary analysis of the Jemalong Irrigation District delivery system was conducted using an unrestricted Mass-Balance Loss Model based on historic and field collected survey data, average seasonal evaporative rates and indicative soil type infiltration rates. Discussions with Jemalong Irrigation Limited staff and review of supplied historic allocation data indicated that the preliminary Mass-Balance Loss Model over-estimated the likely losses in comparison to historic data and operator experience, which estimated around 33% total loss. Jemalong Irrigation Limited staff advised that the model was not an accurate representation of the actual existing reduced channel and storage operations.

Following the above analysis and having established the Jemalong Irrigation Limited operational procedures, the Weir-Storage Model was selected to best represent the existing water delivery system. Preliminary trials of the Weir-Storage Model using indicative infiltration rates estimated a total loss of about 50%, once again considered to be an over-estimate of the losses.

In order to calibrate the model to represent the systems operational losses, and the recorded water losses associated with the Jemalong Irrigation Limited's historic water balances, trials of the Weir-Storage Model were conducted. These trials adopted anecdotal evidence for 'representative years' as nominated by Jemalong Irrigation Limited. The 'check' models were prepared using historic diversions recorded by the Jemalong Weir Meter prior to 2001 and the AFFRA Meter post-2001, and the average-monthly evaporation rates for the selected representative years.

Historic diversions versus sales and losses for the representative year's trialled, as nominated by Jemalong Irrigation Limited, are shown below in Figure 6.

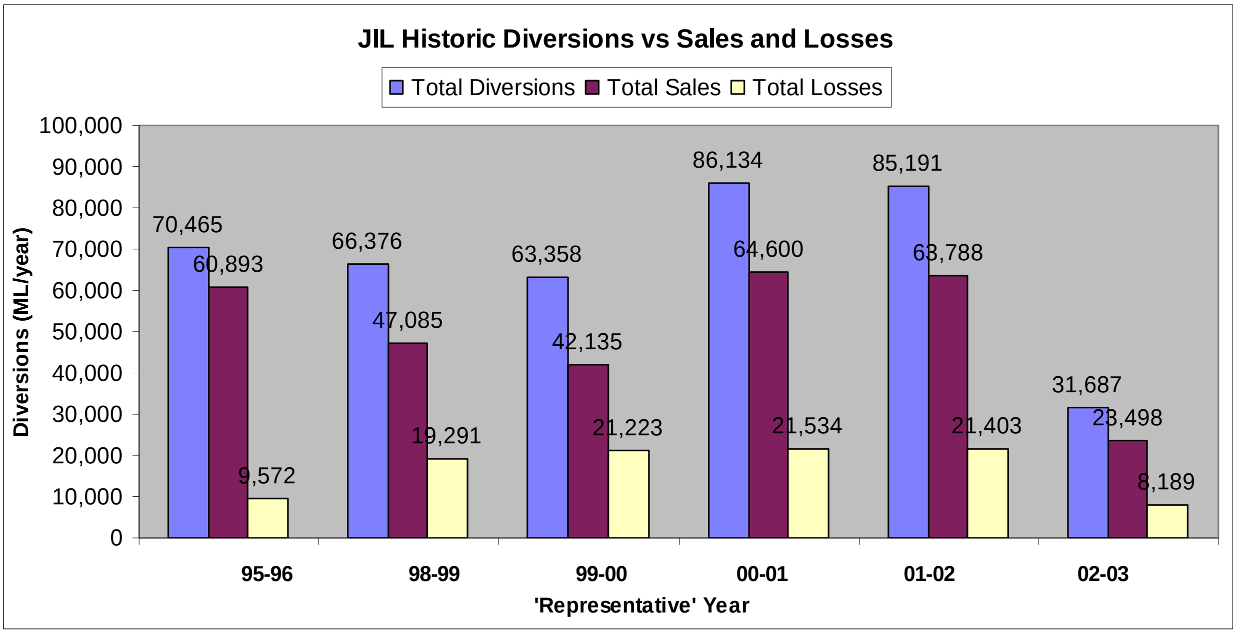


Figure 6, Historic Water Balance Losses versus Calibrated Weir-storage losses

Adopting anecdotal reports of losses and operational depths, the preliminary Weir-Storage Model estimated an average infiltration loss of between 45 and 55ML/day, accounting for up to 80% to 95% of the daily losses within Jemalong Irrigation District. 5% to 20% of the remaining losses are attributed to evaporation.

With the exception of 1995-1996 and 2002-2003, the results shown in Figure 7 for the representative years indicate the average total losses from the Weir-Storage Model are between 20% to 26%. The historic diversion vs. sales record reports losses of about 25 – 34%. This also shows that the anecdotal infiltration loss rates adopted for the Weir-Storage Model appear to under-estimate the total losses by up to about 7%, or a 23% proportion of the comparable historic loss.

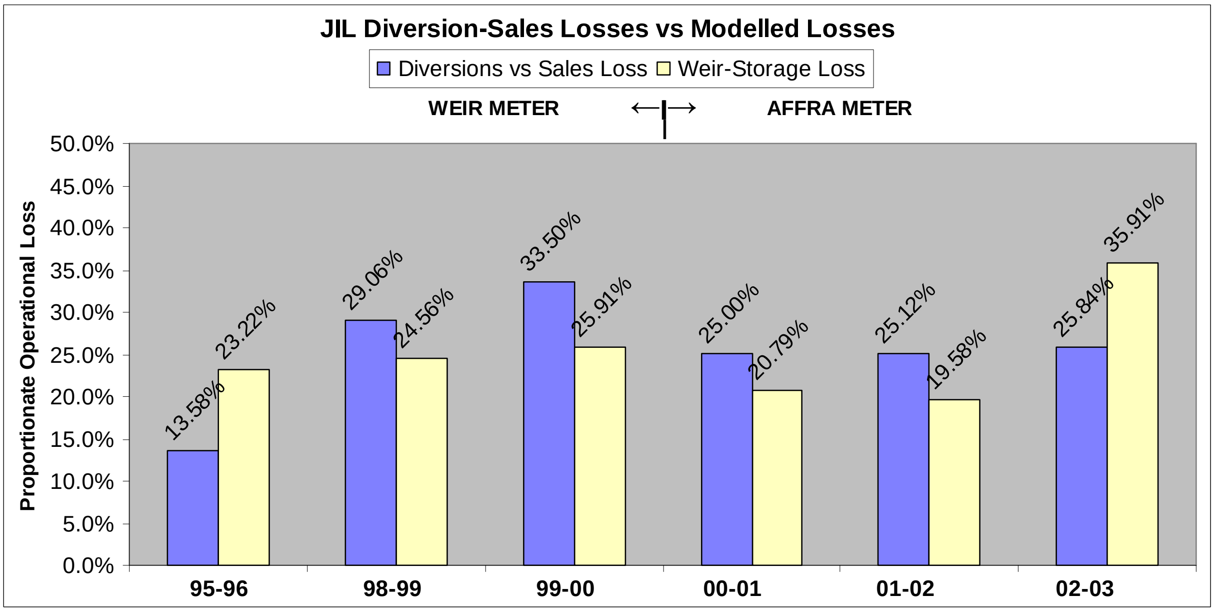


Figure 7, Historic Water Balance Losses versus Preliminary Weir-storage losses

Similar trials using the Mass-Balance Loss Model and the same regularly-operated channels and equivalent infiltration rates as the Weir-Storage Model indicated similar under-estimations.

Results from the Barrick Mine Mass-Balance Loss Model, in Division 2, indicated an average daily loss of 3ML/day for an average diversion of 17ML/day. This result was confirmed by Jemalong Irrigation Limited staff as being a very good representation of their expectation and records.

In light of the consistency of the anecdotal loss information for Division 2, uniformly adopting these infiltration rates for Division 2 meant that calibration of the infiltration rates in Division 1 were required in order to match historic water balances, and qualify the model as representative of the existing system.

The Weir-Storage Model, infiltration rates in Division 1 were uniformly increased by 35.5% to approximately match historic water balance losses. The calibrated loss rates in Division 1 resulted in a close match to the historic recorded water balance for four of the six representative years, as shown below in Figure 8.

Model calibration increased the average infiltration loss for the calibrated Weir-Storage model to approximately 55 to 65ML/day, accounting for up to 98% of the daily losses within the Jemalong Irrigation District.

The modelled loss results of the representative years 1995-96 and 2002-03 were found to be inconsistent with the historic water balance of the other four tested representative years. Reasons for the comparative discrepancy of these results could include significant operational differences to other nominated years, large errors in flow measurements or some other unknown error.

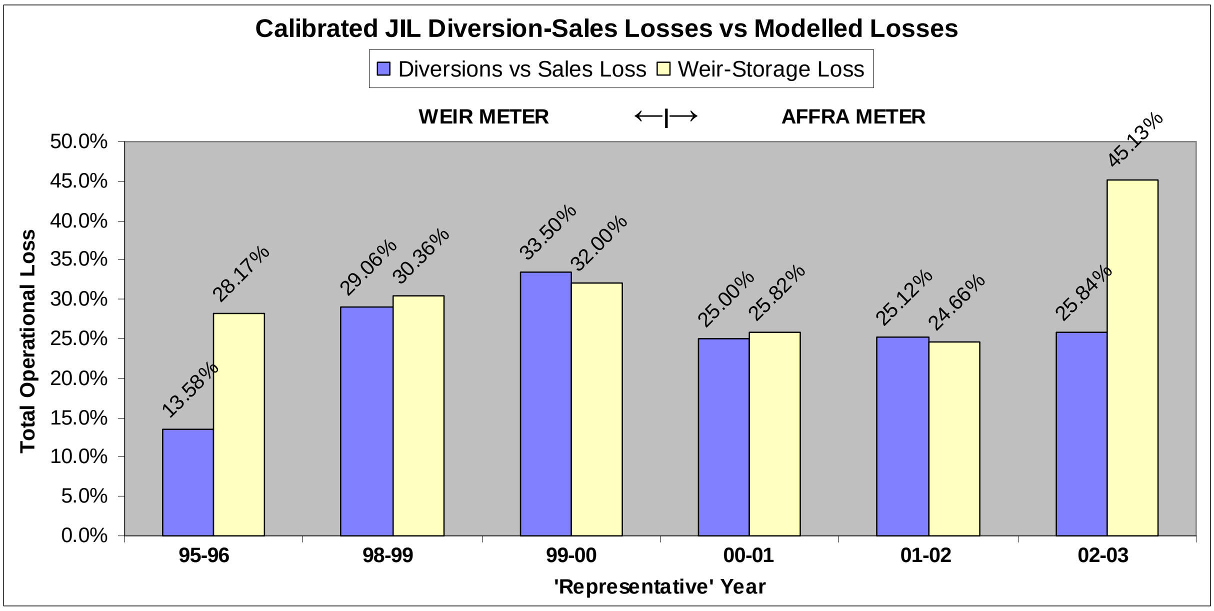


Figure 8, Historic Water Balance Losses versus Calibrated Weir-storage losses.

Correspondence with Jemalong Irrigation Limited indicates that the losses associated with the "wetting-up" of the Jemalong Irrigation District following extended periods of non-use were not able to be quantified.

It is also advised by Jemalong Irrigation Limited that variation in loss estimation is also prevalent following activities that alter channel conditions such as de-silting maintenance or reconstruction. For example the Warroo Main Channel was found to have an increase in apparent losses of approximately 65% following recent de-silting maintenance.

On the basis of extensive modelling, subjective review of all known data, calibration and good agreement with the historic Water Balance records for four of the six representative years, Boyden & Partners consider the Weir-Storage Loss Model to be a good representation of the losses associated with the operations of the Jemalong Irrigation District.

In order to confidently advance the knowledge of loss rates experienced by Jemalong Irrigation Limited during operations, exhaustive infiltration testing in all operated channels would be required.

BASELINE SCHEME LOSSES

A summary of the estimated total losses associated with the existing and future operations of the Jemalong Irrigation District delivery system, as determined by the calibrated Weir-Storage Model is shown in Table 8 below. The year 2000-2001 has been selected as a comparative historic year for the determination of alternative system operations and future modernisation.

It should be noted that for significant differences in future operations, such as if the peak diversions are delivered in the winter months instead of summer, this nominated representative year may not be comparable.

Scenario	***Baseline***	***Baseline***	***Baseline***
Scenario Description	EXISTING SYSTEM	EXISTING SYSTEM	EXISTING SYSTEM
	2000-2001 (calibration)	2000-2001 (calibration)	2009 average annual AWD 43%
ANNUAL ALLOCATION (ML)	74,899	42,942	42,942
% OF MAXIMUM ALLOCATION	Scaled down to 75%	Scaled down to average annual AWD 43%	2009 average annual AWD 43%
Summary of Scheme Operation	*9 months*	*9 months*	*7 months*
AVERAGE INFILTRATION LOSSES (ML/year)			
TOTAL	18,882	18,540	14,663
AVERAGE EVAPORATION LOSSES (ML/year)			
TOTAL	2,102	2,077	1,762
Σ ALL LOSSES (ML)	20,984	20,617	16,425
Proportion of Infiltration Losses (%)	25.2%	43.2%	34.1%
Proportion of Evaporation Losses (%)	2.8%	4.8%	4.1%
Total Proportion Loss of Allocation (%)	28.0%	48.0%	38.2%

Table 8, baseline scheme losses

SCHEME ENGINEERING OPTION ELEMENTS

The information collected from loss modelling and assessment of the Jemaolong Irrigation District's physical characteristics has enabled the establish ment of the areas within the Jemalong Irrigation District that suffer the greatest proportional losses. From this information decisions regarding the most appropriate upgrade options have been derived.

Anecdotal, reported and modelling results have shown that Division 1 has comparatively greater losses than Division 2. Therefore it may be more economical to upgrade Division 1 before Division 2 until more data regarding infiltration rates throughout the scheme can be obtained

CHANNEL UPGRADE

Upgrade option elements for the main delivery channels that have been explored and assessed as they relate to the Jemalong Irrigation District include the following:

Synthetic lining	HDPE
	EPDM
	Coated Geofabric membrane
Pipes	HDPE PIPES
	Concrete pipes
Earth liners	Selected Clay lining
	Modified clay
	Stabilised backfill
Concrete lining	Trowelled
	Shot Crete

An outline of some of the possible technological elements to upgrade the Jemalong Irrigation District delivery channels is presented below. Each of these elements has been assessed for suitability (see assessment details) to the location but not all progressed to the final assessment.

Synthetic lining systems

UV Protected Geofabric

Description:
A multi layered geofabric membrane sprayed with a dual waterproof membrane.

Pro:

Smooth finish

100% reduction of infiltration (claimed).

Con:

No reduction of the effects of evaporation

Subject to UV deterioration

Subject to stock damage

Channel must be groomed prior to installment.

Maintenance is not specifically defined

Prone to some siltation.

Relative newcomer to channel seepage remediation

HDPE Liner

Description:

A geofabric membrane coated in high density polyethylene .

Pro:

100% reduction of infiltration

Con:

No reduction of the effects of evaporation

Subject to UV deterioration

Subject to stock damage

Channel must be groomed prior to instalment

Very stiff hard to weld and bond

Maintenance is not specifically defined

Prone to some siltation.

EPDM RUBBER

Description:

EPDM (ethylene propylene diene monomer) is a durable geomembrane with a 20-year proven performance history in exposed applications.

Pro:

Proven history of exposed life.

100% reduction in infiltration (claimed)

High rate of flexibility and strength

Con:

Service life dependant on quality of the joins.

Seams between pieces can be a problem if created in the field.

No reduction in evaporation

Prone to some siltation.

Pipe Systems

Concrete Pipe.

Description:

Reinforced rubber ring, concrete pipe.

Pro:

Strong and durable

Maintenance costs are low.

100% reduction in infiltration and evaporation.

Con:

Heavy to handle thus cartage costs expensive.

Manufacturers located some distance from project location.

Higher rate of frictional loss when compared to HDPE.

Manufactured in shorter lengths.

HDPE Pipe

Description:

Corrugated high density polyethylene pipe with a smooth internal diameter.

Pro:

100% reduction in infiltration and evaporation.

Smooth internal bore allowing greater capacity.

Light weight easy to handle.

Manufacturers located some distance away but given a significant demand can be manufactured locally.

Maintenance costs low

Con:

Subject to long term UV deterioration if exposed to sunlight.

Earth lining systems

Selected clay

Description:
Locally sourced impervious clay.
Pro:
70-95% reduction in infiltration
Con:
No reduction of the effects of evaporation
Subject aquatic invertebrate damage, (Yabbies burrowing).
Requires to be kept wet.
Maintenance costs are high in seasonal flow channels
Requires suitable material to be available

Modified clay

Description:
Locally sourced clay ameliorated with a lime modifier.
Pro:
80% reduction of infiltration.
Con:
No reduction of the effects of evaporation.
Subject aquatic invertebrate damage, (yabbie burrowing).
Requires suitable material to be available

Stabilized Earth

Description:
Locally sourced stabilized earth ameliorated with cement.
Pro:
70-90% reduction in infiltration
Con:
No reduction of the effects of evaporation.
May crack with ground movement.
Roughness may reduce capacity.
Requires regular maintenance checks
Requires suitable material to be available

Concrete lining systems

Trowel finished concrete liner

Description:
Conventional concrete finished in the channel with a trowel.
Pro:
80-90% reduction in infiltration.
Con:
No reduction of the effects of evaporation.
specialist installation
Labor intensive and specialized
May crack with ground movement.
Prone to siltation.
Requires regular maintenance checks

Shot Crete

Description:
Concrete sprayed onto prepared channel surface.
Pro:
60-70% reduction in infiltration.
Quick installation
Con:
No reduction of the effects of evaporation.
Specialist installation.
May crack with ground movement.
Prone to heavy siltation.
Requires regular maintenance checks

SCHEME GATING AND METERING

Modernisation of irrigation infrastructure may involve the automation of the current manual operation of the check gates and regulators throughout the Jemalong Irrigation District.

Automation involves the retrofitting of control gates to the existing check and regulator gates. Modern controllable and metered gates enable accurate flow and water level measurement at each structure.

It is also possible to install a system wide controller which comprises of a sophisticated real time computer, communications, and modelling and control software. This could enable the Jemalong Irrigation District to record water deliveries accurately.

A system wide controller would benefit from maintaining operator input to monitor the system on ground to ensure there are no system failures and that the system is working as it should.

GATES

Gates form an integral part of the modernisation of a channel network. Gating is dependant on the extent of infrastructure modernisation. Where pipes are proposed to be used gating will be dependant on where flows split as opposed to controlling ponding systems. Where lining is proposed gate upgrades would be recommended to further improve operation efficiency.

The type of gate used is dependant on the flow conditions required for the location. A gates physical function is commonly one of the following three forms:

- Undershot gates
- Overshot gates
- Undershot/overshot gates

Undershot/overshot gates provide a controlled method of retaining water. The gate can be opened at either the bottom or the top. This function is ideal for carefully adjusting the level at which water is retained.

A modern overshot gate such as a Flume gate is often preferred due to the designs ability to accurately measure and control flows.

Image 12 Flume Gate and attached control box (source Rubicon)

The likely locations of gate upgrades will be decided by the Jemalong Irrigation Limited committee. For the purposes of this report it is assumed that all check gates we have record of would be replaced with modern gates.

METERING

The NSW Water Extraction Monitoring Policy addresses the use of water meters and other monitoring techniques in NSW. In addition, the Department of Water and Energy, in conjunction with State Water, has developed the NSW Water Extraction Monitoring Standards which set criteria for the installation of water measurements devices. National standards for water meters are currently being developed under the National Water Initiative, and will apply to meters that are installed after the date that the National Standard commences.

There is a possibility that all metering considered for Jemalong Irrigation Limited main delivery channels and farm off-takes could comply with the above standards when they are announced to be in line with best management practice. Gate upgrades may include metering connected to a channel control system that will give the Jemalong Irrigation Limited greater control over the delivery system.

Image 13 Flume Gate with control (source Rubicon)

SCHEME OFF-TAKE UPGRADE

Water Management Outlets

Many Dethridge wheels in the Jemalong Irrigation District are being replaced with locally produced Water Management Outlets (WMO's). These outlets have the ability to deliver between 1-80ML a day. The larger capacity of the WMO's allows irrigators to utilise more water efficient methods.

Image 14, WMO's locally manufactured by the Jemalong Irrigation Limited

WMO's have the ability to be linked to a SCADA system which would give the Jemalong Irrigation Limited greater control over its operations. The WMO can be fitted with a meter however its accuracy for water flow measurement is yet to be confirmed.

Currently the Jemalong Irrigation Limited has installed approximately 27 WMO's in Division 1 and 18 in Division 2. The location and relative sizes of which have been plotted on a map in Appendix 7.

STOCK AND DOMESTIC WATER DELIVERY

In accordance with the Jemalong Irrigation Limited's water licensing there is an obligation that the Jemalong Irrigation Limited supply a high security stock and domestic allocation. Under present operations, to supply the stock and domestic requirement the Jemalong Irrigation Limited experiences significant water losses.

Four preliminary stock and domestic systems are proposed to be assessed for review by the Jemalong Irrigation Limited board. Each system has been based on a stock and domestic requirement that has been supplied by the Jemalong Irrigation Limited.

SDF1	This option is based on the stock and domestic requirement being delivered over a 24hr period for 365 days. This option follows the existing channel layout
SDF2	This option is based on the stock and domestic requirement being delivered over a 12hr period for 365 days This option follows the existing channel layout
***SDF3**	This option features a layout that follows the roads where possible and has the ability to deliver the required volume of water over 24hrs for 365 days
***SDF4**	This option features a layout that follows the roads where possible and has the ability to deliver the required volume of over a 12 hour period for 365 days of the year

Table 9, Stock & Domestic upgrade options being reviewed

*Use of the road reserves in these options is subject to conditions that are set by Council and the RTA as they apply to the roads which are controlled by each particular entity.

The preliminary layouts and details of the four Stock & Domestic systems can be seen in Appendices 14-22.

OPTION ELEMENTS PROGRESSED TO DETAILED INVESTIGATION (PRELIMINARY)

Element assessment

Each of the modernisation elements that were considered to be applicable to the Jemalong Irrigation Limited underwent analysis using a multi criteria matrix system (Appendices 12 & 13); Each technological option was scored against a set of suitability scores, 3 for most suitable, 2 for just suitable and 1 for least suitable.

The parameters that each element was scored against included the following:

- Infiltration (vertical)
- Infiltration (lateral)
- Evaporation
- High Watertable
- Channel Downtime during construction
- Prone to Stock/Animal damage
- Requires to be fenced off
- Small channel dimensions
- Large channel dimensions
- High water velocity
- Ongoing channel maintenance
- Weed spraying
- Lifespan
- Cost

The scores were tallied and the elements that scored the highest were considered to be the most suitable.

Element ranking

Element	Ranking
HDPE Pipe	1
Concrete Pipe	2
EPDM liner	3
HDPE Liner	4
UV geofabric Liner	5
Shot Crete	6
Trowel finish concrete	7
Stabilised Backfill Liner	8
Modified Clay Liner	9
Clay Liner	10

Table 10, Element ranking from matrix

Using these results we were able to choose the top rating elements and arrange these into plausible modernisation options.

Note Although Concrete Pipes ranked highly we are unable to recommend this element. From a supply cost and construction perspective the difficulty in handling and transporting this infrastructure option makes them significantly less attractive. The relative advantages the concrete pipes have over the other elements in relation to the assessment parameters tended to give a false impression of the suitability of the concrete pipe installation

OPTIONS FOR IRRIGATION MODERNISATION

SYNTHETIC LINING DIVISION 1 & DIVISION 2

This option involves the lining of Division 1 & Division 2 with a synthetic liner such as a coated Geofabric membrane, HDPE or EPDM liner. Infrastructure upgrades with this option would include the replacement of Dethridge wheels throughout the Jemalong Irrigation Limited scheme with Water Management Outlets. Regulator Check gates would be upgraded with modern control gates equipped with metering capacity.

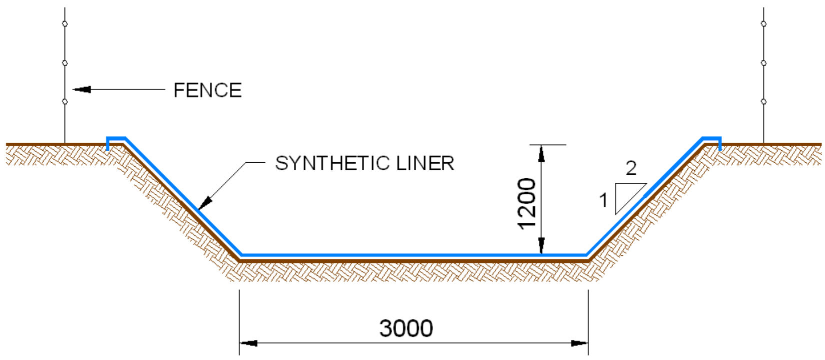


Figure 9, Synthetic Liner concept

PIPING CHANNELS IN DIVISION 1, SYNTHETIC LINING OF THE EXISTING CHANNEL IN DIVISION 1 & NO TREATMENT OF DIVISION 2

This option involves the piping of Division 1 using a pressurised piped system able to deliver volumes based on future operations. The pipe is proposed to be placed next to the existing channel network thus allowing for the existing channel to maintain operations. The existing channel would then be upgraded including lining and infrastructure upgrades such as the inclusion of Water Management Outlets to replace Dethridge wheels, and the upgrade of scheme gating with modern control gates with the capacity to be fitted with meters.

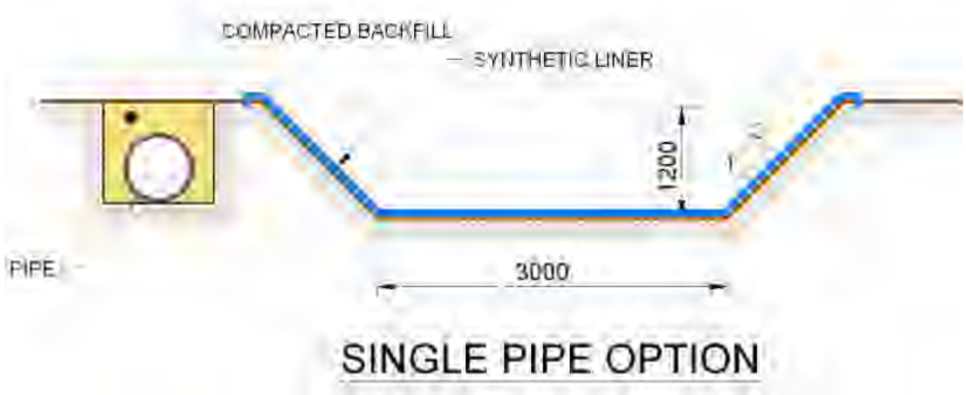


Figure 10, HDPE Pressure Pipe concept

SINGLE PIPE IN DIVISION 1 & NO TREATMENT OF DIVISION 2

This option would see the employment of a single large capacity pressure pipe within Division 1 sized to deliver the current capacity of the channel system. The adjacent channel would not be lined. This pipe, due to its capacity could deliver all peak flow demands. The pipe would be laid next to the channel as above. It is proposed that Division 2 remain untreated.

STABILISED BACKFILL LINING OF DIVISION 1 & DIVISION 2

This option involves the lining of the existing channel network in a stabilised backfill. The availability of backfill material of a suitable standard is very important. The material should preferably be low in permeability, free from shrinkage and swelling, and should have good stability and erosion resistant properties for use in side slopes. The backfill proposed would be ameliorated with a binder such as cement. An infrastructure upgrade is also possible with this option and would include the replacement of Dethridge wheels with Water Management Outlets and the replacement of check gates with modern flow control gates with the capacity to be fitted with meters.

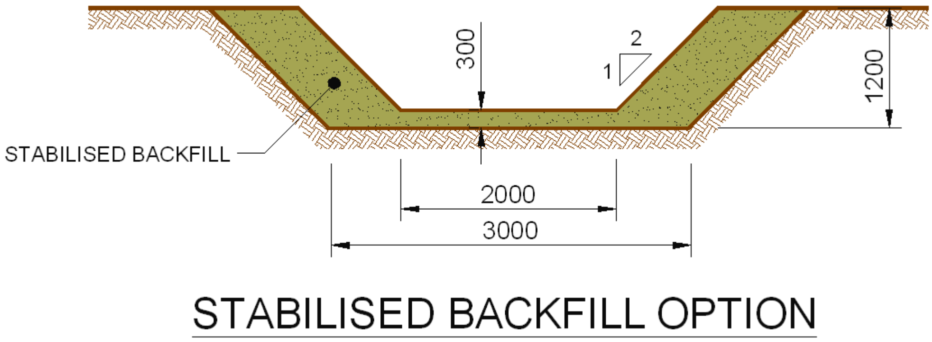


Figure 11, Stabilised Backfill concept

Channel Upgrade Option Costs

Following selection by the Jemalong Irrigation Limited board of the preceding four options as favoured alternatives, seven (7) options (three being variations of the above four) have been selected by the board for preliminary assessment.

Each of the 7 options has undergone objective assessment through a multi criteria matrix system, see Appendix 12.

The cost of each Option has been based on a total channel upgrade, including forcasted maintenance costs, an overall development cost, and the costs associated with gates and WMO upgrades. (See estimated costs for gates and WMO's in the section titled Gate and Meter Upgrades below).

Cost estimates for the 7 options assessed for the channel upgrade have been accumulated using information from the following sources:

- Rawlinsons 2008 Construction Handbook.
- Previous relevant works costing by consultant.
- Pipe prices from manufacturers.
- Lining prices from manufacturers.

Maintenance Cost Estimations

Maintenance costs for the existing scheme have been estimated from information supplied by Jemalong Irrigation Limited. These estimations included:

- Weed spraying costs per annum.
- Channel structure maintenance.
- Channel maintenance.

Maintenance costs for each of the options have been estimated from information provided by manufacturers and assessment by Boyden & Partners in relation to the type of maintenance that is required.
All maintenance costs have been projected over a 20 year period.
All cost estimation has included cartage to the location. For details of costings see Appendix 25-33.

Note: estimated costs are based upon information that applied or was available at the time of the assessment.

Jemalong Irrigation Limited Channel Upgrade Options- Costing Comparisons										
Option	Main Delivery Channel	Cost ($M)	Maintenance ($M) over 20yrs	Division 1 Development	Cost ($M)	Maintenance ($M) over 20yrs	Division 2 Development	Cost ($M)	Maintenance ($M) over 20yrs	Overall Development Cost ($M)
1	Existing		$0.43	Existing		$13.98	Existing		$9.13	$23.54
2	Stabilised Backfill	$0.98	$0.43	Stabilised Backfill	$37.64	$14.00	Stabilised Backfill	$24.49	$9.13	$86.67
3	Geofabric Liner	$0.29	$0.19	Geofabric Liner	$36.92	$20.71	Geofabric Liner	$27.60	$13.55	$99.26
4	HDPE liner	$0.32	$0.17	HDPE liner	$39.67	$18.63	HDPE liner	$29.45	$12.17	$100.41
5	EPDM liner	$0.32	$0.16	EPDM liner	$39.29	$18.24	EPDM liner	$29.20	$11.92	$99.13
6 a				HDPE Pipe + Geofabric liner	$99.67	$20.74	Gates, meters & WMO's	$3.97		$124.38
6 b				HDPE Pipe and HDPE Liner	$102.41	$18.63	Gates, meters & WMO's	$3.97		$125.01
6 c				HDPE Pipe and EPDM Liner	$102.04	$18.24	Gates, Meters & WMO's	$3.97		$124.25
7				Pipe	$203.53		Gates, Meters & WMO's	$3.97		$207.50

Table 11, Channel upgrade option cost comparison

STOCK AND DOMESTIC DELIVERY UPGRADE

The Stock and Domestic Delivery system has been assessed for two different flow regimes applied to two different layouts. The system flow regimes are described as:

1) A system sized to deliver the required supply over 24 hours averaged over 365 days of the year.

2) A system sized to deliver the required supply over 12 hours over 365 days of the year.

The alternate system layouts that have been assessed are described as:

a) A pumped system that essentially follows the existing irrigation channel system layout (Figure 12).

b) A pumped system that follows the district road network with the possibility of using multiple pump off takes from the Lachlan River (Figure 13).

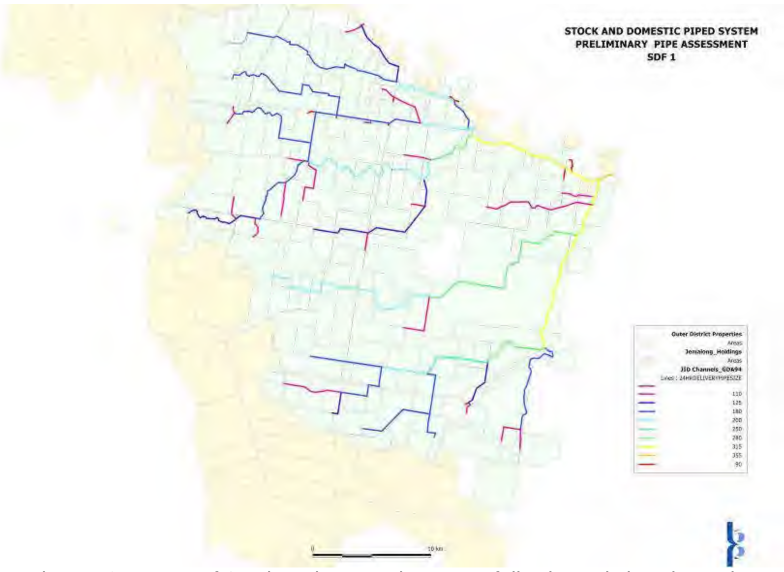


Figure 12, Layout of Stock and Domestic system following existing channel.

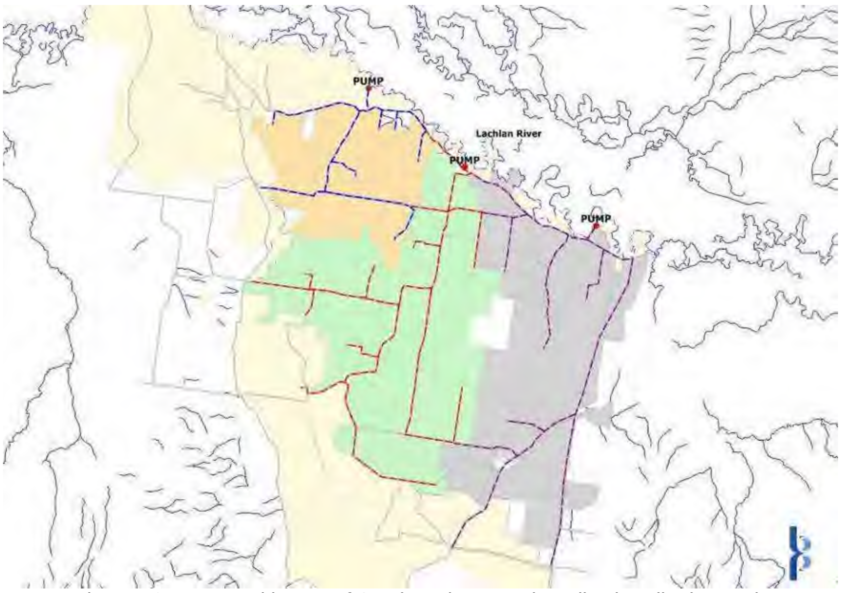


Figure 13, proposed layout of Stock and Domestic Following district roads

The preliminary Stock and Domestic systems outlined for the Jemalong Irrigation Limited, SDF 1, SDF 2, SDF 3 & SDF 4 are presented in both layout form and detailed in Appendix 14-22.

The systems have undergone preliminary costing. The costs below in Table 12 are at best estimates based on pipe costs from manufacturers, and trenching and pump costs estimated from industry standard text where applicable. The costings have been prepared to allow Jemalong Irrigation Limited to objectively assess each option.

STOCK & DOMESTIC OPTION	Cost ($M)
SDF 1 -24hr Delivery	$8.80
SDF 2 -12 Delivery	$11.40
SDF 3 -24hr Delivery	$5.10
SDF 4 - 12 Delivery	$9.91

Table 12, Preliminary Stock & Domestic option costs

GATE AND METER UPGRADES

It is proposed that if Jemalong Irrigation Limited were to upgrade the channel system using a liner then current operation procedures would need to be maintained. Through the upgrading of all check and regulator gates to modern controllable gating technology the Jemalong Irrigation Limited can efficiently deliver and monitor deliveries to all irrigators.

Relative costs for in channel regulator upgrades have been based on the existing structure being replaced with a modern flume gate or the like.

A gate system such as a flume gate costs between $13,000 to $50,000 depending on the size required. The cost would include all software and metering equipment that would allow the system to be fully automated.

The inclusion of automated gate systems does not however alleviate the need for regular inspection of the channel system operation. Automated do not maintain the integrity or stability of an operating system.

The phasing out of the Dethridge Wheel is currently ongoing in the Jemalong Irrigation District. Dethridge Wheels are being replaced by WMO's or Water Management Outlets. A general costing estimate to replace all Dethridge Wheels has been made in the course of preparation of this report. Cost estimates are relative to the size of the WMO required thus we have included a range of costs from minimum to maximum.

WMO's are currently made in 3 sizes:
600mm, 750mm, 900mm. cost range from $16,000 for the 600mm, $18,000 for the 750mm and approximately $20,000 for the 900mm.

A summary of approximated costs has been tabulated using information supplied from gate/meter manufacturers and suppliers. WMO costs have been supplied by Jemalong Irrigation Limited and are an average indicative cost including installation. This costing has been based on an upgrade of the entire schemes gating infrastructure as estimated from information supplied to us from Jemalong Irrigation Limited structure database.

DIVISION INFRASTRUCTURE UPGRADES		
Flume Gate & Meter Upgrade		
ASSET	DIVISION 1 Cost ($M)	DIVISION 2 Cost ($M)
Regulator check gates	$2.11	$1.32
Access Bridge Regulators	$0.69	$0.63
TOTAL	$2.80	$1.95
Water Management Outlets		
Dethridge wheel replacements	$2.40	$2.02

Table 13, Average costs of gate, meter and outlet upgrades.

ENGINEERING ASSESSMENT OF MODERNISATION OPTIONS

ASSESSMENT METHODOLOGY

Irrigation Channel modernisation involves the assessment of available techniques based on site conditions, objectives, economic analysis and consideration of all options. Modernisation works require a maintenance program and ongoing monitoring of effectiveness.

The elements from Engineering Option Element Assessment have been arranged into the seven (7) options:

1) Existing System
2) Stabilsed backfill
3) Geofabric lined membrane liner
4) HDPE liner
5) EPDM liner
6) HPDE Pipe &:
    a. Geofabric membrane liner
    b. HDPE liner
    c. EPDM liner
7) HDPE Pipe

The seven (7) options have been modelled and compared to the baseline scheme which is Option 1 to evaluate the potential water savings that each option is able to achieve, see Appendix 23.

These seven (7) options were subjected to an objective assessment through a multi criteria assessment, see Appendix 13.

ASSESSMENT FINDINGS

Each of the options from Option 2, to Option 7 has been assessed against a control, or baseline scheme, that is Option 1. All savings associated with the upgrade of the channel network have been calculated against the control Option 1. To provide a balanced comparison between all the options the allocation of water was set to the estimated AWD or Available Water Demand for the year 2030 which is 36% of the current entitlement.

Under baseline conditions, which does not incorporate any upgrades, the estimated losses that can be expected under the estimated climate change conditions for the year 2030 are approximately 46% of the of the, present annual allocation or 16,425 ML year.

Options 2-5 consider both Divisions being upgraded. The costs for lining Division 2 in Options 6 and 7 have not been included. However the cost of lining Division 2 in Options 2-5 can simply be added to the overall development cost in Options 6 and 7.

Option 2 – Stabilized Backfill

Under the 2030 climate change scenario this option provides a potential range of savings. This is due partly to the variations that may exist in the parent material that make up the stabilised backfill. The more clay content in the parent material the less permeable the material thus the water savings associated are increased. If the material has less clay content then the final result will be more permeability and thus fewer saving. The range of savings for this option is from 9,030 ML/year to 1,590 ML/year. The estimated cost of this option is $86.67M over a period of 20 years. This equates to a cost of approximately $490 per ML saved per year. For the higher rate of permeability this equates to a cost of approximately $2,788 per ML saved per year.

Option 3 – Geofabric Liner Division 1 & Division 2

Geofabric Liners reduce all losses associated with infiltration, but surface water is still prone to evaporative losses. The evaporative losses however form a very minor proportion of the overall losses. The saving associated with the Geofabric Liner is in the vicinity of 14,660 ML per year against the control in Option 1. The estimated cost of this option is $99.26M over a 20 year period. This equates to a cost of approximately $338 per ML per year.

Option 4 – HDPE Liner Division 1 & Division 2

HDPE liners exhibit similar properties to the Geofabric Liner in terms of its ability to reduce infiltration losses. Maintenance costs are a little less due to there being no facility or requirement to re-coat the liner as in the Geofabric Liner. Water savings and losses are the same as the Geofabric Liner at 14,663 ML saved per year. This option costs approximately $100.41M over a 20 year period. This equates to a cost of approximately $342 spent per ML saved per year.

Option 5 – EPDM Liner Division 1 & Division 2

As with the other Synthetic Liners assessed the EPDM rubber liner exhibits similar qualities in terms of water savings and evaporative losses. The cost of the EDPM is one of the cheapest of the Synthetic Liners over a 20 year period. The EPDM cost approximately $99.13M over the 20 year period. The total savings against the baseline in Option 1 is 14,663 ML per year. This equates to a cost of approximately $338 spent per ML saved per year.

Option 6a, 6b, 6c –Pipe & Liner, (Geofabric, HDPE, EPDM)

This option utilizes a HDPE pressurised pipe system in Division 1 (sized to take 36% of each holdings entitlement over a 6 month period for 24 hours). The remaining channel in Division 1 is to be lined in one of the Synthetic Liners. The existing channel would be in place to augment peak deliveries thus expanding the potential capacity of this system. The utilization of the pipe in Division 1 has the potential to reduce all evaporative and infiltrative losses to nil. Division 2 has not been taken into account however it could be lined with a synthetic. The potential savings are 15,551 ML a year at a maximum cost of $125.01M. This cost would change depending on the choice of liner**.** In terms of dollars spent for water savings in Division 1 that equates to approximately $401 per ML saved in Division 1 only.

Option 7 – HDPE Pipe Division 1, No treatment Division 2

This option uses a large capacity pipeline that is sized to take the same capacity as the current channel system. This system can deliver all the peak demands when required. The remaining channel in this case is not upgraded and so would not require infrastructure upgrade or be subject to maintenance costs. The final cost for this upgrade is $207.50M**.** This option offers the highest possible volume of saving in terms of water 15,610ML per year. In terms of dollars spent for water savings in Division 1 that equates to approximately $664 per ML saved. This option is the most expensive of the options analysed however can deliver the maximum peak volumes when required.

The following figures 14 & 15 are graphical comparisons between the 7 options in terms of total upgrade cost as in figure 14, and the total potential water savings derived from the Option Assessment table in Appendix 23 as in figure 15. A Summary breakdown of the total channel upgrade costs is illustrated in Appendix 24.

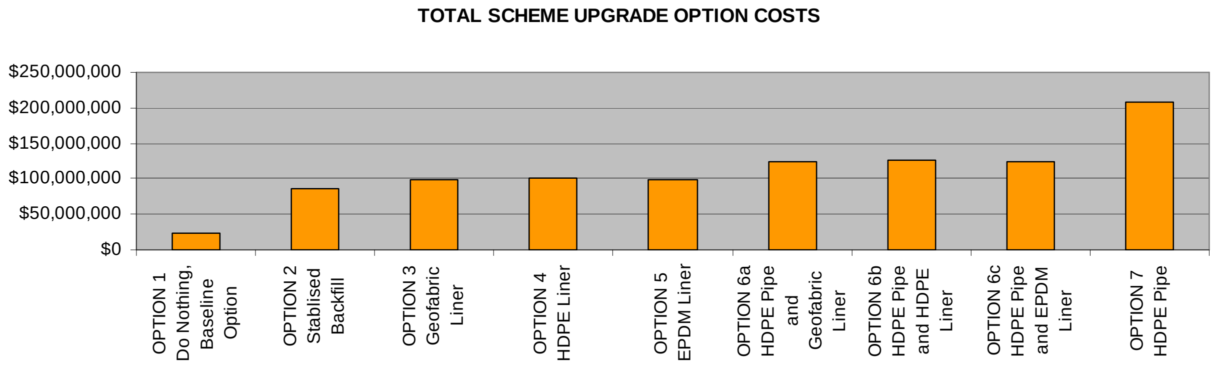


Figure 14, option upgrade total cost comparison

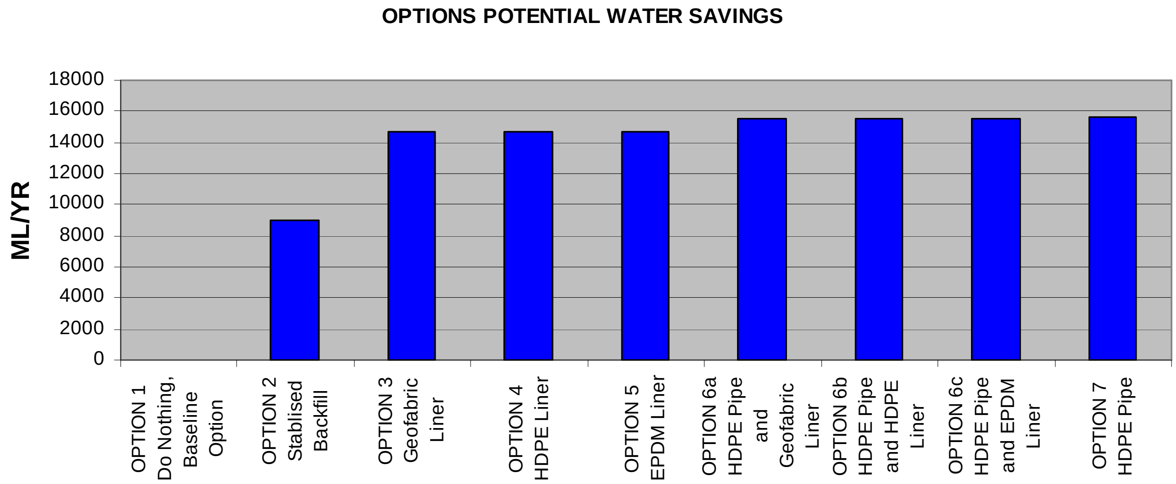


Figure 15, option upgrade total potential water savings

Option Ranking

The 7 Options underwent ranking through a multi criteria matrix. The parameters used for the criteria were:

- Channel downtime during construction
- Infiltration
- Evaporation
- Fencing required
- Capacity
- Maintenance costs
- Construction costs
- Operation/ management

The ranking of the options is summarised in Table 14 below: The full matrix table is presented in Appendix 13.
r

OPTION	RANKING
1	7
2	6
3	5
4	4
5	3
6	2
7	1

Table 14, Option ranking results of multi criteria analysis

This objective ranking agreed with our professional assessment from an engineering point of view.

If the decision to upgrade the current delivery system were to be based on the options ability to provide a flexible delivery of irrigation water, then the Pressurised Pipe system (Option 7) would be our preference at this stage.

Option 7 provides the most benefit to the irrigator and to the surrounding environment. This option would have minimal impact on operations during the construction period thus not requiring landholders to completely shut down operations during what would be a likely extended construction period.

As a peripheral observation there would be the opportunity to integrate Stock & Domestic allocations into this system for Division 1. A piped Division 2 Stock and Domestic System could tap off this line at selected points.

If the decision to upgrade the channel system were to be based solely on price then the Synthetic Lining options would be preferred. Of these options the EPDM rubber liner would be the preferred option as it has a good history and is marginally cheaper that the others.

Another variation of the selected options would be to pipe the main delivery line in the Waroo Channel and line all the remaining lateral lines in Division 1. This would reduce the amount of expensive fencing required and yet provide a near on-demand system with probable significant water savings.

SCHEME CHANNEL GATES AND METERING

Scheme gating and metering upgrades have been based on current locations of regulator, check gates and Dethridge wheel locations. As upgrade size is dependant on required flow for the particular property we have adopted an average cost for each of the elements.

It should be noted that gate and meter upgrades as presented here are only applicable if the Jemalong Irrigation District is to operate as it currently does. If the system were to change to a pressurised pipe system then the need for the majority of regulator check gates would be removed.

Gating and meter upgrade

Regulator, check gate upgrade has been based on information provided by the Jemalong Irrigation Limited in regard to location and quantity of regulator check gates throughout the system.

Channel reconfiguration

As a peripheral observation the reconfiguration of channels could provide great savings in terms of material costs. The main channel that would be considered for straightening is the Warroo Main channel.

The potential to save approximately 7kms of material is a possibility if the Waroo Main were to be re-aligned. This would have impact on Approximately 11 holdings. The properties of which the channel currently intersects would need to adjust their paddocks.

STOCK AND DOMESTIC SUPPLY ALTERNATIVES

The alternative Stock and Domestic systems have been conservatively sized using information supplied by Jemalong Irrigation Limited (see tabulated data), in regards to Holdings and their required High Security Stock and Domestic Licensed requirement. The volumes supplied were presented as a ML per year requirement. For purposes of preliminary sizing this has been broken down to Litres per second. Out of district requirements have been met in areas where data has been provided.

Through our assessment of the available options for a Stock and Domestic supply it became apparent that if the Division 1 were to be upgraded to a pressurised system it may be possible to integrate the Stock and Domestic supply into the same pipe system thus reducing the required infrastructure for this section. Division 2 could be connected to this system.

Another alternative possibility is to run the system over 24hrs 365 days in a year as in SDF1 and incorporate on farm tanks that may be used to augment peak demand during the day. Tank replenishment would take place during the night after peak demand has been satisfied.

OPTION ADVANTAGES AND DISADVANTAGES

Each of the above Stock and Domestic options have advantages and disadvantages in terms of delivery rates, pipe capacities, final cost estimates and route advantages. Below is a summary of the advantages and disadvantages of each option:

SDF 1:

Advantages

- Follows an already existing channel route
- Delivers a consistent flow over 24hrs
- Is not as expensive as SDF 2

Disadvantages

- May not be able to deliver peak demand
- May require on farm tanks to store water for peak demand
- Following the existing route is long, i.e. lots of bends etc, (this could be straightened)
- If the pump fails system is shut down

SDF 2

Advantages

- Follows existing channel route
- Has a larger capacity, thus may deliver peak demand capacities
- May not require the use of on farm tanks

Disadvantages

- Higher capital outlay than SDF 1
- Following the existing channel route is long, i.e. bends etc, (this could be straightened)
- If pump fails system is shut down

SDF 3

Advantages

- Re-routing may reduce total length of pipe required
- Pipe sizes can be reduced
- Individual networks may be linked
- Network pump could be shut down for maintenance during which time another network pump may take over
- Less capital outlay compared to other options

Disadvantages

- 24hr delivery may not meet peak demands
- On farm tanks may be required to store supply for peak demand
- Farm off-take points may be a long way from homesteads
- Extra cost for trenching maybe incurred for road crossings
- Construction may require roads to be temporarily closed
- Three pumps incur higher maintenance costs

SDF 4

Advantages

- Re-routing may reduce total length of pipe required
- Pipe sizes can be reduced
- Individual networks may be linked
- Network pump could be shut down for maintenance during which time another network pump may take over
- Capacity to deliver a higher volume
- May negate the need for on farm tanks to meet peak demands.

Disadvantages

- Extra cost for trenching maybe incurred for road crossings
- Construction may require roads to be temporarily closed
- Higher capital outlay
- Three pumps incur higher maintenance costs

RANKING

Ranking of the Stock and Domestic options was completed simply taking into account the advantages and disadvantages of the four options assessed. From our assessment the following order of ranking was reached:

1. **SDF 4,** although the most expensive of the road routing options this option has the extra capacity that allows greater flexibility in terms of water management.

2. **SDF 3,** the cheaper of the road routing options however constrained by its capacity to deliver peak flows, farm tanks would probably be required.

3. **SDF 2,** the most expensive of the existing channel route options and also the most expensive overall, however it has the capacity to deliver a larger volume thus providing some flexibility for the landholder.

4. **SDF 1**, the cheapest of the existing channel route options, however it does not provide flexibility in water management due to its restricted capacity, this option may require on farm tanks to buffer peak supply demands.

OTHER ENGINEERING ISSUES

GROUND WATER

Two groundwater formations exist in the Jemalong Irrigation District.

1. The Lachlan formation
2. The Cowra formation

Water moves through each of these formations differently. The Lachlan formation is approximately 100m deep, whilst the Cowra formation overlays the Lachlan formation. Both formations run in a similar direction. That is, they enter via deep channels to the south under Lake Cowal and move in a north westerly direction (LWMP 2001).

Since intensive farming practices have increased and the area has been depleted of deep rooted vegetation a shallow groundwater mound has become apparent (LWMP 2001).

In 2001 reports indicated the shallow groundwater mound extended from near the Jemalong Weir across to the prior stream under the Waroo Main channel. The general trend is that this mound continues to grow with water table depths being as close as two meters below the surface in some areas around the Waroo Main channel (LWMP 2001).

Although there have been high groundwater levels in the past the majority of the Jemalong Irrigation District, have groundwater levels averaging below 6m over the district for the year 2007/2008.

It is possible for water levels to rise, however this is dependant on a number of factors including, the future climate, groundwater extraction volumes and channel modernisation in terms of seepage remediation in the channel system.

In the case that the water table levels in this location were to rise, infrastructures such as channel linings have the potential risk to float and thus suffer major damage.

GRADES

Through a grade analysis (Appendix 4) carried out on the Jemalong Irrigation District it has been established that many of the existing channels have grades in the order of 0.02%-0.03% and some with as little as 0.01%-0.02%. The lack of grade makes it very difficult to recommend a wide variety of pipe types as the roughness of the internal diameter becomes a major determining factor in the viability of transporting large volumes of water over these areas.

CONCLUSIONS

1) The Jemalong Irrigation Scheme – Modernisation Plan has been supported by the Board and members of Jemalong Irrigation Limited and every access and assistance was provided by the Jemalong Irrigation Limited to the consultants and authors of this report.

2) The investigation identified an abundance of record but limited specific, technical data with regard to the losses that are being experienced by the Scheme. Though the Scheme maintains historic records of its construction and there has been ongoing investigations in relation to the leakage/losses associated with the Warroo Main channel, there is very little ongoing investigation or documentation with regard to the losses that are being experienced by the remainder of the Scheme. Even the investigations that have been completed for the Warroo Main channel are vague when it comes to specific locations of tests and actual results of those tests.

3) The investigation identified that the Jemalong Irrigation Scheme has identified that the Scheme is characterized by two separate two separate geological unites. In the northern reaches of the Scheme (Division 1) the channels main channels have been excavated into the alluvial sub-grade material. These channels are considered generally more “leaky” than the channels of the southern reaches (Division 2) which have been excavated into much older and more clayey sub-grade material.

4) The investigation has identified that there is great variability with regard to the porosity of the Division 1 channel system. This conclusion is supported by both other texts and anecdotal evidence.

5) The investigation identified that though worthy of consideration, the volume of water lost from the Scheme due to evaporation was not significant in comparison to the volume lost from the Scheme through infiltration from the channel system.

6) The investigation identified that the capacity of the Scheme channels, including existing structure capacities, determine the maximum delivery of water and thereby the maximum application rates for irrigation.

7) Because of the nature and operation of the Jemalong Irrigation Scheme it is, in our opinion, not feasible for the Scheme to use so called “Block Watering” arrangements as used by some other Schemes. In the case of Jemalong, the operation of the system is dependant upon maintaining constant water levels for extended periods within selected reaches of the Scheme in order to satisfy water orders to the adjacent irrigators through their Dethridge wheel metered channels.

8) Significant gains can be realized throughout the Jemalong Irrigation Scheme through the elimination of infiltration losses from the Scheme irrigation channel delivery system. Sealing of the Division 1 channel system, particularly the Warroo Main channel will, in our opinion, significantly reduce water losses within the overall Scheme. In this regard however more and better examination needs to be completed of the remaining Division 1 and Division 2 channels in order to identify more precisely the “leakiest” channels so that prioritisation of works can be determined.

9) High pressure piping of low flows within the Scheme, supplemented by lining of the existing or a re-aligned channel system can offer significant benefits to the Scheme, including providing a major portion of a Stock and Domestic water supply system as well as significantly reducing Scheme loses without limiting lower flow irrigation supplies.

10) Scheme modelling has shown that if the existing Scheme is to be operated in the long term with lower water allocations and flows within the Scheme are proportionally lowered to that new lower allocation then the proportional loss of water from the Scheme would be significantly increased and the long term viability of the Scheme as a whole would be put into significant question.

RECOMENDATIONS

1) It is recommended that further and more detailed investigation be undertaken of the existing channel infiltration rates in order to more specifically identify the reaches throughout the scheme which are most likely contributing to the majority of losses that are being experienced. These investigations could include monitored pondage tests and field infiltration tests conducted and documented using appropriate scientific methods. The results of these tests can be incorporated within the developed system models to determine the likely impact of the infiltration/loss rates that are determined.

2) It is recommended that close consideration be given to the options that include the use of a high pressure pipe system throughout Division 1 in combination with the synthetic lining of the adjacent channel. Such a system offers opportunities of flexibility of construction as well as short and long term operational flexibility and while not totally eliminating the ability of members to irrigate throughout the construction period of either the pipe or channel lining.

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APPENDICES

APPENDIX 1: METHODOLOGY TABLE

Stage 1 Channel Assessment

Item	Method
Channel survey & mapping compilation	• Desktop research through the supplied Jemalong Irrigation Limited database
Channel conditions	• Observations recorded during field trips • Field sampling of channel material • Indicative infiltration testing
Channel grades	• Originally assessed using supplied original survey and Works as Executed drawings
Channel capacities	• Assessment through analysis of channel dimensions from supplied survey data, Boyden & Partners field survey data and operator knowledge.
Data collation	• Field and desktop data compiled.

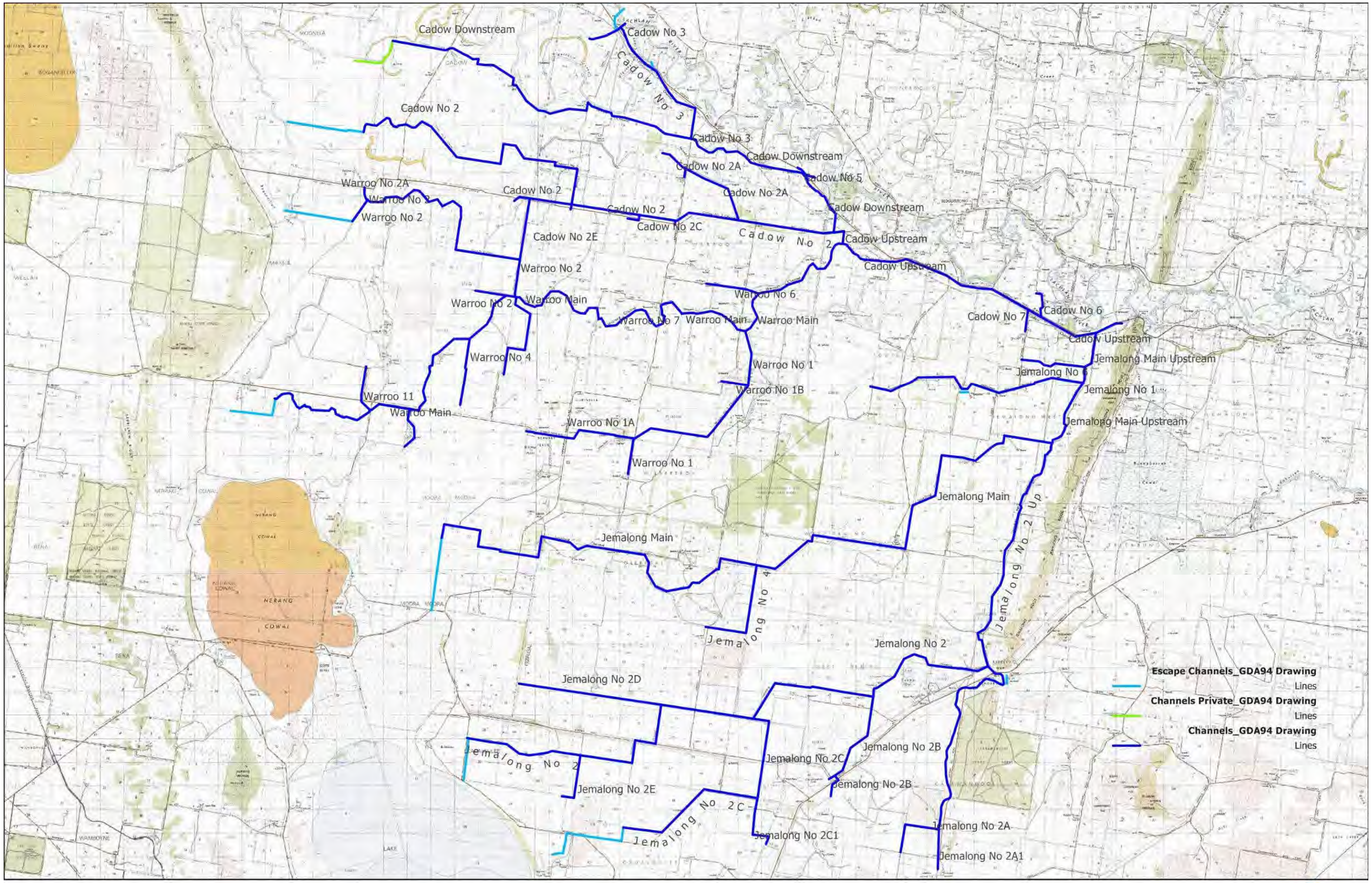
Stage 2 Analyses of Data

Evaporation data analysed	• Condobolin Agriculture research Station
Seepage data	• Estimated using Combined Approach (LWRRDC 2001)
Losses	• Estimated using a Mass Balance Model • Estimated using a Weir Storage Model

Stage 3 Modernisation Options

Options elements	• Options elements assessed for suitability to location
Option Construction	• Options constructed from elements and assessed for suitability.
Final Option Costing	• Final costing of options that were assessed in detail presented as possible scenarios based on the benefit and suitability for the Jemalong Irrigation District conditions

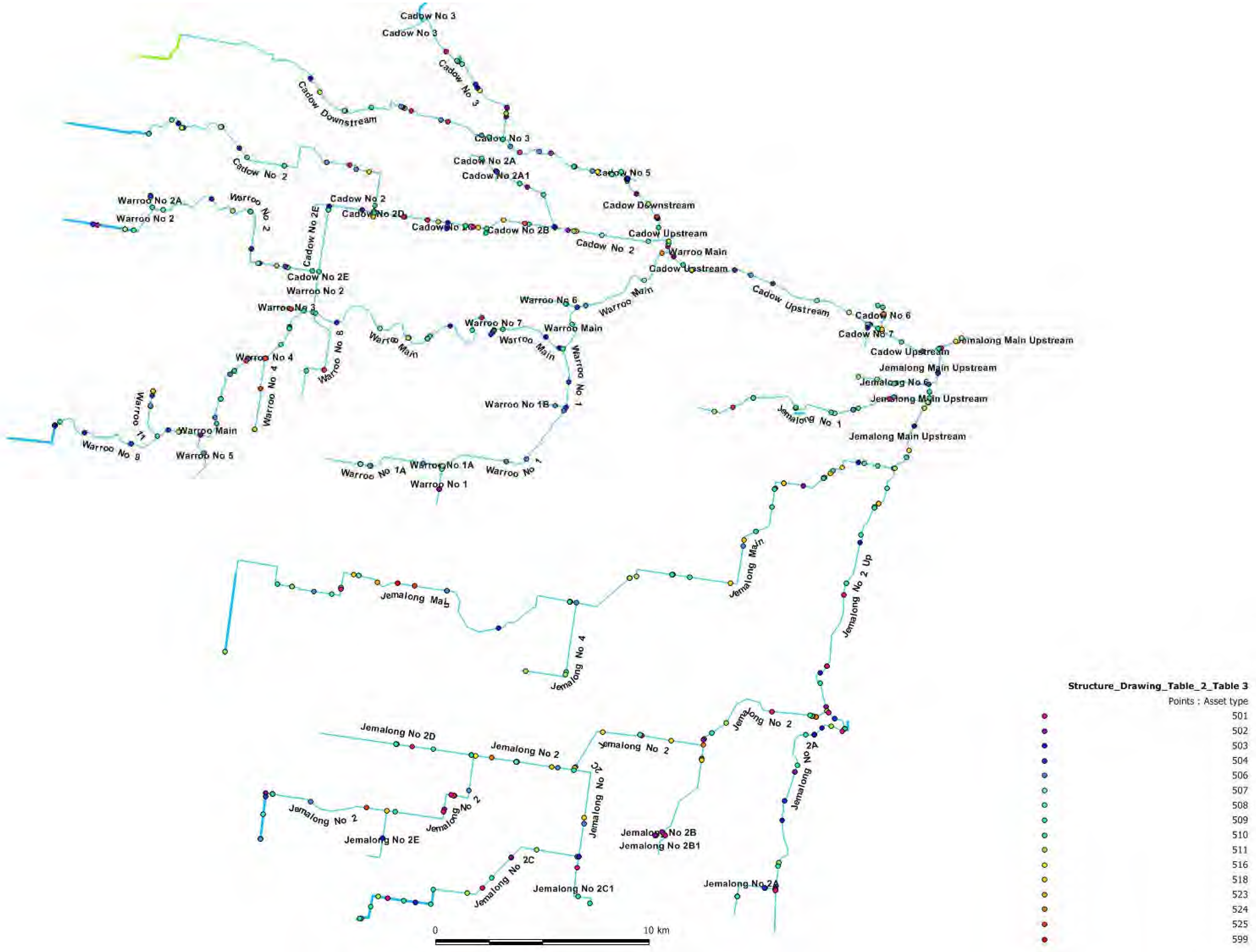
APPENDIX 2: JEMALONG IRRIGATION LIMITED CHANNEL SCHEMATIC



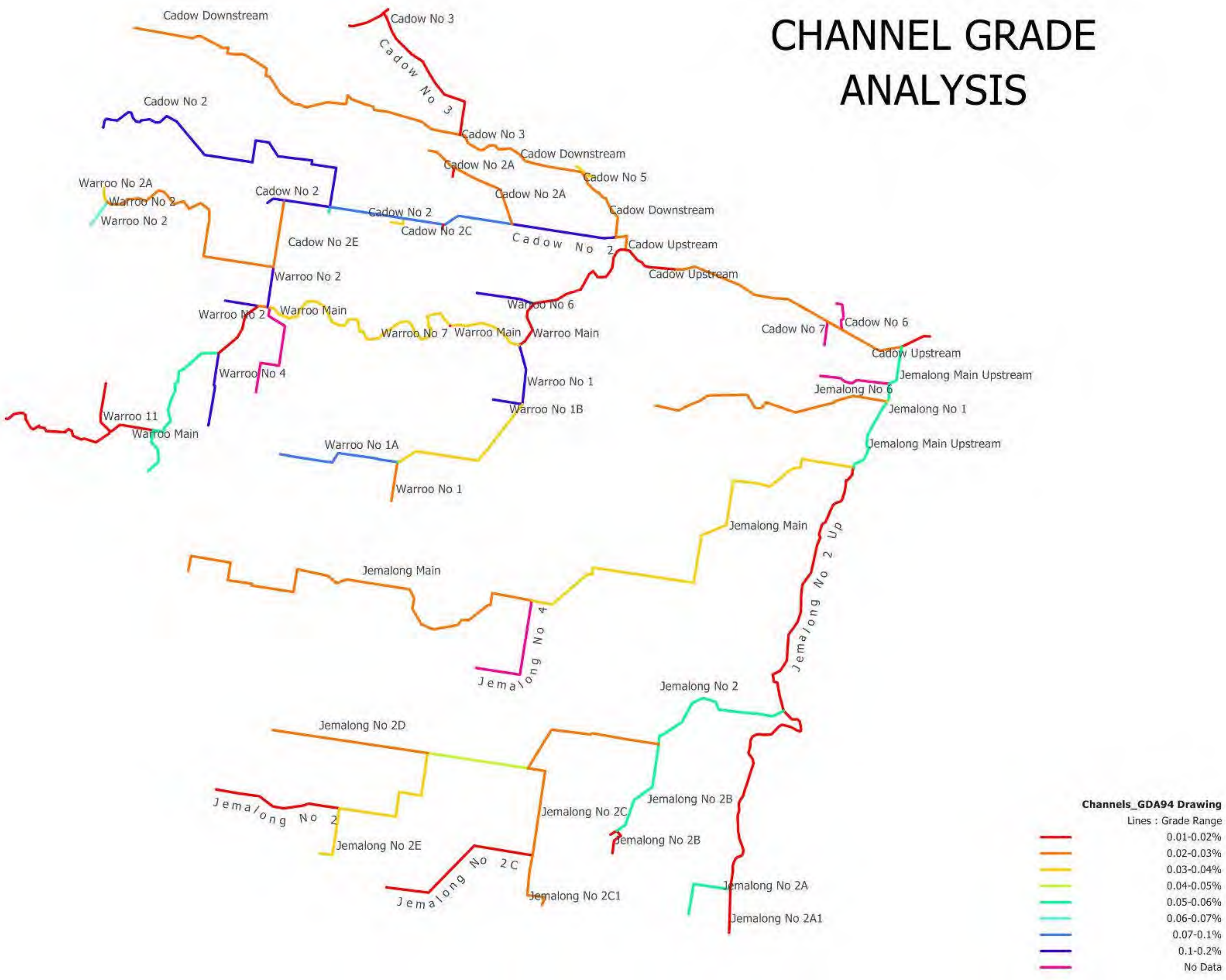
Jemalong Irrigation Scheme Schematic

Australia MGA94 (55)
Australian Geocentric 1994 (GDA94)

APPENDIX 3: JEMALONG IRRIGATION LIMITED STRUCTURE MAP



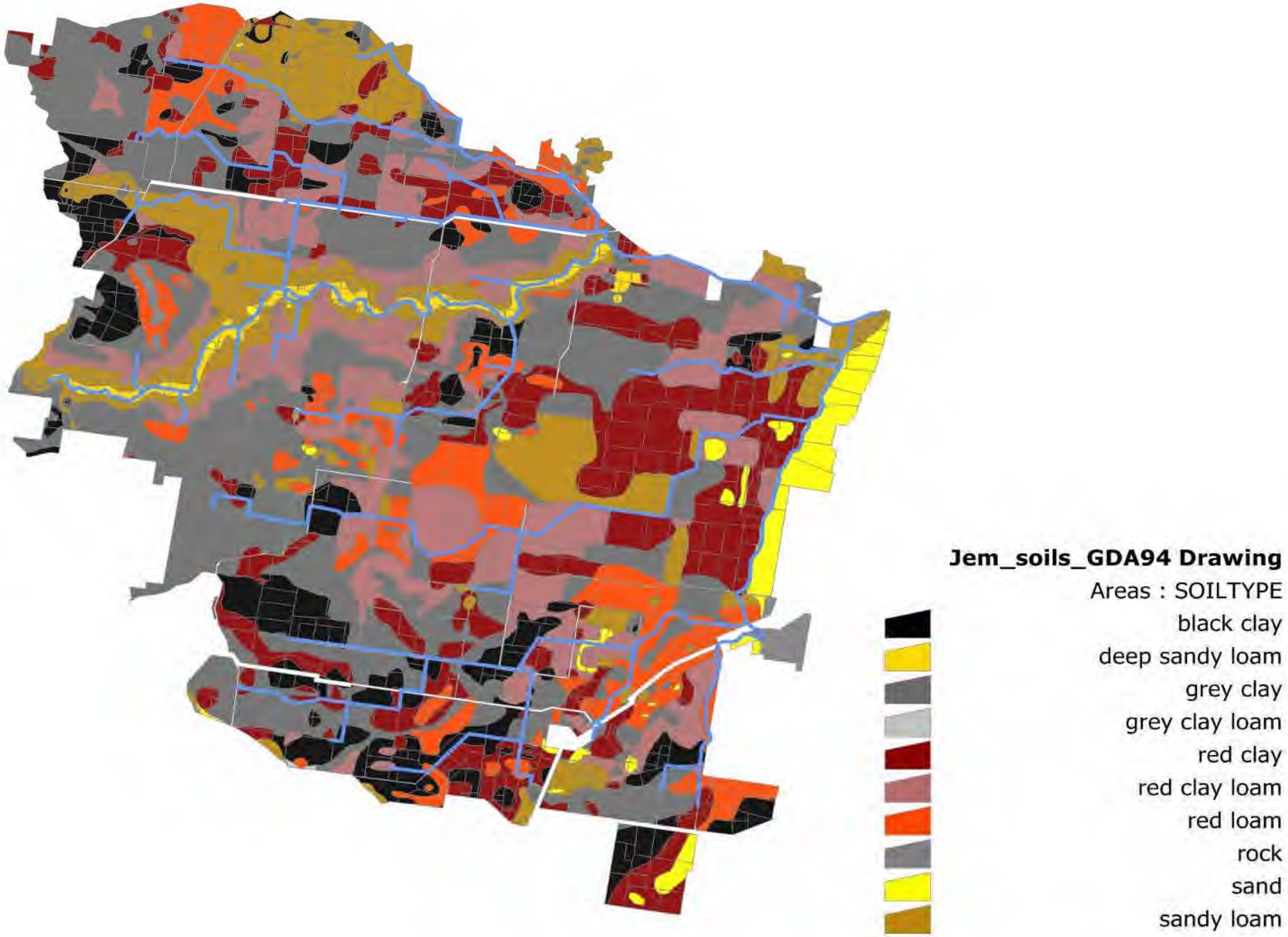
APPENDIX 4: CHANNEL GRADE ANALYSIS.



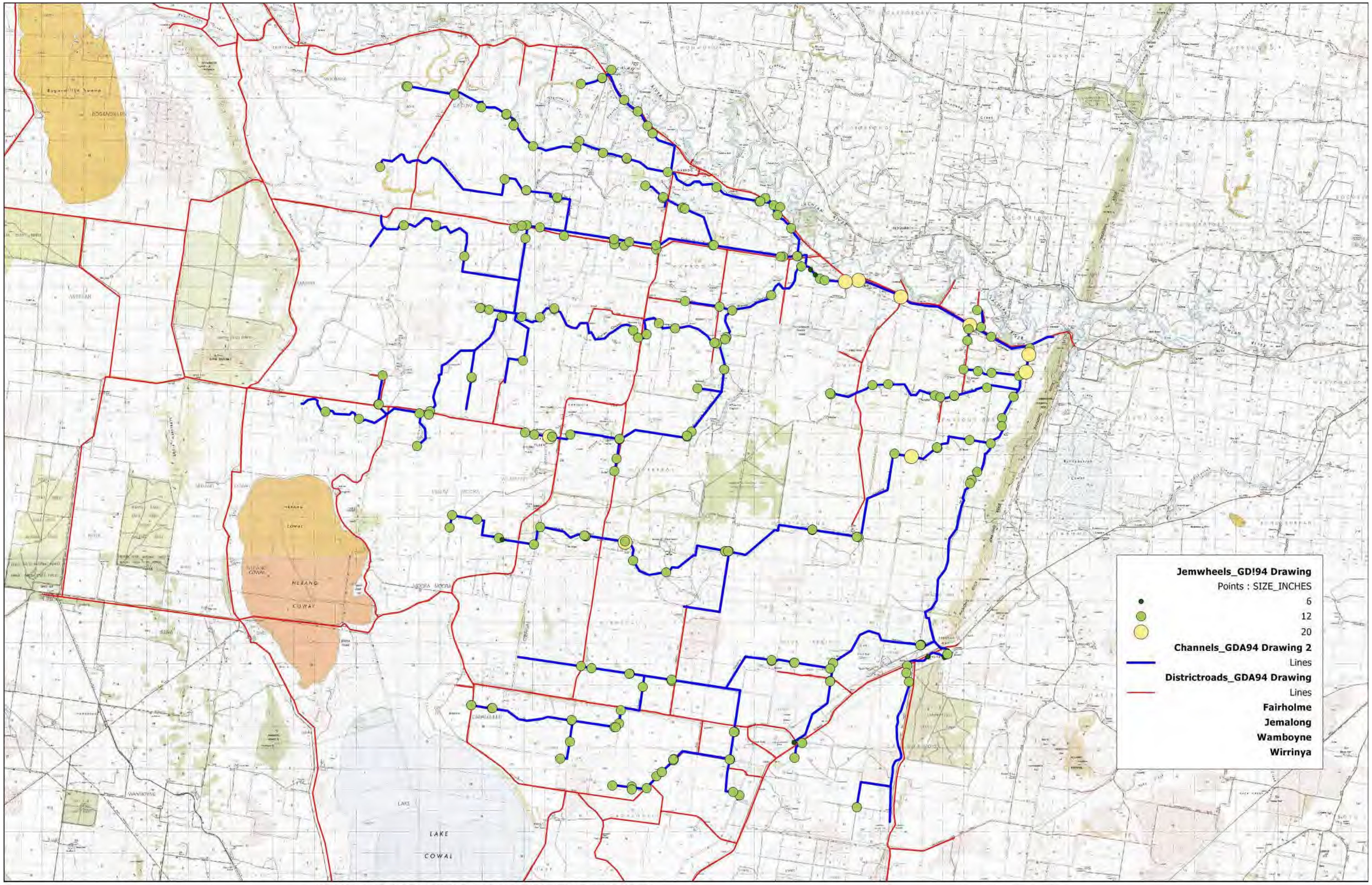
APPENDIX 5: CHANNEL GRADE ANALYSES RESULTS

CHANNEL NAME	GRADE	CHANNEL NAME	GRADE
Cadow No 5	0.03%	Cadow Downstream	0.02%
Cadow No 5	0.03%	Cadow Downstream	0.02%
Cadow No 2	0.11%	Cadow No 2	0.07%
Cadow No 2D	0.05%	Cadow No 2	0.07%
Cadow No 3	0.01%	Cadow No 2	0.11%
Cadow No 3	0.01%	Cadow No 2	0.11%
Cadow No 3	0.01%	Cadow No 2	0.07%
Cadow No 5A	0.03%	Cadow No 2	0.07%
Cadow Downstream	0.02%	Cadow No 2A	0.03%
Cadow No 2	0.11%	Cadow No 2A	0.03%
Cadow No 2B	0.01%	Cadow No 2A	0.03%
Cadow No 2C	0.03%	Cadow No 2B	0.01%
Warroo No 2A	0.04%	Cadow No 2C	0.03%
Cadow No 2A1	0.01%	Cadow No 3	0.01%
Cadow No 2E	0.03%	Cadow Upstream	0.01%
Jemalong No 2A	0.06%	Cadow Upstream	0.03%
Jemalong No 2B1	0.01%	Cadow Upstream	0.03%
Jemalong No 2E	0.03%	Cadow Upstream	0.03%
Warroo No 2	0.20%	Cadow Upstream	0.03%
Warroo No 6	0.18%	Cadow Upstream	0.03%
Jemalong No 2	0.01%	Jemalong Main	0.04%
Warroo Main	0.01%	Jemalong Main Upstream	0.06%
Warroo Main	0.06%	Jemalong Main Upstream	0.06%
Warroo No 2	0.07%	Jemalong Main Upstream	0.01%
Warroo No 5	0.06%	Jemalong Main Upstream	0.06%
Warroo No 4	0.13%	Jemalong No 1	0.03%
Warroo Main	0.01%	Jemalong No 2	0.05%
Warroo Main	0.02%	Jemalong No 2	0.03%
Warroo Main	0.02%	Jemalong No 2	0.04%
Warroo No 2	0.02%	Jemalong No 2	0.03%
Jemalong No 2B	0.01%	Jemalong No 2 Up	0.02%
Jemalong Main	0.03%	Jemalong No 2A	0.01%
Warroo No 3	0.13%	Jemalong No 2B	0.05%
Cadow No 2E	0.03%	Jemalong No 2C	0.01%
Warroo No 2	0.20%	Jemalong No 2C	0.03%
Cadow No 2D	0.05%	Jemalong No 2C1	0.03%
Warroo No 2	0.02%	Jemalong No 2D	0.03%
Warroo 11	0.01%	Warroo Main	0.03%
Warroo No 1	0.11%	Warroo Main	0.02%
Warroo No 1B	0.11%	Warroo Main	0.02%
Warroo No 3	0.13%	Warroo Main	0.02%
Warroo No 4	0.13%	Warroo Main	0.03%
Warroo No 1A	0.09%	Warroo No 1	0.02%
Warroo No 9	0.01%	Warroo No 1	0.03%
Warroo No 5	0.06%	Warroo No 1A	0.06%
Jemalong No 1	0.03%	Warroo No 6	0.02%

APPENDIX 6: JEMALONG IRRIGATION DISTRICT SURFACE SOIL CONDITIONS



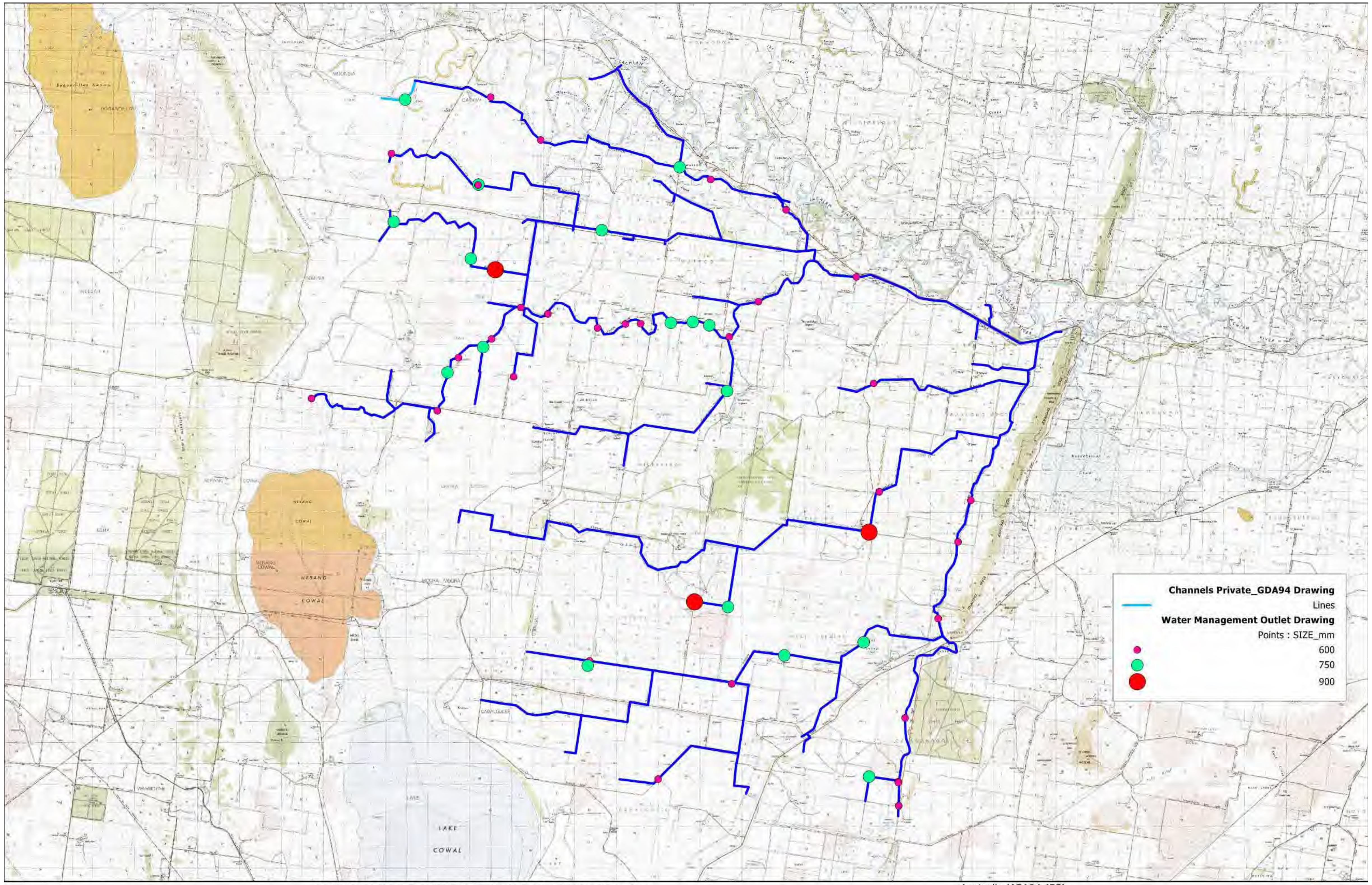
APPENDIX 7: DETHRIDGE WHEEL OUTLET LOCATIONS



JEMALONG IRRIGATION DISTRICT
DETHRIDGE WHEEL LOCATIONS
& SIZES

Australia MGA94 (55)
Australian Geocentric 1994 (GDA94)
1:160000

APPENDIX 8: WATER MANAGEMENT OUTLETS



JEMALONG IRRIGATION DISTRICT
WATER MANAGEMENT OUTLET LOCATIONS
& SIZES

Australia MGA94 (55)
Australian Geocentric 1994 (GDA94)
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APPENDIX 9: JEMALONG IRRIGATION LIMITED CHANNEL AND STRUCTURE CAPACITIES

JEMALONG IRRIGATION SCHEME

CHANNEL/STRUCTURE CAPACITY MAP

APPENDIX 10, C.A.R.S PAN EVAPORATION DATA

	Condobolin Agricultural Station Climatic Statistics								
	Pan Evaporation Summary								
	1989	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**
Jan	8.5	10.5	9.0	10.3	8.4	10.8	6.9	9.1	9.6	8.9
Feb	8.5	7.8	10.0	6.7	8.9	7.7	8.0	9.4	9.8	9.8
Mar	5.7	7.5	7.7	6.8	6.2	7.0	8.0	7.0	7.8	9.1
Apr	2.7	3.0	4.7	4.3	4.8	4.6	4.8	4.9	5.3	4.3
May	1.6	2.0	2.4	2.0	2.2	3.3	1.9	2.3	2.5	1.9
Jun	1.0	1.3	1.5	1.3	1.6	2.1	1.2	1.7	1.4	1.3
Jul	1.4	1.3	1.5	1.8	1.3	2.1	1.5	1.1	1.9	1.0
Aug	1.8	2.0	2.9	2.0	2.1	3.2	2.8	2.0	2.3	1.7
Sep	3.7	3.0	4.4	2.9	2.9	5.4	3.5	3.6	2.9	2.6
Oct	6.5	4.9	6.4	4.9	4.2	7.4	6.2	5.3	5.4	4.2
Nov	7.4	8.1	8.4	6.0	7.1	8.3	6.5	7.0	9.2	6.4
Dec	10.5	10.1	8.4	5.8	7.7	11.3	9.2	9.7	11.1	9.6
	1999	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**
Jan	9.8	9.0	11.2	11.4	12.1	10.4	10.8	10.8	10.6	7.3
Feb	8.3	8.1	8.3	7.4	8.8	9.8	9.3	10.8	9.9	6.8
Mar	5.1	5.5	6.8	5.4	6.3	6.8	7.6	7.3	7.1	7.0
Apr	3.2	2.9	4.4	4.0	4.1	4.8	5.6	4.8	5.0	4.7
May	2.3	1.9	2.2	2.1	3.0	2.8	3.1	2.7	2.8	2.5
Jun	1.7	1.4	1.2	2.3	2.0	1.6	1.8	1.4	1.4	1.7
Jul	1.8	1.4	1.3	2.4	1.9	1.7	1.4	1.3	1.6	2.1
Aug	2.2	1.9	2.5	3.3	2.3	2.8	2.6	2.5	2.8	2.6
Sep	3.8	4.1	3.6	5.3	4.5	3.9	3.2	5.1	5.7	5.4
Oct	4.2	5.2	5.4	6.2	5.7	6.1	4.5	8.5	8.1	7.8
Nov	6.4	5.0	7.5	9.8	8.5	8.5	7.9	10.3	7.8	8.1
Dec	8.0	9.3	10.3	11.0	9.5	9.3	11.4	11.1	7.7	10.4

APPENDIX 11: MODELLING DETAILS

Part A – Modelling Background

The Jemalong Irrigation District can be defined as a relatively “data poor” region, and thus a “bottom-up” analysis using both the Weir-Storage Loss Model and the Mass-Balance Loss Model was required. (CSIRO, 2008) These models have been adopted to reasonably determine the current operational performance of the channels, based upon recorded data and anecdotal reports.

A Weir-Storage Loss Model was found by Boyden & Partners to be the best representation of the existing operations of Jemalong Irrigation Limited. The secondary Mass-Balance Loss Model found to be suitable for the estimation of conveyance losses for open-channel flows, such as those associated with diversions to the Barrick Mine.

The geometric characteristics of both models were adopted from the historic survey of original works conducted during the period 1939-1942, provided by Jemalong Irrigation Limited The longitudinal works-as-executed survey plans had cross-sections extracted to both of the spreadsheet models at 1000ft intervals (approximately 300m) or at the location of any change in cross-sectional dimension or recorded structure.

More recently, some existing channels have been expanded and other additional channel reaches were reconstructed. In these areas, channel reaches have been modeled with recent cross-sectional geometries where survey data was available (Karl Lupis, March 2004) or as per verbal reports from Jemalong Irrigation Limited (February and March 2009). Some other channel reaches have since been extinguished from the current irrigation operations, and are not indicated on maps prepared by Boyden & Partners. Although there is evidence to suggest continual deterioration of channels over time, both model types have been constructed upon the basis of the best available data of channel cross-sections and grades from historic survey, and anecdotal reports from an experienced systems operator.

A typical trapezoidal cross-section of an indicative channel reach is shown below in Figure 8.

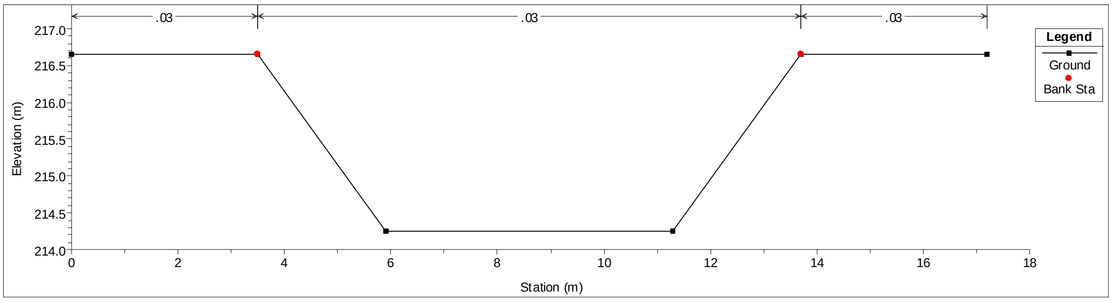


Figure 16, Typical Channel Cross-section.

The characteristics of the channel network and their subsequent operational losses are derived from:

- Existing soil types and vegetative cover within the channels;
- The shape, geometry and longitudinal grade between upstream and downstream channel cross-sections;
- The depth of operations; and for the case of the Mass-Balance hydraulic model:
- Manning’s equation.

The “input data” requirements for each model’s functions are:

- Channel reach length (maximum was 300m or to nearest structure/change in geometry);
- Diversion supply rate (Mass-Balance Model only, adopted as average metered flow for Barrick Mine);
- Depth of water operated (as per model calculations, or set to “full” or half-full” by anecdotal reports);
- Average evaporative rate (adopted as ‘average summer’ for Mass-Balance Model, otherwise adopted as the historic monthly-average);
- Infiltration rates (Initially as per soil maps and indicative infiltration testing, now based on anecdotal reports plus calibration);
- Longitudinal grade (adopted from historic survey data);

- Roughness/friction co-efficient or Manning's "n" value was a constant 0.030. This value is consistent with assumptions for system capacities as noted on the historic survey. It is also representative of a channel that is earthen, winding and sluggish with grass, with some weeds (Chow 1973);
- Channel cross-sectional geometry (adopted from historic survey data, and calibrated as per anecdotal reports).

Part-B "WEIR-STORAGE LOSS MODEL"

Background - Operations of Jemalong Irrigation Limited replicated by Weir-Storage Loss Model

The operations of the Jemalong Irrigation Limited delivery system are primarily characterized by open-earthen channels to transfer water diversions from the Jemalong Weir, to throughout the irrigation district. In order to minimize the opportunity for channel capacities to be exceeded by unsteady flows and waves, and to ensure minimal supply times to irrigators following an order, check-gates are operated to allow the steady filling of upstream channel reaches. Water supplies are transferred to irrigators via Dethridge-Wheels or similar meters located high in the channel batters. Following the filling of upstream channel reaches, check-gates are later opened to release these flows to downstream irrigators. In this way, the system could be better described as a storage system more than an open-channel system, and hence can be appropriately modeled as a Weir-Storage Loss Model.

Weir-Storage Loss Model Concept

A 'Weir-Storage Loss Model', was selected as the best representation of the existing irrigation system operations, based on anecdotal reports from an experienced system operator. The concept of the Weir-Storage model is based upon the reported scenario that depths of operation within the Jemalong Irrigation District are maintained as 'full' or 'half-full' in the majority of the main channel reaches, over a nominal irrigation delivery period of nine months. Depths have been related to the 'Full Supply Level' as shown on historic works-as-executed survey plans, provided by Jemalong Irrigation Limited. These depths are regulated by the operation of 'check-gates' in the channel network, to supply irrigators.

The Weir-Storage model has been composed using reports of a reduced operations system, such that only channel reaches that were reported to be operated for the nominal nine months were included. The contribution of losses from spurs and channels operated only during deliveries has been separately documented, due to the irregularity and inconsistency of these operations.

Application of the Weir-Storage Loss Model

The modeling of the existing delivery system was crucial in effectively estimating the operational losses, and was comprehensively constructed using a Microsoft Excel spreadsheet. The losses associated with the relative wetted areas such as perimeter and the top-water surface for a particular depth of operation, were determine by the definition of geometric characteristics in the model such as batter slope, longitudinal grade, base-width, hydraulic roughness, full-supply depth and length.

The channels represented by the spreadsheet Weir-Storage Loss Model were assigned a constant depth of full, half-full or empty as per operator reports. An infiltration rate was applied to the wetted perimeter area of the operated channels, to simulate the condition of seepage associated with the operations of each individual channel reach. The ongoing losses associated with the infiltration and evaporation, for the operations of the system in 'storage', has been summated for each operated channel reach for comparison with historic water balances.

Preliminary infiltration rates were based upon indicative infiltration tests taken at channel inverts for each soil type, indicated by available soil maps. The losses associated with these soil-based infiltration rates were reported by Jemalong Irrigation Limited, and confirmed by historic water balances to be an overestimate of the actual losses. These have since been amended to equivalent infiltration loss rates based on operator reports, and further calibrated in Division 1 by a uniform increase of 35.5% to closely match historic water balances. Losses due to evaporation have been modeled by the application of an evaporative loss rate to the top water surface area of the channel, based on historic monthly averages.

The wetted perimeter of the channel cross-section was determined by the equation:

$$P = b + 2d\sqrt{(z^2 + 1)} \qquad \text{…………………(1)}$$

Where

- P = Wetted Perimeter, in m²
- b = Base-width of the channel, in m
- d = depth from water surface to the channel base, in m
- z = Slope of the batter, z:1 i.e. 2:1 would indicate a run of 2m to a rise of 1m.

The top-width of the water surface was determined by:

$$T = b + 2dz \qquad \text{…………………(2)}$$

Where: T = Top Surface Width, in m

The wetted cross-sectional of the channel was determined by:

$$A = bd + zd^2 \qquad \text{…………………(3)}$$

Where: A = Wetted Cross-sectional area

Part-C "MASS-BALANCE LOSS MODEL"
Background - Operations of Jemalong Irrigation Limited replicated by Mass-Balance Loss Model
Recent water delivery methods to areas such as the Barrick Gold Mine, located south of the channel reach 'Jemalong 2C' in Division 2 can be characterised by an open-channel system. The hydraulics of this type of system and the related conveyance losses can be approximated with the use of a hydraulic Mass-Balance Loss Model. A sensitivity analysis for the flow rates for the Mine-supply were applied as the average, upper and lower extremes of the recorded metered readings, approximating recent operations as *steady-state*.

Steady-state refers to a conceptual type of hydraulics analysis, such that conditions in the system do not change over time. It is defined as:

"Steady-state flow refers to the condition where the fluid properties at any single point in the system do not change over time. These fluid properties include temperature, pressure, and velocity. One of the most significant properties that is constant in a steady-state flow system is the system mass flow rate. This means that there is no accumulation of mass within any component of the system." (http://www.engineersedge.com/fluid_flow/steady_state_flow.htm)

The average flow rate to the mine was selected as the best representation for the recent operations and known conveyance losses, as confirmed by Jemalong Irrigation Limited.

Mass-Balance Loss Model Concept
The expression "mass-balance" in the context of this report refers to the conveyance hydraulics versus losses of the Jemalong Irrigation District The concept is based on the development of a measurable balance of the irrigation water supply, such that inflows to a 'channel reach' are equal to the outflow discharges plus conveyance losses.

Application of the Mass-Balance Loss Model
The hydraulic relationships of the open-channel discharges were able to be predicted using the widely-used Manning's equation. This equation determines the velocity of a body of water in transit, based upon the geometric characteristics and hydraulic roughness of the channel cross-section. In this model, the remainder of discharge entering a channel reach after conveyance losses could be simply calculated, but its depth was unknown. These depths were solved to match the inflow by Manning's Equation, within the Mass-Balance Loss Model. The procedure for predicting each depth, and to match the inflow for multiple in-line cross-sections was automated using a 'Macro' programming-function in Microsoft Excel. The discharge to downstream reaches was determined by the inflow minus conveyance losses of the upstream channel reach.

The velocity of flow is found by Manning's Equation:

$$V = R^{2/3}S^{1/2} / n \qquad \ldots\ldots\ldots\ldots\ldots(4)$$

Where:
- V = Average velocity of the flow, in m/s
- R = Hydraulic radius of the channel cross-section, in m
- S = Friction slope of the flow, in m/m (unit-less)
- n = Hydraulic roughness of the channel surface, unit-less

The hydraulic radius of the flow is found by:

$$R = A / P \qquad \ldots\ldots\ldots\ldots\ldots(5)$$

Where:
- A = Cross-sectional area of the flow, in m^2
- P = Wetted Perimeter of the flow, in m

And the quantity of discharge is defined by:

$$Q = V \times A \qquad \ldots\ldots\ldots\ldots\ldots(6)$$

Where:
- Q = Quantity of discharge, in m^3/s (kL/s)

The balance of the discharge to a downstream section, i.e. the Mass-Balance is defined by:

$Q_{out} = Q_{in} – L_{evap} – L_{infil}$ ………………….(7)

Where:

Q_{out} = Discharge from a channel reach, in m³/s (kL/s)
Q_{in} = Discharge into a channel reach, in m³/s (kL/s)
L_{evap} = Losses within a channel reach due to evaporation, in m³/s (kL/s)
L_{infil} = Losses within a channel reach due to infiltration, in m³/s (kL/s)

Hydraulic 'Flow Splits' at Channel Intersections

The division or 'splitting' of inflows at all channel reach intersections were modelled using field observations of operational hydraulics at typical intersections. It was observed by Boyden & Partners that flows downstream of these channel branch splits/intersections were generally at an equal depth, provided that check-gates were open. These flow depths were noted as generally equal, regardless of entry angles, attributed to the relatively low grades and subsequent minimal velocity-based head-loss of the flow. The mass-balance model was then calibrated with this same hydraulic relationship, such that both of the downstream reach flow depths were equal. The downstream cross-sectional geometry, longitudinal grades, and obstructions such as check-gates, constrained the quantity of inflow to a given channel reach. Anecdotal reports from an experienced operator indicated the known system capacities, to which the model was later calibrated, to ensure these capacities were not exceeded during hydraulic model trials.

Sensitivity Analysis of the Contribution of Losses from Irregularly-Run Spurs and Channels

	Division 1 Losses Only				
Scenario of Infiltration Loss Rate Application	"Wet-up" Losses (2 or 3x Regular) (ML/day)	Regular Losses (ML/day)	**Total Losses (ML/month)**	***Proportion of the Total Losses*** for 1998-1999	***Proportion Loss of the Total Allocation*** for 1998-1999
2 x Infiltration Rate for 2 days, 1 x Infiltration Rate for 8 days	33.8	17.5	**207.4**	9.3%	2.8%
3 x Infiltration Rate for 2 days, 1 x Infiltration Rate for 8 days	50.1	17.5	**239.9**	10.7%	3.3%
2 x Infiltration Rate for 1 day, 1 x Infiltration Rate for 9 days	33.8	17.5	**191.1**	8.5%	2.6%
3 x Infiltration Rate for 1 day, 1 x Infiltration Rate for 9 days	50.1	17.5	**207.4**	9.3%	2.8%

Summary of the operations of the Mass Balance Loss Model

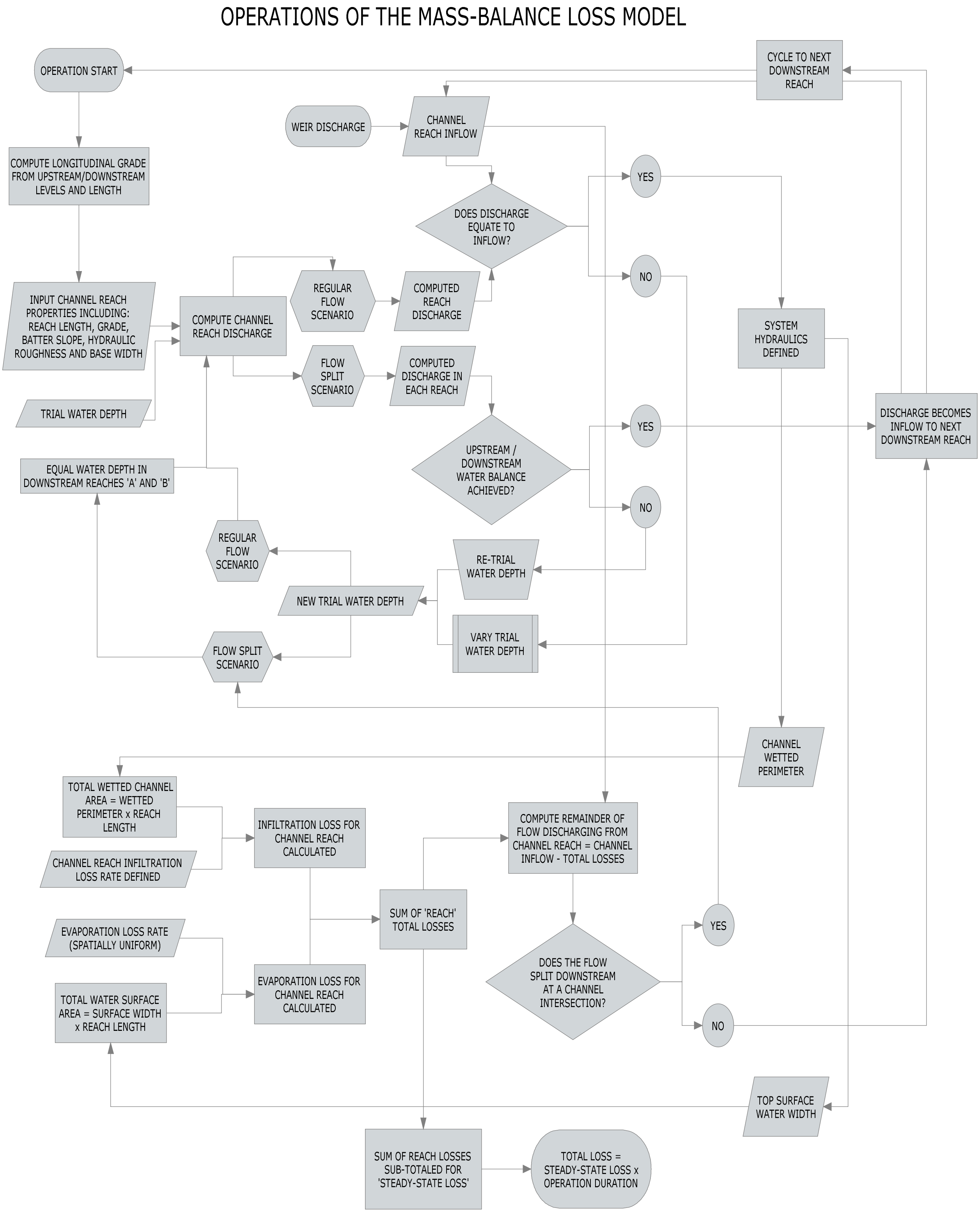


Figure 17, Summary of the operations of the Mass Balance Loss Model

APPENDIX 12: ELEMENT MULTI-CRITERIA RANKING MATRIX

Elements	Earth Liners			Hard Surface Liners		Flexible Membranes			Pipes	
	Stabilsed Backfill	Clay lining	Modified Clay Lining	Shotcrete	Trowel	HDPE	EPDM	UV protected Geofabric	Concrete	HDPE
Selection Parameters										
Infiltration (vertical)	2	2	2	3	3	3	3	3	3	3
Infiltration (lateral)	2	2	2	3	3	3	3	3	3	3
Evaporation	1	1	1	1	1	1	1	1	3	3
High Watertable	1	1	1	1	1	1	1	1	1	2
Channel Downtime during construction	1	1	1	1	1	2	2	2	3	3
Prone to Stock/Animal damage	2	1	2	2	2	1	1	1	3	3
Requires to be fenced off	1	1	2	2	2	1	1	1	3	3
Small channel dimensions	1	1	2	2	2	2	2	2	2	3
Large channel dimensions	3	3	2	2	2	2	2	2	3	3
High water velocity	2	2	2	3	3	2	2	2	2	3
Ongoing channel maintenance	2	1	1	1	1	2	2	2	3	3
Weed spraying	1	1	1	3	3	3	3	3	3	3
Lifespan	2	2	2	2	2	2	3	1	3	3
Cost	2	1	2	1	1	3	3	3	1	1
Scores	23	20	23	27	27	28	29	27	36	39
Ranking	8	10	9	7	6	4	3	5	2	1

Scoring

More suitable	3
Suitable	2
Less Suitable	1

***NOTE: where an element has scored equally with another the ranking has come down to cost*.**

APPENDIX 13: OPTION MULTI-CRITERIA RANKING MATRIX

Options	**Option 1**		**Option 2**		**Option 3**		**Option 4**		**Option 5**		**Option 6**		**Option 7**	
Division	Division 1	Division 2	Division 1	Division 2	Division 1	Division 2	Division 1	Division 2	Division 1	Division 2	Division 1	Division 2	Division 1	Division 2
Treatment	Existing scheme	Existing Scheme	Stabilised Backfill	Stabilised Backfill	Geo fabric Liner	Geo fabric Liner	HDPE Liner	HDPE Liner	EPDM Liner	EPDM Liner	Pipe+ Liner	Possible Liner	Pipe	Possible Liner
Parameters														
Channel downtime	3		1		1		1		1		2		3	
Infiltration	1		2		3		3		3		3		3	
Evaporation	1		1		1		1		1		2		3	
Fencing required	0		1		1		1		1		1		3	
Capacity	3		3		3		3		3		3		3	
Maintenance costs	1		1		2		2		2		2		3	
Construction costs	0		3		2		2		2		1		1	
Operation/ management	1		1		1		1		1		2		3	
Score	10		13		14		14		14		16		22	
Ranking	7		6		5		4		3		2		1	

Scoring

More suitable	3
Suitable	2
Less Suitable	1

Note: WHERE AN OPTION HAS SCORED EQUALLY WITH ANOTHER ITS RANKING HAS BEEN ASSUMED THROUGH COST.

APPENDIX 14: STOCK AND DOMESTIC PRELIMINARY ASSESSMENT PARAMETERS

The following table is a summary of the parameters used in the analysis of the stock and domestic piped systems.
A comprehensive breakdown of this summary was used for the pipe sizing of the Stock and Domestic pipe systems.
For the sizing of each system the location and Stock and Domestic requirement for each holding has been taken into account in the course of the analysis.

Total Requirement	1400 ML/Year
No of Holdings Jemalong Irrigation District	156
No of Out of District Holdings	13
Total Flow requirement in litres/second for a 24hr delivery over 365 days	44 L/sec
Total Flow requirement litres/second for a 12hr delivery over 365 days	88 L/sec

APPENDIX 15: SDF 1 DETAILS

SDF1

Layout
The layout follows the current channel system.

Requirement
Stock and domestic requirement volume for each holding delivered over 24hrs, see previous tabulated data. Flow requirements in litres per second to supply each holding per reach have been analysed and transferred to the channel layout.

Pipes
Pipes have been sized under the following criteria:

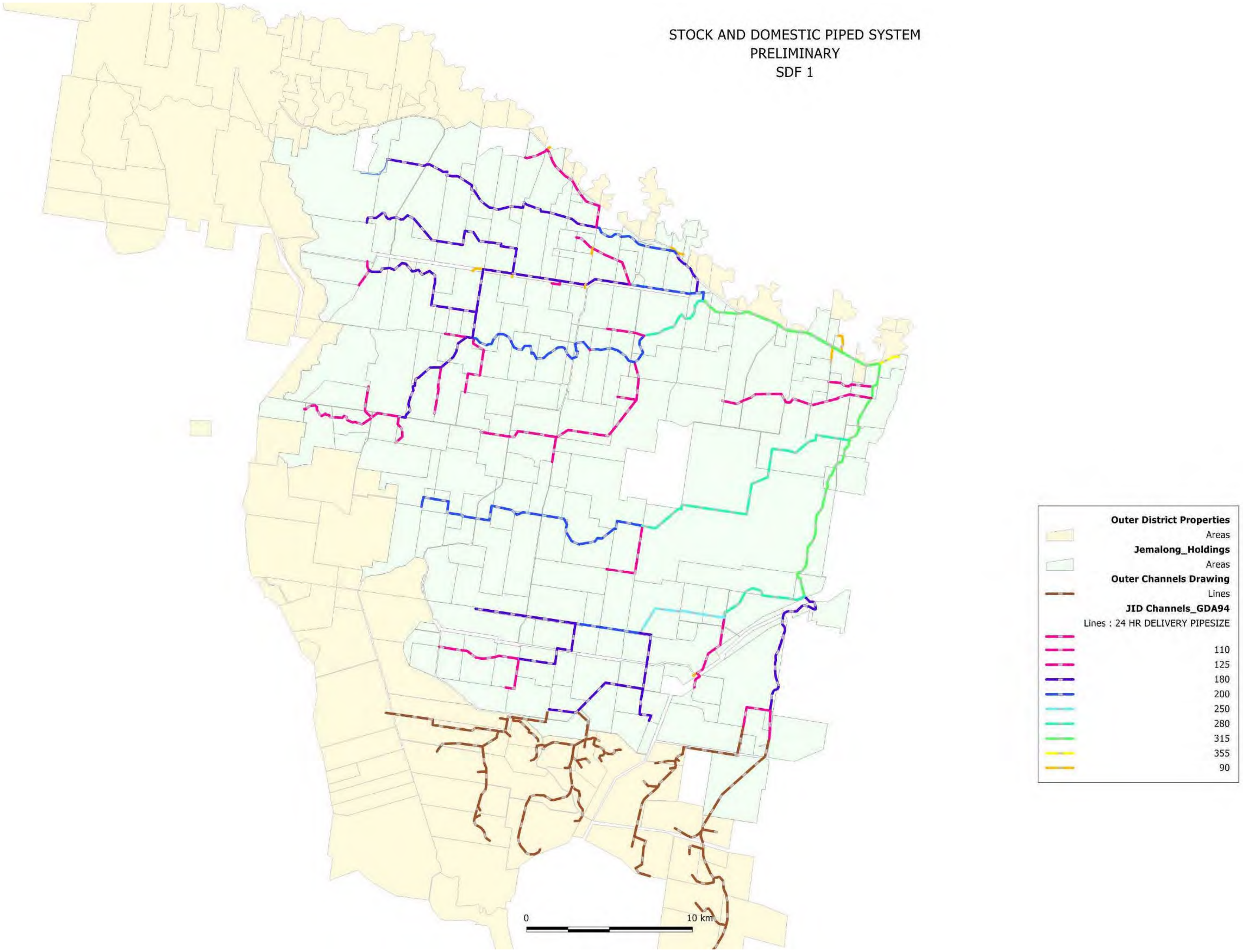
- Volume of flow required in litres per second.
- Length of the reach to be piped.
- Grade of the natural surface of the land of which the pipe will traverse, (sourced from digital elevation map).

Pipes sized are HDPE 100 class 6.3. This is a durable class that can take some pressure if required. Approximate pipe costing has been sourced from manufacturers and industry standard quantities text and includes delivery cost.

Trenches
Trench work cost estimates have been included per reach in the total price. Trenches have been sized per the requirement of the pipe with a minimum cover of at least 500mm. Pricing includes bedding the pipe in natural sand and backfilling the remaining trench. Costings have been sourced from industry standard quantities text.

Pump
Pump required for SDF 1 would be required to pump from the river and into the pump system. The pump would need to be able to pump at least 44l/s at 8m of head from the river to the pipe network. Head loss throughout the pipe network has been reduced by over sizing. Over sizing also allows for some flexibility i.e., the allowing for any future for increases in demand or supply requirements.

APPENDIX 16: SDF 1 LAYOUT



APPENDIX 17: SDF 2 DETAILS

SDF 2

Layout

The layout follows the current channel system.

Requirement

Stock and domestic requirement volume delivered over 12hrs
This system uses the calculated requirement from the data provided by Jemalong Irrigation Limited and has been sized to deliver this volume over a 12hr period. The extra sizing allows for greater flexibility.
Stock and domestic requirement volume for each holding delivered over 12hrs, see previous tabulated data. Flow requirements in litres per second to supply each holding per reach have been analysed and transferred to the channel layout.

Pipes

Pipes have been sized under the following criteria:
Volume of flow required in litres per second.
Length of the reach to be piped.
Grade of the natural surface of the land of which the pipe will traverse, (sourced from digital elevation map).

Pipes sized are HDPE 100 class 6.3. This is a durable class that can take some pressure if required. Approximate pipe costing has been sourced from manufacturers and industry standard quantities text and includes delivery cost.

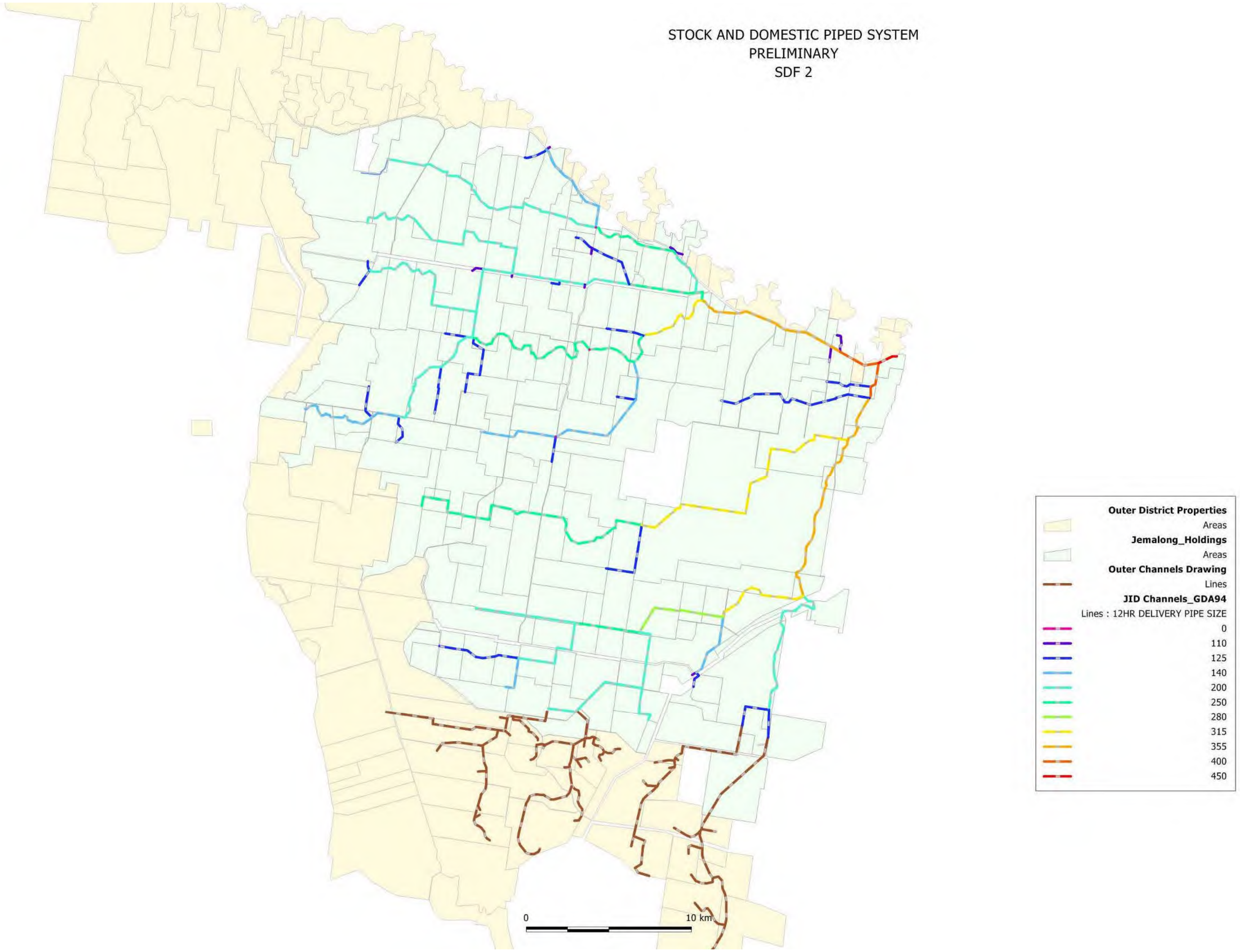
Trenches

Trench work cost estimates have been included per reach in the total price. Trenches have been sized per the requirement of the pipe with a minimum cover of at least 500mm. Pricing includes bedding the pipe in natural sand and backfilling the remaining trench. Costings have been sourced from industry standard quantities text.

Pump

Pump required for SDF 2 would be required to pump from the river and into the pump system. The pump would need to be able to pump at a minimum 88.7l/s at 8m of head from the river to the pipe network. Head loss throughout the pipe network has been reduced by over sizing. Over sizing also allows for some flexibility i.e., the allowing for any future for increases in demand or supply requirements.

APPENDIX 18 SDF 2 LAYOUT



APPENDIX 19: SDF 3 DETAILS

SDF 3

Layout

The layout follows the district roads where possible.

Requirement

Stock and domestic requirement volume delivered over 24hrs.
This system uses the calculated requirement from the data provided by Jemalong Irrigation Limited and has the capacity to deliver above this volume over a 24hr period. The extra sizing allows for greater flexibility.
Stock and domestic requirement volume for each holding delivered over 24hrs, see previous tabulated data. Flow requirements in litres per second to supply each holding per reach have been analysed and transferred to the channel layout.

Pipes

Three sub networks have been sized, SD1, SD2, SD3. Each network will have its own supply pump but will be able to be linked to the other networks.
Pipes have been sized under the following criteria:
Volume of flow required in litres per second.
Length of the reach to be piped.
Grade of the natural surface of the land of which the pipe will traverse, (sourced from digital elevation map).

Pipes sized are HDPE 100 class 6.3. This is a durable class pressure pipe. Approximate pipe costing has been sourced from manufacturers and industry standard quantities text and includes delivery cost.
It is possible that each of the networks, SD1, SD2, and SD3 can be linked to pick up supply from another, thus providing flexibility over the pump loads.

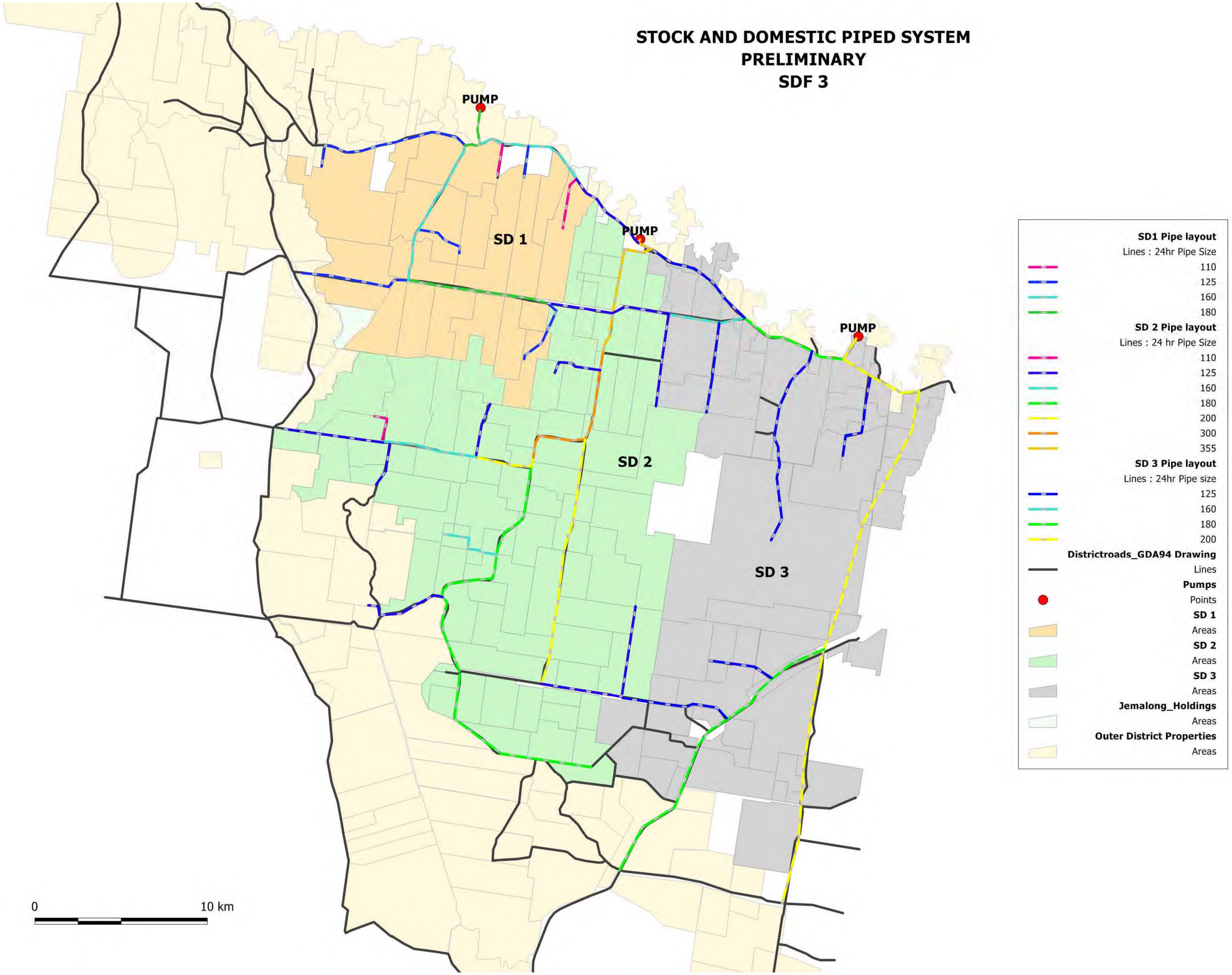
Trenches

Trench work cost estimates have been included per reach in the total price. Trenches have been sized per the requirement of the pipe with a minimum cover of at least 500mm. Pricing includes bedding the pipe in natural sand and backfilling the remaining trench. Costings have been sourced from industry standard quantities text.

Pump

Three pumps are required for SDF 3; these pumps would be required to pump from the river and into the pipe network. The pumps would need to be able to pump at a minimum 40l/s at a total 36m of head. The pumps in this concept should be sized to be able to supply the 3 networks, SD1, SD2 and SD3. This would ensure a supply if there were a breakdown. This Head loss throughout the pipe network has been reduced by over sizing where possible. Over sizing also allows for some flexibility i.e., the allowing for any future for increases in demand or supply requirements.

APPENDIX 20: SDF 3 LAYOUT



APPENDIX 21: SDF 4 DETAILS

SDF 4

Layout

The layout follows the district roads where possible as in SDF 3.

Requirement

Stock and domestic requirement volume delivered over 12hrs/ 365 days.
This system uses the calculated requirement from the data provided by Jemalong Irrigation Limited and has the capacity to deliver above this volume over a 12hr period. The extra sizing allows for greater flexibility.
Stock and domestic requirement volume for each holding delivered over 12hrs, see previous tabulated data. Flow requirements in litres per second to supply each holding per reach have been analysed and transferred to the channel layout.

Pipes

Three sub networks have been sized, SD1, SD2, SD3. Each network will have its own supply pump but will be able to be linked to the other networks.
Pipes have been sized under the following criteria:
Volume of flow required in litres per second.
Length of the reach to be piped.
Grade of the natural surface of the land of which the pipe will traverse, (sourced from digital elevation map).

Pipes sized are HDPE 100 class 6.3. This is a durable class pressure pipe. Approximate pipe costing has been sourced from manufacturers and industry standard quantities text and includes delivery cost.
It is possible that each of the networks, SD1, SD2, and SD3 can be linked to pick up supply from another, thus providing flexibility over the pump loads.

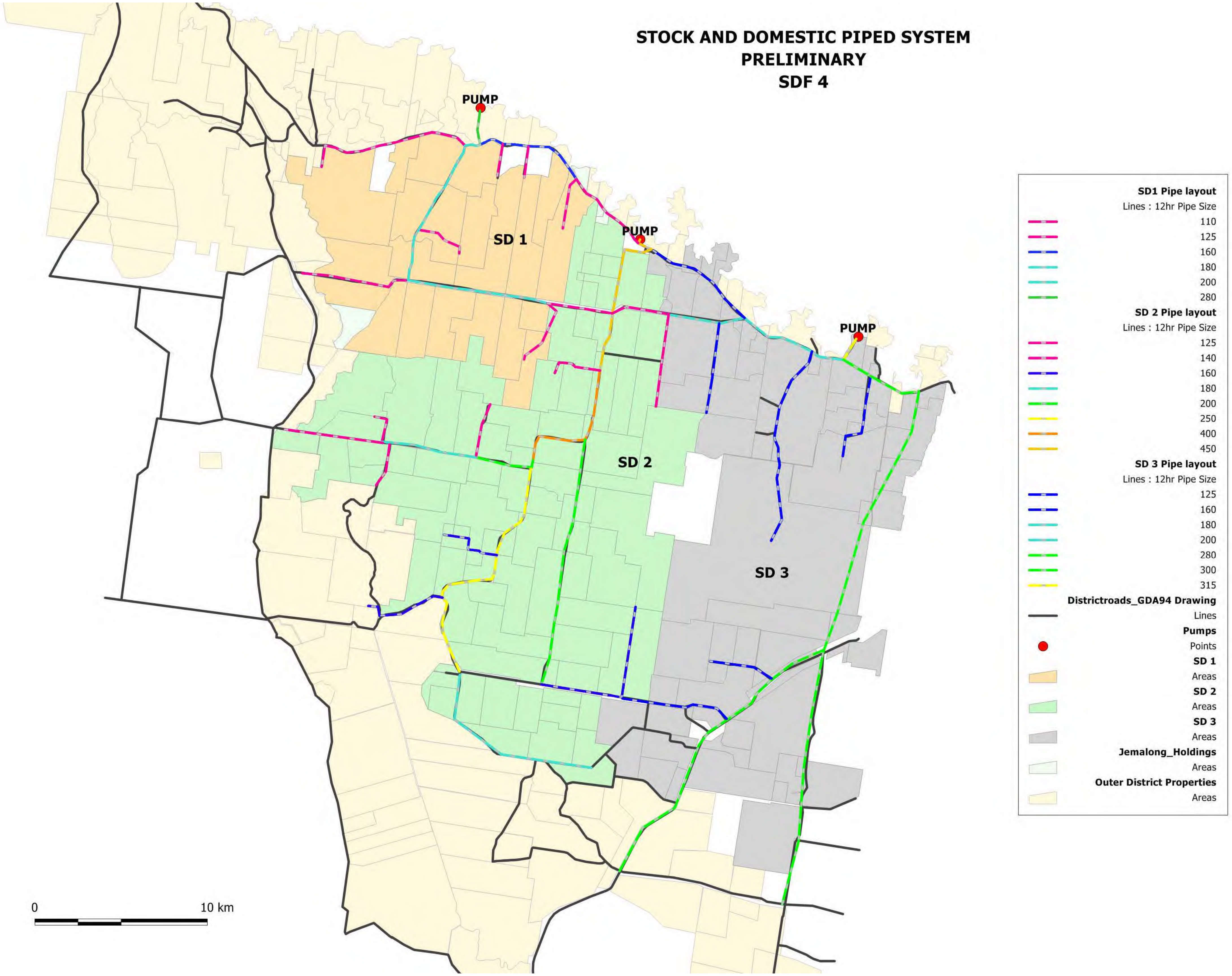
Trenches

Trench work cost estimates have been included per reach in the total price. Trenches have been sized per the requirement of the pipe with a minimum cover of at least 500mm. Pricing includes bedding the pipe in natural sand and backfilling the remaining trench. Costings have been sourced from industry standard quantities text.

Pump

Three pumps are required for SDF 3; these pumps would be required to pump from the river and into the pipe network. The pumps would need to be able to pump at a minimum 80/s at a total 36m of head. The pumps in this concept should be sized to be able to supply the 3 networks, SD1, SD2 and SD3. This would ensure a supply if there were a breakdown. This Head loss throughout the pipe network has been reduced by over sizing where possible. Over sizing also allows for some flexibility i.e., the allowing for any future for increases in demand or supply requirements.

APPENDIX 22: SDF 4 LAYOUT



APPENDIX 23: OPTION ASSESSMENT

SCENARIO	Baseline	Baseline	Baseline	Option 1	Option 2a	Option 2b	Option 3	Option 4	Option 5	Option 6	Option 7
Scenario Description	EXISTING SYSTEM 2000-2001	EXISTING SYSTEM 2000-2001	EXISTING SYSTEM	DO NOTHING	LOW INFILTRATION STABILISED BACKFILL	HIGH INFILTRATION STABILISED BACKFILL	GEO-FABRIC LINER	HDPE LINER	EPDM LINER	PIPE AND LINER	PIPE
ANNUAL ALLOCATION (ML)	74,899	42,942	42,942	35,951	35,951	35,951	35,951	35,951	35,951	35,951	35,951
% OF MAXIMUM ALLOCATION	Scaled down to **75%**	Scaled down to **43%**	2009 average annual AWD, **43%**	2030 average annual AWD, **36%**	2030 average annual AWD, **36%**	2030 average annual AWD, **36%**	2030 average annual AWD, **36%**	2030 average annual AWD, **36%**	2030 average annual AWD, **36%**	2030 average annual AWD, **36%**	2030 average annual AWD, **36%**
Summary of Scheme Operation	*9 months*	*9 months*	*7 months*	*7 months*	*7 months*	*7 months*	*7 months*	*7 months*	*7 months*	*7 months*	*7 months*
Σ AVERAGE INFILTRATION LOSSES (ML/year)											
TOTAL	18,882	18,540	14,663	14,663	5,635	13,078	0	0	0	0	0
Σ AVERAGE EVAPORATION LOSSES (ML/year)											
TOTAL	2,102	2,077	1,762	1,762	1,762	1,762	1,762	1,762	1,762	874	815
Σ ALL LOSSES (ML)	**20,984**	**20,617**	**16,425**	**16,425**	**7,397**	**14,840**	**1,762**	**1,762**	**1,762**	**874**	815
Proportion of Infiltration Losses to Allocation (%)	25.2%	43.2%	34.1%	40.8%	15.7%	36.4%	0.0%	0.0%	0.0%	0.0%	0.0%
Proportion of Evaporation Losses to Allocation (%)	2.8%	4.8%	4.1%	4.9%	4.9%	4.9%	4.9%	4.9%	4.9%	2.4%	2.3%
Total Proportion Loss of Allocation (%)	**28.0%**	**48.0%**	**38.2%**	**45.7%**	**20.6%**	**41.3%**	**4.9%**	**4.9%**	**4.9%**	**2.4%**	**2.3%**
Potential Water Savings (ML) [(a)]	**0**	**0**	**0**	**0**	**9,028**	**1,585**	**14,663**	**14,663**	**14,663**	**15,551**	**15,610**

APPENDIX 24: CHANNEL UPGRADE COSTING SUMMARY

CHANNEL OPTIONS - COST SUMMARY

	MAIN SUPPLY CHANNEL		DIVISION 1							DIVISION 2							TOTAL SCHEME
OPTION	CHANNEL UPGRADE COST ($M)	*MAINTENANCE COST ($M)	CHANNEL UPGRADE COST ($M)	SPURS UPGRADE COST ($M)	*COMBINED MAINTENANCE COST ($M)	PUMP COST ($M)	FLUME GATE AND METER COST ($M)	WATER MANAGEMENT OUTLET COST ($M)	TOTAL ($M)	CHANNEL UPGRADE COST ($M)	SPURS UPGRADE COST ($M)	*COMBINED MAINTENANCE COST ($M)	PUMP COST ($M)	FLUME GATE AND METER COST ($M)	WATER MANAGEMENT OUTLET COST ($M)	TOTAL ($M)	TOTAL ($M)
OPTION 1 Do Nothing, Baseline Option		$0.43			$13.98				**$13.98**			$9.13				**$9.13**	**$23.54**
OPTION 2 Stablised Backfill	$0.98	$0.43	$21.30	$11.10	$14.00		$2.80	$2.43	**$51.64**	$16.67	$3.86	$9.13		$1.95	$2.02	**$33.62**	**$86.67**
OPTION 3 Geofabric Liner	$0.29	$0.19	$18.94	$12.75	$20.71		$2.80	$2.43	**$57.63**	$18.55	$5.08	$13.55		$1.95	$2.02	**$41.15**	**$99.26**
OPTION 4 HDPE Liner	$0.32	$0.17	$20.68	$13.76	$18.63		$2.80	$2.43	**$58.30**	$20.04	$5.45	$12.17		$1.95	$2.02	**$41.62**	**$100.41**
OPTION 5 EPDM Liner	$0.32	$0.16	$20.44	$13.62	$18.24		$2.80	$2.43	**$57.53**	$19.83	$5.40	$11.92		$1.95	$2.02	**$41.12**	**$99.13**
OPTION 6a HDPE Pipe and Geofabric Liner			$62.72	$31.41	$20.74	$0.30	$2.80	$2.43	**$120.41**					$1.95	$2.02	**$3.97**	**$124.38**
OPTION 6b HDPE Pipe and HDPE Liner			$64.46	$32.42	$18.63	$0.30	$2.80	$2.43	**$121.04**					$1.95	$2.02	**$3.97**	**$125.01**
OPTION 6c HDPE Pipe and EPDM Liner			$64.23	$32.28	$18.24	$0.30	$2.80	$2.43	**$120.28**					$1.95	$2.02	**$3.97**	**$124.25**
OPTION 7 HDPE Pipe			$155.75	$46.54		$1.24			**$203.53**					$1.95	$2.02	**$3.97**	**$207.50**

APPENDIX 25: OPTION 1 COST BREAKDOWN

OPTION 1 - Do Nothing, Baseline Scheme

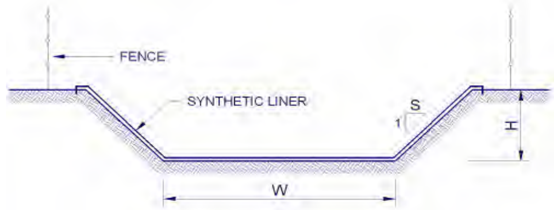
		CHANNEL NAME	CONSTRUCTION COST	MAINTENANCE COST OVER 20YRS	COMBINED COST
CHANNELS		Jem. Main U/S	$0	$430,178	$430,178
CHANNELS		**TOTAL**	**$0**	**$430,178**	**$430,178**
CHANNELS	DIVISION 1	Cadow D/S	$0	$1,985,154	$1,985,154
CHANNELS	DIVISION 1	Cadow No.2	$0	$1,618,649	$1,618,649
CHANNELS	DIVISION 1	Cadow U/S	$0	$2,796,009	$2,796,009
CHANNELS	DIVISION 1	Warroo Main	$0	$2,075,701	$2,075,701
CHANNELS	DIVISION 1	Warroo No.1	$0	$492,913	$492,913
CHANNELS	DIVISION 1	**TOTAL**	**$0**	**$8,968,426**	**$8,968,426**
CHANNELS	DIVISION 2	Jemalong Main U/S south	$0	$469,365	$469,365
CHANNELS	DIVISION 2	Jemalong Main	$0	$2,154,531	$2,154,531
CHANNELS	DIVISION 2	Jemalong No.1	$0	$352,728	$352,728
CHANNELS	DIVISION 2	Jemalong No.2	$0	$1,794,277	$1,794,277
CHANNELS	DIVISION 2	Jemalong No.2 U/S	$0	$1,251,298	$1,251,298
CHANNELS	DIVISION 2	Jemalong No.2A	$0	$778,763	$778,763
CHANNELS	DIVISION 2	Jemalong No.2C	$0	$599,185	$599,185
CHANNELS	DIVISION 2	**TOTAL**	**$0**	**$7,400,146**	**$7,400,146**
SPURS AND IRREGULAR FLOWS	DIVISION 1	Cadow No.2	$0	$181,404	$181,404
SPURS AND IRREGULAR FLOWS	DIVISION 1	Cadow No.2A	$0	$288,425	$288,425
SPURS AND IRREGULAR FLOWS	DIVISION 1	Cadow No.2A1	$0	$15,985	$15,985
SPURS AND IRREGULAR FLOWS	DIVISION 1	Cadow No.2B	$0	$8,127	$8,127
SPURS AND IRREGULAR FLOWS	DIVISION 1	Cadow No.2C	$0	$35,866	$35,866
SPURS AND IRREGULAR FLOWS	DIVISION 1	Cadow No.2D	$0	$8,140	$8,140
SPURS AND IRREGULAR FLOWS	DIVISION 1	Cadow No.2E	$0	$152,731	$152,731
SPURS AND IRREGULAR FLOWS	DIVISION 1	Cadow No.2E Lateral	$0	$247,980	$247,980
SPURS AND IRREGULAR FLOWS	DIVISION 1	Cadow No.3	$0	$372,303	$372,303
SPURS AND IRREGULAR FLOWS	DIVISION 1	Cadow No.3A	$0	$72,162	$72,162
SPURS AND IRREGULAR FLOWS	DIVISION 1	Cadow No.5	$0	$32,198	$32,198
SPURS AND IRREGULAR FLOWS	DIVISION 1	Cadow No.5A	$0	$18,210	$18,210
SPURS AND IRREGULAR FLOWS	DIVISION 1	Cadow No.6	$0	$94,658	$94,658
SPURS AND IRREGULAR FLOWS	DIVISION 1	Cadow No.7	$0	$88,090	$88,090
SPURS AND IRREGULAR FLOWS	DIVISION 1	Warroo Main	$0	$1,549,986	$1,549,986
SPURS AND IRREGULAR FLOWS	DIVISION 1	Warroo No.1	$0	$93,098	$93,098
SPURS AND IRREGULAR FLOWS	DIVISION 1	Warroo No.1A	$0	$249,515	$249,515
SPURS AND IRREGULAR FLOWS	DIVISION 1	Warroo No.1B	$0	$58,919	$58,919
SPURS AND IRREGULAR FLOWS	DIVISION 1	Warroo No.2	$0	$731,025	$731,025
SPURS AND IRREGULAR FLOWS	DIVISION 1	Warroo No.2A	$0	$23,638	$23,638
SPURS AND IRREGULAR FLOWS	DIVISION 1	Warroo No.3	$0	$62,823	$62,823
SPURS AND IRREGULAR FLOWS	DIVISION 1	Warroo No.4	$0	$115,873	$115,873
SPURS AND IRREGULAR FLOWS	DIVISION 1	Warroo No.5	$0	$72,533	$72,533
SPURS AND IRREGULAR FLOWS	DIVISION 1	Warroo No.6	$0	$163,912	$163,912
SPURS AND IRREGULAR FLOWS	DIVISION 1	Warroo No.8	$0	$191,903	$191,903
SPURS AND IRREGULAR FLOWS	DIVISION 1	Warroo No.11	$0	$77,728	$77,728
SPURS AND IRREGULAR FLOWS	DIVISION 1	**TOTAL**	**$0**	**$5,007,232**	**$5,007,232**
SPURS AND IRREGULAR FLOWS	DIVISION 2	Jemalong No.1	$0	$204,338	$204,338
SPURS AND IRREGULAR FLOWS	DIVISION 2	Jemalong No.2A	$0	$110,425	$110,425
SPURS AND IRREGULAR FLOWS	DIVISION 2	Jemalong No.2A1	$0	$72,022	$72,022
SPURS AND IRREGULAR FLOWS	DIVISION 2	Jemalong No.2B	$0	$230,619	$230,619
SPURS AND IRREGULAR FLOWS	DIVISION 2	Jemalong No.2B1	$0	$58,887	$58,887
SPURS AND IRREGULAR FLOWS	DIVISION 2	Jemalong No.2C1	$0	$138,918	$138,918
SPURS AND IRREGULAR FLOWS	DIVISION 2	Jemalong No.2D	$0	$402,578	$402,578
SPURS AND IRREGULAR FLOWS	DIVISION 2	Jemalong No.2E	$0	$109,601	$109,601
SPURS AND IRREGULAR FLOWS	DIVISION 2	Jemalong No.4	$0	$205,668	$205,668
SPURS AND IRREGULAR FLOWS	DIVISION 2	Jemlong No.6	$0	$190,583	$190,583
SPURS AND IRREGULAR FLOWS	DIVISION 2	**TOTAL**	**$0**	**$1,723,641**	**$1,723,641**

APPENDIX 26: OPTION 2 COST BREAKDOWN

OPTION 2 - Stabilised Backfill					
		CHANNEL NAME	CONSTRUCTION COST	MAINTENANCE COST OVER 20YRS	COMBINED COST
CHANNELS		Jem. Main U/S	$981,436	$430,178	$1,411,614
CHANNELS		TOTAL	$981,436	$430,178	$1,411,614
CHANNELS	DIVISION 1	Cadow D/S	$5,466,655	$1,985,154	$7,451,809
CHANNELS	DIVISION 1	Cadow No.2	$3,649,145	$1,618,649	$5,267,794
CHANNELS	DIVISION 1	Cadow U/S	$6,379,805	$2,796,009	$9,175,815
CHANNELS	DIVISION 1	Warroo Main	$4,692,601	$2,075,701	$6,768,302
CHANNELS	DIVISION 1	Warroo No.1	$1,105,321	$492,913	$1,598,234
CHANNELS	DIVISION 1	TOTAL	$21,293,527	$8,968,426	$30,261,954
CHANNELS	DIVISION 2	Jemalong Main U/S south	$1,060,957	$469,365	$1,530,322
CHANNELS	DIVISION 2	Jemalong Main	$4,839,736	$2,154,531	$6,994,267
CHANNELS	DIVISION 2	Jemalong No.1	$791,450	$352,728	$1,144,178
CHANNELS	DIVISION 2	Jemalong No.2	$4,035,264	$1,794,277	$5,829,541
CHANNELS	DIVISION 2	Jemalong No.2 U/S	$2,840,089	$1,251,298	$4,091,386
CHANNELS	DIVISION 2	Jemalong No.2A	$1,757,201	$778,763	$2,535,964
CHANNELS	DIVISION 2	Jemalong No.2C	$1,342,108	$599,185	$1,941,293
CHANNELS	DIVISION 2	TOTAL	$16,666,804	$7,400,146	$24,066,950
SPURS AND IRREGULAR FLOWS	DIVISION 1	Cadow No.2	$404,559	$181,404	$585,963
SPURS AND IRREGULAR FLOWS	DIVISION 1	Cadow No.2A	$647,330	$288,425	$935,755
SPURS AND IRREGULAR FLOWS	DIVISION 1	Cadow No.2A1	$35,503	$15,985	$51,489
SPURS AND IRREGULAR FLOWS	DIVISION 1	Cadow No.2B	$18,050	$8,127	$26,176
SPURS AND IRREGULAR FLOWS	DIVISION 1	Cadow No.2C	$80,054	$35,866	$115,920
SPURS AND IRREGULAR FLOWS	DIVISION 1	Cadow No.2D	$18,078	$8,140	$26,218
SPURS AND IRREGULAR FLOWS	DIVISION 1	Cadow No.2E	$342,499	$152,731	$495,230
SPURS AND IRREGULAR FLOWS	DIVISION 1	Cadow No.2E Lateral	$561,052	$247,980	$809,033
SPURS AND IRREGULAR FLOWS	DIVISION 1	Cadow No.3	$838,542	$372,303	$1,210,845
SPURS AND IRREGULAR FLOWS	DIVISION 1	Cadow No.3A	$161,022	$72,162	$233,183
SPURS AND IRREGULAR FLOWS	DIVISION 1	Cadow No.5	$72,015	$32,198	$104,213
SPURS AND IRREGULAR FLOWS	DIVISION 1	Cadow No.5A	$40,676	$18,210	$58,886
SPURS AND IRREGULAR FLOWS	DIVISION 1	Cadow No.6	$213,390	$94,658	$308,048
SPURS AND IRREGULAR FLOWS	DIVISION 1	Cadow No.7	$199,352	$88,090	$287,442
SPURS AND IRREGULAR FLOWS	DIVISION 1	Warroo Main	$3,520,768	$1,549,986	$5,070,754
SPURS AND IRREGULAR FLOWS	DIVISION 1	Warroo No.1	$208,372	$93,098	$301,469
SPURS AND IRREGULAR FLOWS	DIVISION 1	Warroo No.1A	$557,775	$249,515	$807,289
SPURS AND IRREGULAR FLOWS	DIVISION 1	Warroo No.1B	$131,608	$58,919	$190,527
SPURS AND IRREGULAR FLOWS	DIVISION 1	Warroo No.2	$1,639,686	$731,025	$2,370,711
SPURS AND IRREGULAR FLOWS	DIVISION 1	Warroo No.2A	$52,499	$23,638	$76,137
SPURS AND IRREGULAR FLOWS	DIVISION 1	Warroo No.3	$140,031	$62,823	$202,855
SPURS AND IRREGULAR FLOWS	DIVISION 1	Warroo No.4	$257,004	$115,873	$372,877
SPURS AND IRREGULAR FLOWS	DIVISION 1	Warroo No.5	$160,550	$72,533	$233,083
SPURS AND IRREGULAR FLOWS	DIVISION 1	Warroo No.6	$202,950	$163,912	$366,862
SPURS AND IRREGULAR FLOWS	DIVISION 1	Warroo No.8	$426,269	$191,903	$618,172
SPURS AND IRREGULAR FLOWS	DIVISION 1	Warroo No.11	$172,066	$77,728	$249,794
SPURS AND IRREGULAR FLOWS	DIVISION 1	TOTAL	$11,101,701	$5,007,232	$16,108,933
SPURS AND IRREGULAR FLOWS	DIVISION 2	Jemalong No.1	$457,149	$204,338	$661,487
SPURS AND IRREGULAR FLOWS	DIVISION 2	Jemalong No.2A	$245,309	$110,425	$355,734
SPURS AND IRREGULAR FLOWS	DIVISION 2	Jemalong No.2A1	$159,981	$72,022	$232,004
SPURS AND IRREGULAR FLOWS	DIVISION 2	Jemalong No.2B	$515,180	$230,619	$745,800
SPURS AND IRREGULAR FLOWS	DIVISION 2	Jemalong No.2B1	$131,640	$58,887	$190,528
SPURS AND IRREGULAR FLOWS	DIVISION 2	Jemalong No.2C1	$311,089	$138,918	$450,007
SPURS AND IRREGULAR FLOWS	DIVISION 2	Jemalong No.2D	$904,538	$402,578	$1,307,116
SPURS AND IRREGULAR FLOWS	DIVISION 2	Jemalong No.2E	$244,815	$109,601	$354,416
SPURS AND IRREGULAR FLOWS	DIVISION 2	Jemalong No.4	$457,662	$205,668	$663,330
SPURS AND IRREGULAR FLOWS	DIVISION 2	Jemlong No.6	$430,250	$190,583	$620,833
SPURS AND IRREGULAR FLOWS	DIVISION 2	TOTAL	$3,857,614	$1,723,641	$5,581,254

Boyden & Partners

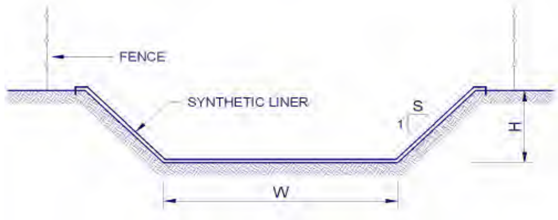
APPENDIX 27: OPTION 3 COST BREAKDOWN



OPTION 3 - Geofabric Liner

		CHANNEL NAME	CONSTRUCTION COST	MAINTENANCE COST OVER 20YRS	COMBINED COST
CHANNELS		Jem. Main U/S	$291,166	$186,990	$478,157
		TOTAL	**$291,166**	**$186,990**	**$478,157**
	DIVISION 1	Cadow D/S	$4,530,917	$2,960,490	$7,491,407
		Cadow No.2	$3,944,533	$2,408,635	$6,353,168
		Cadow U/S	$4,425,696	$4,211,020	$8,636,715
		Warroo Main	$4,649,991	$3,097,373	$7,747,364
		Warroo No.1	$1,386,373	$729,572	$2,115,945
		TOTAL	**$18,937,509**	**$13,407,090**	**$32,344,599**
	DIVISION 2	Jemalong Main U/S south	$1,056,195	$700,289	$1,756,484
		Jemalong Main	$5,798,343	$3,194,490	$8,992,833
		Jemalong No.1	$976,928	$522,400	$1,499,328
		Jemalong No.2	$4,679,754	$2,663,494	$7,343,248
		Jemalong No.2 U/S	$2,451,682	$1,874,613	$4,326,295
		Jemalong No.2A	$1,850,052	$1,159,848	$3,009,901
		Jemalong No.2C	$1,732,740	$885,865	$2,618,605
		TOTAL	**$18,545,693**	**$11,001,000**	**$29,546,694**
SPURS AND IRREGULAR FLOWS		Cadow No.2	$579,780	$267,031	$846,811
		Cadow No.2A	$793,750	$427,273	$1,221,023
		Cadow No.2A1	$55,680	$23,434	$79,114
		Cadow No.2B	$28,307	$11,914	$40,221
		Cadow No.2C	$112,492	$52,840	$165,332
		Cadow No.2D	$28,352	$11,933	$40,285
		Cadow No.2E	$429,233	$226,068	$655,301
		Cadow No.2E Lateral	$541,904	$370,325	$912,230
		Cadow No.3	$932,057	$553,483	$1,485,540
		Cadow No.3A	$227,837	$106,283	$334,120
		Cadow No.5	$96,437	$47,534	$143,971
		Cadow No.5A	$56,196	$26,848	$83,045
		Cadow No.6	$230,979	$140,849	$371,828
		Cadow No.7	$190,995	$131,583	$322,578
		Warroo Main	$2,951,176	$2,323,899	$5,275,075
		Warroo No.1	$274,124	$137,537	$411,661
		Warroo No.1A	$756,293	$368,162	$1,124,454
		Warroo No.1B	$181,747	$86,869	$268,616
		Warroo No.2	$2,043,050	$1,082,282	$3,125,331
		Warroo No.2A	$82,335	$34,652	$116,987
		Warroo No.3	$203,138	$92,428	$295,566
		Warroo No.4	$414,497	$169,637	$584,133
		Warroo No.5	$269,669	$105,972	$375,641
		Warroo No.6	$318,287	$133,958	$452,245
		Warroo No.8	$666,646	$281,361	$948,007
		Warroo No.11	$288,450	$113,573	$402,023
		TOTAL	**$12,753,412**	**$7,327,729**	**$20,081,140**
		Jemalong No.1	$608,019	$301,743	$909,762
		Jemalong No.2A	$382,807	$161,917	$544,724
		Jemalong No.2A1	$250,196	$105,596	$355,792
		Jemalong No.2B	$710,125	$340,047	$1,050,172
		Jemalong No.2B1	$178,454	$86,890	$265,344
		Jemalong No.2C1	$403,967	$205,336	$609,302
		Jemalong No.2D	$1,076,428	$597,045	$1,673,472
		Jemalong No.2E	$338,226	$161,591	$499,817
		Jemalong No.4	$688,933	$302,082	$991,015
		Jemlong No.6	$445,905	$283,989	$729,894
		TOTAL	**$5,083,060**	**$2,546,236**	**$7,629,295**

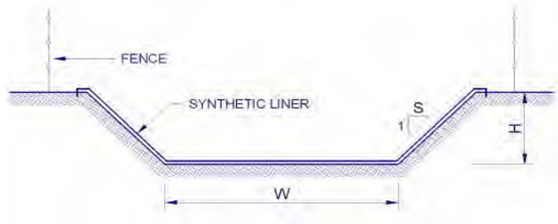
APPENDIX 28: OPTION 4 COST BREAKDOWN



OPTION 4 - HDPE Liner

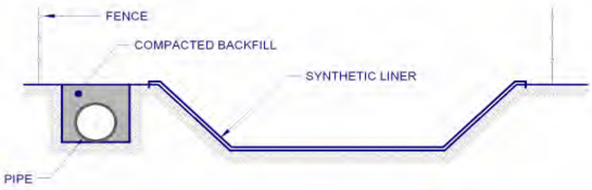
		CHANNEL NAME	CONSTRUCTION COST	MAINTENANCE COST OVER 20YRS	COMBINED COST
CHANNELS		Jem. Main U/S	$316,004	$167,998	$484,002
		TOTAL	**$316,004**	**$167,998**	**$484,002**
	DIVISION 1	Cadow D/S	$4,922,453	$2,659,791	$7,582,244
		Cadow No.2	$4,268,648	$2,163,988	$6,432,637
		Cadow U/S	$4,939,113	$3,783,304	$8,722,417
		Warroo Main	$5,057,683	$2,782,771	$7,840,454
		Warroo No.1	$1,488,676	$655,469	$2,144,144
		TOTAL	**$20,676,574**	**$12,045,322**	**$32,721,896**
	DIVISION 2	Jemalong Main U/S south	$1,148,475	$629,161	$1,777,636
		Jemalong Main	$6,240,420	$2,870,023	$9,110,444
		Jemalong No.1	$1,049,840	$469,340	$1,519,180
		Jemalong No.2	$5,045,013	$2,392,961	$7,437,974
		Jemalong No.2 U/S	$2,690,614	$1,684,208	$4,374,822
		Jemalong No.2A	$2,005,062	$1,042,042	$3,047,104
		Jemalong No.2C	$1,858,022	$795,887	$2,653,909
		TOTAL	**$20,037,447**	**$9,883,621**	**$29,921,068**
SPURS AND IRREGULAR FLOWS		Cadow No.2	$618,783	$239,909	$858,691
		Cadow No.2A	$853,271	$383,875	$1,237,146
		Cadow No.2A1	$59,206	$21,054	$80,260
		Cadow No.2B	$30,100	$10,704	$40,804
		Cadow No.2C	$120,161	$47,473	$167,634
		Cadow No.2D	$30,148	$10,721	$40,869
		Cadow No.2E	$460,926	$203,106	$664,032
		Cadow No.2E Lateral	$590,346	$332,711	$923,057
		Cadow No.3	$1,007,088	$497,266	$1,504,354
		Cadow No.3A	$243,297	$95,488	$338,785
		Cadow No.5	$103,234	$42,706	$145,940
		Cadow No.5A	$60,073	$24,121	$84,194
		Cadow No.6	$249,939	$126,543	$376,482
		Cadow No.7	$208,174	$118,218	$326,392
		Warroo Main	$3,245,475	$2,087,859	$5,333,334
		Warroo No.1	$293,685	$123,567	$417,252
		Warroo No.1A	$809,139	$330,767	$1,139,906
		Warroo No.1B	$194,288	$78,045	$272,333
		Warroo No.2	$2,194,517	$972,354	$3,166,871
		Warroo No.2A	$87,549	$31,133	$118,682
		Warroo No.3	$216,691	$83,040	$299,731
		Warroo No.4	$440,269	$152,407	$592,675
		Warroo No.5	$286,000	$95,208	$381,208
		Warroo No.6	$338,444	$120,352	$458,796
		Warroo No.8	$708,943	$252,783	$961,726
		Warroo No.11	$305,941	$102,037	$407,978
		TOTAL	**$13,755,687**	**$6,583,446**	**$20,339,133**
		Jemalong No.1	$651,077	$271,095	$922,171
		Jemalong No.2A	$407,130	$145,471	$552,601
		Jemalong No.2A1	$266,070	$94,871	$360,941
		Jemalong No.2B	$759,185	$305,508	$1,064,694
		Jemalong No.2B1	$190,925	$78,064	$268,990
		Jemalong No.2C1	$433,056	$184,480	$617,536
		Jemalong No.2D	$1,158,894	$536,402	$1,695,297
		Jemalong No.2E	$361,556	$145,178	$506,734
		Jemalong No.4	$733,767	$271,399	$1,005,166
		Jemlong No.6	$483,707	$255,144	$738,851
		TOTAL	**$5,445,368**	**$2,287,613**	**$7,732,981**

APPENDIX 29: OPTION 5 COST BREAKDOWN



OPTION 5 - EPDM Liner					
		CHANNEL NAME	CONSTRUCTION COST	MAINTENANCE COST OVER 20YRS	COMBINED COST
CHANNELS		Jem. Main U/S	$312,617	$164,473	$477,090
		TOTAL	**$312,617**	**$164,473**	**$477,090**
	DIVISION 1	Cadow D/S	$4,869,062	$2,603,991	$7,473,053
		Cadow No.2	$4,224,451	$2,118,590	$6,343,041
		Cadow U/S	$4,869,102	$3,703,934	$8,573,036
		Warroo Main	$5,002,089	$2,724,391	$7,726,479
		Warroo No.1	$1,474,725	$641,718	$2,116,443
		TOTAL	**$20,439,429**	**$11,792,623**	**$32,232,052**
	DIVISION 2	Jemalong Main U/S south	$1,135,891	$615,961	$1,751,853
		Jemalong Main	$6,180,137	$2,809,813	$8,989,950
		Jemalong No.1	$1,039,898	$459,493	$1,499,391
		Jemalong No.2	$4,995,205	$2,342,759	$7,337,964
		Jemalong No.2 U/S	$2,658,032	$1,648,875	$4,306,907
		Jemalong No.2A	$1,983,924	$1,020,181	$3,004,105
		Jemalong No.2C	$1,840,938	$779,190	$2,620,128
		TOTAL	**$19,834,026**	**$9,676,273**	**$29,510,299**
SPURS AND IRREGULAR FLOWS		Cadow No.2	$613,464	$234,875	$848,340
		Cadow No.2A	$845,155	$375,822	$1,220,976
		Cadow No.2A1	$58,725	$20,612	$79,338
		Cadow No.2B	$29,855	$10,479	$40,335
		Cadow No.2C	$119,115	$46,477	$165,593
		Cadow No.2D	$29,903	$10,496	$40,399
		Cadow No.2E	$456,604	$198,845	$655,449
		Cadow No.2E Lateral	$583,740	$325,731	$909,471
		Cadow No.3	$996,857	$486,833	$1,483,690
		Cadow No.3A	$241,189	$93,485	$334,674
		Cadow No.5	$102,307	$41,810	$144,117
		Cadow No.5A	$59,544	$23,615	$83,159
		Cadow No.6	$247,353	$123,888	$371,242
		Cadow No.7	$205,831	$115,738	$321,569
		Warroo Main	$3,205,344	$2,044,058	$5,249,401
		Warroo No.1	$291,018	$120,975	$411,992
		Warroo No.1A	$801,933	$323,828	$1,125,761
		Warroo No.1B	$192,578	$76,408	$268,986
		Warroo No.2	$2,173,863	$951,955	$3,125,817
		Warroo No.2A	$86,838	$30,480	$117,318
		Warroo No.3	$214,843	$81,298	$296,141
		Warroo No.4	$436,754	$149,209	$585,964
		Warroo No.5	$283,773	$93,211	$376,984
		Warroo No.6	$335,696	$117,827	$453,523
		Warroo No.8	$703,175	$247,480	$950,655
		Warroo No.11	$303,556	$99,897	$403,452
		TOTAL	**$13,619,013**	**$6,445,332**	**$20,064,345**
		Jemalong No.1	$645,205	$265,408	$910,613
		Jemalong No.2A	$403,813	$142,420	$546,232
		Jemalong No.2A1	$263,906	$92,881	$356,786
		Jemalong No.2B	$752,495	$299,099	$1,051,594
		Jemalong No.2B1	$189,225	$76,427	$265,651
		Jemalong No.2C1	$429,089	$180,609	$609,699
		Jemalong No.2D	$1,147,649	$525,149	$1,672,798
		Jemalong No.2E	$358,374	$142,132	$500,507
		Jemalong No.4	$727,653	$265,706	$993,359
		Jemlong No.6	$478,552	$249,791	$728,343
		TOTAL	**$5,395,962**	**$2,239,621**	**$7,635,583**

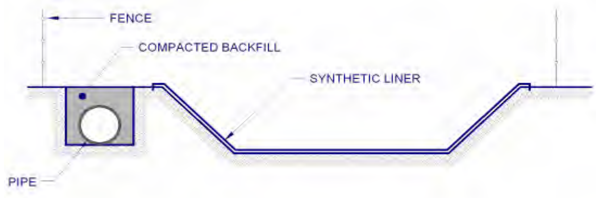
APPENDIX 30: OPTION 6A COST BREAKDOWN



OPTION 6a - HDPE Pipe & Geofabric Liner

		CHANNEL NAME	CONSTRUCTION COST	MAINTENANCE COST OVER 20YRS	COMBINED COST
CHANNELS		Jem. Main U/S	n/a	n/a	n/a
		TOTAL			**n/a**
	DIVISION 1	Cadow D/S	$13,760,210	$2,960,490	$16,720,700
		Cadow No.2	$12,790,666	$2,408,635	$15,199,301
		Cadow U/S	$13,640,221	$4,211,020	$17,851,241
		Warroo Main	$18,771,065	$3,097,373	$21,868,438
		Warroo No.1	$3,761,681	$729,572	$4,491,253
		TOTAL	**$62,723,843**	**$13,407,090**	**$76,130,933**
	DIVISION 2	Jemalong Main U/S south	n/a	n/a	n/a
		Jemalong Main	n/a	n/a	n/a
		Jemalong No.1	n/a	n/a	n/a
		Jemalong No.2	n/a	n/a	n/a
		Jemalong No.2 U/S	n/a	n/a	n/a
		Jemalong No.2A	n/a	n/a	n/a
		Jemalong No.2C	n/a	n/a	n/a
		TOTAL	**n/a**	**n/a**	**n/a**
SPURS AND IRREGULAR FLOWS		Cadow No.2	$1,240,078	$267,031	$1,507,109
		Cadow No.2A	$1,916,226	$427,273	$2,343,499
		Cadow No.2A1	$96,600	$23,434	$120,035
		Cadow No.2B	$47,290	$11,914	$59,203
		Cadow No.2C	$318,376	$52,840	$371,216
		Cadow No.2D	$51,329	$11,933	$63,262
		Cadow No.2E	$1,164,264	$226,068	$1,390,332
		Cadow No.2E Lateral	$866,724	$370,325	$1,237,050
		Cadow No.3	$1,835,337	$553,483	$2,388,821
		Cadow No.3A	$485,598	$106,283	$591,881
		Cadow No.5	$141,211	$47,534	$188,745
		Cadow No.5A	$82,745	$26,848	$109,594
		Cadow No.6	$450,129	$140,849	$590,978
		Cadow No.7	$352,955	$131,583	$484,538
		Warroo Main	$7,990,054	$2,323,899	$10,313,953
		Warroo No.1	$596,839	$137,537	$734,376
		Warroo No.1A	$2,113,773	$368,162	$2,481,935
		Warroo No.1B	$384,709	$86,869	$471,577
		Warroo No.2	$5,528,694	$1,082,282	$6,610,976
		Warroo No.2A	$149,060	$34,652	$183,712
		Warroo No.3	$435,928	$92,428	$528,357
		Warroo No.4	$1,224,957	$169,637	$1,394,593
		Warroo No.5	$806,034	$105,972	$912,006
		Warroo No.6	$576,230	$133,958	$710,188
		Warroo No.8	$1,458,583	$281,361	$1,739,944
		Warroo No.11	$1,101,102	$113,573	$1,214,675
		TOTAL	**$31,414,827**	**$7,327,729**	**$38,742,555**
		Jemalong No.1	n/a	n/a	n/a
		Jemalong No.2A	n/a	n/a	n/a
		Jemalong No.2A1	n/a	n/a	n/a
		Jemalong No.2B	n/a	n/a	n/a
		Jemalong No.2B1	n/a	n/a	n/a
		Jemalong No.2C1	n/a	n/a	n/a
		Jemalong No.2D	n/a	n/a	n/a
		Jemalong No.2E	n/a	n/a	n/a
		Jemalong No.4	n/a	n/a	n/a
		Jemlong No.6	n/a	n/a	n/a
		TOTAL	**n/a**	**n/a**	**n/a**

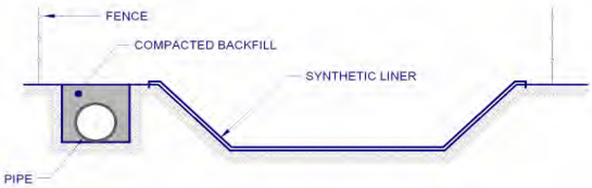
APPENDIX 31: OPTION 6B COST BREAKDOWN



OPTION 6b - HDPE Pipe & HDPE Liner

		CHANNEL NAME	CONSTRUCTION COST	MAINTENANCE COST OVER 20YRS	COMBINED COST
CHANNELS		Jem. Main U/S	n/a	n/a	n/a
		TOTAL			**n/a**
	DIVISION 1	Cadow D/S	$14,151,747	$2,659,791	$16,811,538
		Cadow No.2	$13,114,782	$2,163,988	$15,278,770
		Cadow U/S	$14,153,639	$3,783,304	$17,936,943
		Warroo Main	$19,178,757	$2,782,771	$21,961,527
		Warroo No.1	$3,863,983	$655,469	$4,519,452
		TOTAL	**$64,462,908**	**$12,045,322**	**$76,508,230**
	DIVISION 2	Jemalong Main U/S south	n/a	n/a	n/a
		Jemalong Main	n/a	n/a	n/a
		Jemalong No.1	n/a	n/a	n/a
		Jemalong No.2	n/a	n/a	n/a
		Jemalong No.2 U/S	n/a	n/a	n/a
		Jemalong No.2A	n/a	n/a	n/a
		Jemalong No.2C	n/a	n/a	n/a
		TOTAL	**n/a**	**n/a**	**n/a**
SPURS AND IRREGULAR FLOWS		Cadow No.2	$1,279,080	$239,909	$1,518,989
		Cadow No.2A	$1,975,748	$383,875	$2,359,622
		Cadow No.2A1	$100,127	$21,054	$121,181
		Cadow No.2B	$49,082	$10,704	$59,786
		Cadow No.2C	$326,046	$47,473	$373,519
		Cadow No.2D	$53,125	$10,721	$63,846
		Cadow No.2E	$1,195,956	$203,106	$1,399,063
		Cadow No.2E Lateral	$915,166	$332,711	$1,247,877
		Cadow No.3	$1,910,369	$497,266	$2,407,634
		Cadow No.3A	$501,058	$95,488	$596,546
		Cadow No.5	$148,008	$42,706	$190,714
		Cadow No.5A	$86,621	$24,121	$110,743
		Cadow No.6	$469,089	$126,543	$595,632
		Cadow No.7	$370,134	$118,218	$488,352
		Warroo Main	$8,284,353	$2,087,859	$10,372,212
		Warroo No.1	$616,400	$123,567	$739,967
		Warroo No.1A	$2,166,619	$330,767	$2,497,386
		Warroo No.1B	$397,249	$78,045	$475,294
		Warroo No.2	$5,680,161	$972,354	$6,652,515
		Warroo No.2A	$154,274	$31,133	$185,407
		Warroo No.3	$449,481	$83,040	$532,522
		Warroo No.4	$1,250,729	$152,407	$1,403,135
		Warroo No.5	$822,366	$95,208	$917,574
		Warroo No.6	$596,387	$120,352	$716,739
		Warroo No.8	$1,500,880	$252,783	$1,753,663
		Warroo No.11	$1,118,593	$102,037	$1,220,630
		TOTAL	**$32,417,102**	**$6,583,446**	**$39,000,548**
		Jemalong No.1	n/a	n/a	n/a
		Jemalong No.2A	n/a	n/a	n/a
		Jemalong No.2A1	n/a	n/a	n/a
		Jemalong No.2B	n/a	n/a	n/a
		Jemalong No.2B1	n/a	n/a	n/a
		Jemalong No.2C1	n/a	n/a	n/a
		Jemalong No.2D	n/a	n/a	n/a
		Jemalong No.2E	n/a	n/a	n/a
		Jemalong No.4	n/a	n/a	n/a
		Jemlong No.6	n/a	n/a	n/a
		TOTAL	**n/a**	**n/a**	**n/a**

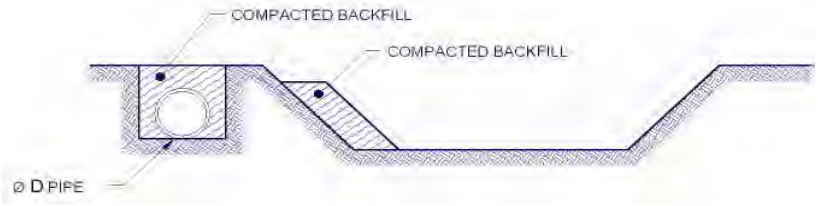
APPENDIX 32: OPTION 6C COST BREAKDOWN



OPTION 6c - HDPE Pipe & EDPM Liner

		CHANNEL NAME	CONSTRUCTION COST	MAINTENANCE COST OVER 20YRS	COMBINED COST
CHANNELS		Jem. Main U/S	n/a	n/a	n/a
CHANNELS		**TOTAL**	n/a	n/a	**n/a**
CHANNELS	DIVISION 1	Cadow D/S	$14,098,356	$2,603,991	$16,702,347
CHANNELS	DIVISION 1	Cadow No.2	$13,070,584	$2,118,590	$15,189,174
CHANNELS	DIVISION 1	Cadow U/S	$14,083,628	$3,703,934	$17,787,561
CHANNELS	DIVISION 1	Warroo Main	$19,123,163	$2,724,391	$21,847,553
CHANNELS	DIVISION 1	Warroo No.1	$3,850,033	$641,718	$4,491,750
CHANNELS	DIVISION 1	**TOTAL**	**$64,225,763**	**$11,792,623**	**$76,018,386**
CHANNELS	DIVISION 2	Jemalong Main U/S south	n/a	n/a	n/a
CHANNELS	DIVISION 2	Jemalong Main	n/a	n/a	n/a
CHANNELS	DIVISION 2	Jemalong No.1	n/a	n/a	n/a
CHANNELS	DIVISION 2	Jemalong No.2	n/a	n/a	n/a
CHANNELS	DIVISION 2	Jemalong No.2 U/S	n/a	n/a	n/a
CHANNELS	DIVISION 2	Jemalong No.2A	n/a	n/a	n/a
CHANNELS	DIVISION 2	Jemalong No.2C	n/a	n/a	n/a
CHANNELS	DIVISION 2	**TOTAL**	**n/a**	**n/a**	**n/a**
SPURS AND IRREGULAR FLOWS		Cadow No.2	$1,273,762	$234,875	$1,508,637
SPURS AND IRREGULAR FLOWS		Cadow No.2A	$1,967,631	$375,822	$2,343,452
SPURS AND IRREGULAR FLOWS		Cadow No.2A1	$99,646	$20,612	$120,258
SPURS AND IRREGULAR FLOWS		Cadow No.2B	$48,838	$10,479	$59,317
SPURS AND IRREGULAR FLOWS		Cadow No.2C	$325,000	$46,477	$371,477
SPURS AND IRREGULAR FLOWS		Cadow No.2D	$52,880	$10,496	$63,376
SPURS AND IRREGULAR FLOWS		Cadow No.2E	$1,191,635	$198,845	$1,390,480
SPURS AND IRREGULAR FLOWS		Cadow No.2E Lateral	$908,560	$325,731	$1,234,291
SPURS AND IRREGULAR FLOWS		Cadow No.3	$1,900,137	$486,833	$2,386,971
SPURS AND IRREGULAR FLOWS		Cadow No.3A	$498,950	$93,485	$592,435
SPURS AND IRREGULAR FLOWS		Cadow No.5	$147,081	$41,810	$188,891
SPURS AND IRREGULAR FLOWS		Cadow No.5A	$86,093	$23,615	$109,708
SPURS AND IRREGULAR FLOWS		Cadow No.6	$466,504	$123,888	$590,392
SPURS AND IRREGULAR FLOWS		Cadow No.7	$367,791	$115,738	$483,529
SPURS AND IRREGULAR FLOWS		Warroo Main	$8,244,221	$2,044,058	$10,288,279
SPURS AND IRREGULAR FLOWS		Warroo No.1	$613,733	$120,975	$734,708
SPURS AND IRREGULAR FLOWS		Warroo No.1A	$2,159,413	$323,828	$2,483,241
SPURS AND IRREGULAR FLOWS		Warroo No.1B	$395,539	$76,408	$471,947
SPURS AND IRREGULAR FLOWS		Warroo No.2	$5,659,507	$951,955	$6,611,462
SPURS AND IRREGULAR FLOWS		Warroo No.2A	$153,563	$30,480	$184,042
SPURS AND IRREGULAR FLOWS		Warroo No.3	$447,633	$81,298	$528,931
SPURS AND IRREGULAR FLOWS		Warroo No.4	$1,247,214	$149,209	$1,396,424
SPURS AND IRREGULAR FLOWS		Warroo No.5	$820,139	$93,211	$913,349
SPURS AND IRREGULAR FLOWS		Warroo No.6	$593,638	$117,827	$711,465
SPURS AND IRREGULAR FLOWS		Warroo No.8	$1,495,112	$247,480	$1,742,592
SPURS AND IRREGULAR FLOWS		Warroo No.11	$1,116,208	$99,897	$1,216,105
SPURS AND IRREGULAR FLOWS		**TOTAL**	**$32,280,428**	**$6,445,332**	**$38,725,760**
SPURS AND IRREGULAR FLOWS		Jemalong No.1	n/a	n/a	n/a
SPURS AND IRREGULAR FLOWS		Jemalong No.2A	n/a	n/a	n/a
SPURS AND IRREGULAR FLOWS		Jemalong No.2A1	n/a	n/a	n/a
SPURS AND IRREGULAR FLOWS		Jemalong No.2B	n/a	n/a	n/a
SPURS AND IRREGULAR FLOWS		Jemalong No.2B1	n/a	n/a	n/a
SPURS AND IRREGULAR FLOWS		Jemalong No.2C1	n/a	n/a	n/a
SPURS AND IRREGULAR FLOWS		Jemalong No.2D	n/a	n/a	n/a
SPURS AND IRREGULAR FLOWS		Jemalong No.2E	n/a	n/a	n/a
SPURS AND IRREGULAR FLOWS		Jemalong No.4	n/a	n/a	n/a
SPURS AND IRREGULAR FLOWS		Jemlong No.6	n/a	n/a	n/a
SPURS AND IRREGULAR FLOWS		**TOTAL**	**n/a**	**n/a**	**n/a**

APPENDIX 33: OPTION 7 COST BREAKDOWN



OPTION 7 - HDPE Pipe

		CHANNEL NAME	CONSTRUCTION COST	MAINTENANCE COST OVER 20YRS	COMBINED COST
CHANNELS		Jem. Main U/S	$0	$0	$0
		TOTAL	$0	$0	**$0**
	DIVISION 1	Cadow D/S	$23,000,000	$0	$23,000,000
		Cadow No.2	$23,958,000	$0	$23,958,000
		Cadow U/S	$47,671,715	$0	$47,671,715
		Warroo Main	$51,206,824	$0	$51,206,824
		Warroo No.1	$9,918,283	$0	$9,918,283
		TOTAL	$155,754,822	$0	**$155,754,822**
	DIVISION 2	Jemalong Main U/S south	n/a	n/a	n/a
		Jemalong Main	n/a	n/a	n/a
		Jemalong No.1	n/a	n/a	n/a
		Jemalong No.2	n/a	n/a	n/a
		Jemalong No.2 U/S	n/a	n/a	n/a
		Jemalong No.2A	n/a	n/a	n/a
		Jemalong No.2C	n/a	n/a	n/a
		TOTAL	**n/a**	**n/a**	**n/a**
SPURS AND IRREGULAR FLOWS		Cadow No.2A	$4,765,009	$0	$4,765,009
		Cadow No.2A1	$248,034	$0	$248,034
		Cadow No.2E	$2,559,410	$0	$2,559,410
		Cadow No.3	$6,035,325	$0	$6,035,325
		Warroo No.1	$9,918,283	$0	$9,918,283
		Warroo No.1B	$809,685	$0	$809,685
		Warroo No.2	$9,360,059	$0	$9,360,059
		Warroo No.4	$2,887,459	$0	$2,887,459
		Warroo No.5	$1,779,485	$0	$1,779,485
		Warroo No.6	$1,593,413	$0	$1,593,413
		Warroo No.8	$4,553,834	$0	$4,553,834
		Warroo No.11	$2,030,485	$0	$2,030,485
		TOTAL	$46,540,482	$0	**$46,540,482**
		Jemalong No.1	n/a	n/a	n/a
		Jemalong No.2A	n/a	n/a	n/a
		Jemalong No.2A1	n/a	n/a	n/a
		Jemalong No.2B	n/a	n/a	n/a
		Jemalong No.2B1	n/a	n/a	n/a
		Jemalong No.2C1	n/a	n/a	n/a
		Jemalong No.2D	n/a	n/a	n/a
		Jemalong No.2E	n/a	n/a	n/a
		Jemalong No.4	n/a	n/a	n/a
		Jemlong No.6	n/a	n/a	n/a
		TOTAL	**n/a**	**n/a**	**n/a**

APPENDIX E: ECONOMIC IMPACT ASSESSMENT

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lawrence consulting

Economic Impact of the Jemalong Irrigation District Modernisation Plan

June 2009

Contents

INTRODUCTION

Lawrence Consulting was commissioned by Western Land Planning to undertake an assessment of the economic impact of a number of alternative scenarios proposed under a modernisation plan for the Jemalong Irrigation District on the Mid-Lachlan Catchment region.

The following sections of this report present the results of the economic impact analysis.

Disclaimer

Lawrence Consulting does not warrant the accuracy of this information and accepts no liability for any loss or damage that you may suffer as a result of your reliance on this information, whether or not there has been any error, omission or negligence on the part of Lawrence Consulting or its employees.

Approach

This section outlines the input-output methodology that was used to examine the expected economic activity generated by the proposed modernisation plan on the economy of the Mid-Lachlan Catchment region. All input data, except where referenced in the report, has been supplied by the proponent.

The contribution / shock to the economy of the region being analysed of the development examined is applied to the relevant industry sectors of the input-output model of the regional economy to examine the impact of the development. This analysis utilised regional input-output tables developed specifically for the Mid-Lachlan Catchment region to identify the expected impact of the proposed development.

The stimulus from economic activity can be traced through the economy in several different ways:

- The first round effect, or direct effect, are those from the activities expenditure in purchasing goods from other industries;

- The second round effects are those from the supplying industries increasing their purchases to meet the additional demand. The second and subsequent rounds of purchasing are termed the indirect effects; and

- The consumption-induced effects, which recognise that the level of local production is important in determining regional levels of household consumption, that this in turn will be spent locally to a large extent and therefore influence the level of regional consumption and the level of output of each sector.

(Note: Caution should be exercised when interpreting the consumption impacts as they are generally expected to overestimate the actual impact.)

These effects can be represented by multipliers. There are commonly four different types of multipliers:

- Output;
- Income;
- Employment; and
- Value added.

Output

The output impact measures the increase in gross sales throughout the whole economy by summing all the individual transactions resulting, directly and indirectly, from the economic stimulus. The output impacts, are however, regarded as overstating the impact on the economy as they count all goods and services used in one stage of production as an input to later stages of production, hence counting their contribution more than once.

Income

The income impact measures the additional amount of wages and salaries paid to employees of the industry under consideration and to other industries benefiting from the stimulus to the economy.

Employment

The employment impact measures the number of jobs created by the stimulus, both directly and indirectly. It should be noted that the short-term response to increased demand might be for employers to ask existing staff to work overtime. As a consequence, lower employment than the level indicated by the economic impact of the stimulus will result. This short-term scenario is particularly true where the demand stimulus is seen as temporary or where there is spare capacity in the economy (i.e. unemployment).

Value Added

The value added or Gross Regional Product[1] (GRP) impact measures only the net activity at each stage of production. GRP is defined as the addition of consumption, investment and government expenditure, plus exports of goods and services, minus imports of goods and services for a region. The GRP impacts are the preferred measure for the assessment and contribution of a stimulus to the economy.

Limitations

Limitations or qualifiers that should be raised when using input-output analysis include:

- The inputs purchased by each industry are a function of the level of output of that industry. The input function is generally assumed linear and homogenous of degree one (which implies constant returns to scale and no substitution between inputs);

- Each commodity (or group of commodities) is supplied by a single industry or sector of production. This implies that there is only one method used to produce each commodity and that each sector has only a single primary output;

- The total effect of carrying on several types of production is the sum of the separate effects. This rules out external economies and diseconomies and is known simply as the additivity assumption. This generally does not reflect real world operations;

- The system is in equilibrium at given prices. This is obviously not the case in an economic system subject to external influences;

- In the static input-output model, there are no capacity constraints so that the supply of each good is perfectly elastic. Each industry can supply whatever quantity is demanded of it and there are no capital restrictions. This assumption would come into play depending upon the magnitude of the changes in quantities demanded, brought about through changes in taxation levels; and

[1] This is also known as Gross State Product (GSP) or Gross National Product (GNP) depending on the level of the analysis.

- The input-output model is an optimisation model that allocates resources between sectors to their most efficient use. This is not expected to happen all of the time in the "real world" and as such results from the input output analysis may overestimate the actual impact delivered on ground.

Input-output techniques provide a solid approach for taking account of the inter-relationships between the various sectors of the economy in the short-term and hence are an appropriate tool for determining the direct, indirect and induced economic impact of the proposed modernisation plan for the Jemalong Irrigation District.

Description of Stimulus

Industry and infrastructure developments such as the proposed modernisation plan for the Jemalong Irrigation District generate economic benefits for the regional economy through expenditure associated with the increased turnover within the region that would otherwise not have occurred. If the proposed development will generate increased economic activity for the region over and above that of the economic activity generated by the existing land use then it may be considered a positive development for the region in economic terms.

Scheme Description

A modernisation plan has been developed for the Jemalong Irrigation District – currently managed by Jemalong Irrigation Limited – in the Mid-Lachlan Catchment region of New South Wales. Irrigators within the scheme have a delivery entitlement at their farm gate, which is assumed not to change with modernisation.

The scenarios for the scheme that have been assessed in the input-output analysis are the existing (or 'do nothing') and upgrade scenarios for on-farm infrastructure only. These scenarios have been separately assessed under two alternative water supply conditions:

1. A 36% available water determination (AWD) – this is the average annual AWD that can be best expected in the year 2030, taking climate change as predicted by the CSIRO into account; and

2. A 10% AWD – an allocation at which water cannot be delivered through the existing channels at present but which may be able to be delivered by some of the scheme channel upgrade options.

The 'upgrade' scenario is a mix of technology including drop, lateral move, centre pivot and upgraded flood irrigation. The ratios within this mix have been determined through discussions with each farmer within the Jemalong Irrigation District. The total area of each technology in each scenario has been adjusted according to water availability.

Catchment Area

The catchment selected for the analysis is the area comprised of the Lachlan, Parkes, Forbes and Bland Local Government Areas (LGAs) as a proxy for the Mid-Lachlan Catchment region. This conservative approach was adopted because of the limitations in extending the input-output methodology to the collection district (CD) level. These LGAs were included in investigations in order to assess the impact of changes in the Mid-Lachlan Catchment area of interest and on the retail and service capacity of major centres within the region.

Sectors Impacted

The sectors of the economy that will be impacted through the analysis include:

- Sheep;
- Grains;
- Beef; and
- Other agriculture.

Disaggregated industry outputs were provided as part of the analysis to demonstrate the impacts on all 109 sectors included in the input-output model, with specific interest in the following:

- Sheep
- Grains

- Beef cattle
- Dairy cattle
- Other agriculture
- Services to agriculture, hunting and trapping
- Non-ferrous metal ores
- Services to mining
- Meat and meat products
- Fruit and vegetable products
- Oils and fats
- Basic chemical
- Medicinal and pharmaceutical products, pesticides
- Other chemical products
- Cement, lime and concrete slurry
- Sheet metal products
- Fabricated metal products
- Motor vehicles and parts, other transport equipment
- Agricultural, mining, etc. machinery
- Other machinery and equipment
- Prefabricated buildings
- Water supply, sewerage and drainage services
- Residential building
- Other construction
- Wholesale trade
- Wholesale mechanical repairs
- Retail trade
- Retail mechanical repairs
- Accommodation, cafes and restaurants
- Road transport
- Services to transport, storage
- Communication services
- Banking
- Non-bank finance
- Insurance
- Services to finance, investment and insurance
- Scientific research, technical and computer services
- Legal, accounting, marketing and business management services
- Government administration
- Education
- Health services
- Community services
- Libraries, museums and the arts
- Sport, gambling and recreational services

Disaggregated industry outputs for all sectors are provided in Appendix A.

Data Inputs

The assessment is to estimate the economic impact to the Mid-Lachlan Catchment region of both the existing industry in the Jemalong Irrigation Scheme under current irrigation / infrastructure systems and a number of alternative systems. The existing and upgrade irrigation scenarios and their associated total annual enterprise income levels for the catchment area (outlined in Table 1) have been based on two alternative future available water determination (AWD) levels for irrigated properties in the region at the year 2030 (36% and 10%).

Table 1: Total Enterprise Income, Existing and Alternative Scenarios ($)

Scenario	Description	Annual Total Enterprise Income				
		Grains	Other Agriculture	Sheep	Beef	Total
1	Existing infrastructure in 2030 (36% AWD)	16,855,933	3,296,744	2,510,923	1,076,110	23,739,710
2	Upgraded infrastructure in 2030 (36% AWD)	18,369,670	4,824,016	2,510,923	1,076,110	26,780,718
3	Existing infrastructure in 2030 (10% AWD)	13,588,404	-	2,510,923	1,076,110	17,175,436
4	Upgraded infrastructure in 2030 (10% AWD)	14,642,609	1,111,327	2,510,923	1,076,110	19,340,969

Displacements & Leakages

Displacement arises when an economic stimulus such as a development project or initiative (Jemalong Irrigation District Modernisation Plan) takes market share from other existing local firms or organisations, or ‘displaces’ alternative uses of project funds that might otherwise have occurred. Leakages are defined as the proportion of project outputs that flow out of the catchment area, i.e. purchases from outside the region.

For the purpose of this analysis, is has been assumed that the Mid-Lachlan Catchment economy is a closed economy, that is, any displacement and leakages are considered marginal. All expenditure related to these elements of the project is therefore assumed to be made within the region in order to represent the additional economic activity generated by the proposed modernisation plan.

Economic Impact

Scenario 1: 36% AWD – Existing Infrastructure

The current Jemalong Irrigation District would generate economic activity for the Mid-Lachlan Catchment region through total enterprise income of approximately $23.7 million per annum in 2030, based on a 36% AWD. The direct, indirect and induced economic impacts associated with the scheme under this scenario include (refer Table 2):

- An estimated direct output of $23.7 million and additional flow on increases in output of $20.0 million through other industries, for a total industry impact of $43.7 million. A further $12.9 million in output in the region can be associated with consumption induced effects;
- Estimated direct income (wages and salaries) of $1.7 million, with $2.7 million in additional income generated through flow on effects in other industries and a further $1.6 million from household spending;
- Approximately 181.1 direct full-time equivalent (FTE) employment positions, with an estimated additional 92.2 employment positions gained indirectly through other industries for a total industry employment impact of 273.2 FTEs; and
- An estimated contribution to GRP of $12.3 million from direct effects, with a further flow on impact of $8.4 million through other industries for a total industry value added of $20.7 million. An additional $2.9 million in gross regional product can be attributed to consumption induced effects.

Table 2: Economic Impact of Jemalong Irrigation District Modernisation Plan, Scenario 1 (Existing)[a]

	Direct (D)	Indirect (I)	Total Industry Impact (D + I)	Consumption Induced (C)	Total Impact (D + I + C)
Output ($m)	23.7	20.0	43.7	12.9	56.6
Income ($m)	1.7[b]	2.7	4.4	1.6	6.1
Employment (FTE)	181.1	92.2	273.2	37.3	310.5
Value Added ($m)	12.3	8.4	20.7	2.9	23.7

Note: (a) Figures represent annual impacts. (b) The level of direct wages and salaries returned to agricultural sectors is generally proportionally lower than other industries due to a higher level of compensation derived through gross operating surplus/gross mixed income.

Scenario 2: 36% AWD – Upgraded Infrastructure

The direct, indirect and induced economic impacts for the Mid-Lachlan Catchment region associated with the expected total enterprise income of approximately $26.8 million per annum under Scenario 2 of the Jemalong Irrigation District Modernisation Plan include (refer Table 3):

- An estimated direct output of $26.8 million and additional flow on increases in output of $22.2 million through other industries, for a total industry impact of $49.0 million. A further $14.8 million in output in the region can be associated with consumption induced effects;
- Estimated direct income (wages and salaries) of $2.1 million, with $3.0 million in additional income generated through flow on effects in other industries and a further $1.9 million from household spending;
- Approximately 197.7 direct full-time equivalent (FTE) employment positions, with an estimated additional 102.8 employment positions gained indirectly through other industries for a total industry employment impact of 300.6 FTEs; and

- An estimated contribution to GRP of $14.0 million from direct effects, with a further flow on impact of $9.3 million through other industries for a total industry value added of $23.4 million. An additional $3.4 million in gross regional product can be attributed to consumption induced effects.

Table 3: Economic Impact of Jemalong Irrigation District Modernisation Plan, Scenario 2[(a)]					
	Direct (D)	Indirect (I)	Total Industry Impact (D + I)	Consumption Induced (C)	Total Impact (D + I + C)
Output ($m)	26.8	22.2	49.0	14.8	63.9
Income ($m)	2.1	3.0	5.1	1.9	7.0
Employment (FTE)	197.7	102.8	300.6	42.9	343.5
Value Added ($m)	14.0	9.3	23.4	3.4	26.7

Note: (a) Figures represent annual impacts.

Scenario 3: 10% AWD – Existing Infrastructure

The direct, indirect and induced economic impacts for the Mid-Lachlan Catchment region associated with the expected total enterprise income of approximately $17.2 million per annum under Scenario 3 of the Jemalong Irrigation District Modernisation Plan include (refer Table 4):

- An estimated direct output of $17.2 million and additional flow on increases in output of $15.2 million through other industries, for a total industry impact of $32.3 million. A further $8.7 million in output in the region can be associated with consumption induced effects;

- Estimated direct income (wages and salaries) of $1.0 million, with $2.0 million in additional income generated through flow on effects in other industries and a further $1.1 million from household spending;

- Approximately 145.1 direct full-time equivalent (FTE) employment positions, with an estimated additional 69.1 employment positions gained indirectly through other industries for a total industry employment impact of 214.3 FTEs; and

- An estimated contribution to GRP of $8.7 million from direct effects, with a further flow on impact of $6.3 million through other industries for a total industry value added of $15.0 million. An additional $2.0 million in gross regional product can be attributed to consumption induced effects.

Table 4: Economic Impact of Jemalong Irrigation District Modernisation Plan, Scenario 3[(a)]					
	Direct (D)	Indirect (I)	Total Industry Impact (D + I)	Consumption Induced (C)	Total Impact (D + I + C)
Output ($m)	17.2	15.2	32.3	8.7	41.1
Income ($m)	1.0	2.0	3.0	1.1	4.1
Employment (FTE)	145.1	69.1	214.3	25.2	239.4
Value Added ($m)	8.7	6.3	15.0	2.0	17.0

Note: (a) Figures represent annual impacts.

Scenario 4: 10% AWD – Upgraded Infrastructure

The direct, indirect and induced economic impacts for the Mid-Lachlan Catchment region associated with the expected total enterprise income of approximately $19.3 million per annum under Scenario 4 of the Jemalong Irrigation District Modernisation Plan include (refer Table 5):

- An estimated direct output of $19.3 million and additional flow on increases in output of $16.8 million through other industries, for a total industry impact of $36.1 million. A further $10.1 million in output in the region can be associated with consumption induced effects;

- Estimated direct income (wages and salaries) of $1.2 million, with $2.2 million in additional income generated through flow on effects in other industries and a further $1.3 million from household spending;

- Approximately 156.9 direct full-time equivalent (FTE) employment positions, with an estimated additional 76.7 employment positions gained indirectly through other industries for a total industry employment impact of 233.6 FTEs; and

- An estimated contribution to GRP of $9.9 million from direct effects, with a further flow on impact of $7.0 million through other industries for a total industry value added of $16.9 million. An additional $2.3 million in gross regional product can be attributed to consumption induced effects.

Table 5: Economic Impact of Jemalong Irrigation District Modernisation Plan, Scenario 4(a)

	Direct (D)	Indirect (I)	Total Industry Impact (D + I)	Consumption Induced (C)	Total Impact (D + I + C)
Output ($m)	19.3	16.8	36.1	10.1	46.2
Income ($m)	1.2	2.2	3.5	1.3	4.7
Employment (FTE)	156.9	76.7	233.6	29.2	262.8
Value Added ($m)	9.9	7.0	16.9	2.3	19.2

Note: (a) Figures represent annual impacts.

SUMMARY OF NET IMPACTS

The net economic impacts associated with the proposed Jemalong Irrigation District Modernisation Plan for both available water determination (AWD) levels assessed – i.e. increased economic activity for the region over and above that of the economic activity generated by the existing infrastructure (Scenarios 1 and 3) – for the Mid-Lachlan Catchment region are summarised in Table 6. Each of the alternative upgrade scenarios provided for in the modernisation plan result in positive net impact when compared to the existing infrastructure scenarios, with the greater net benefits stemming from the higher AWD (36%).

In summary, the net economic impacts (direct and indirect) associated with these scenarios include:

Scenario 2 (36% AWD)

- An estimated increase in direct output of $3.0 million and additional flow on increases in output of $2.2 million through other industries, for a total net industry impact of $5.3 million;
- An estimated increase in direct income (wages and salaries) of $0.3 million, with $0.3 million in additional income generated through flow on effects in other industries;
- An additional 16.7 direct full-time equivalent (FTE) employment positions, with an estimated increase of 10.7 employment positions gained indirectly through other industries, for a total net industry employment impact of 27.3 FTEs; and
- An estimated increase in GRP of $1.7 million from direct effects, with a further flow on impact of $1.0 million through other industries for a total net industry value added of $2.6 million.

Scenario 4 (10% AWD)

- An estimated increase in direct output of $2.2 million and additional flow on increases in output of $1.6 million through other industries, for a total net industry impact of $3.8 million;
- An estimated increase in direct income (wages and salaries) of $0.2 million, with $0.2 million in additional income generated through flow on effects in other industries;
- An additional 11.8 direct full-time equivalent (FTE) employment positions, with an estimated increase of 7.6 employment positions gained indirectly through other industries, for a total net industry employment impact of 19.4 FTEs; and
- An estimated increase in GRP of $1.2 million from direct effects, with a further flow on impact of $0.7 million through other industries for a total net industry value added of $1.9 million.

Table 6: Net Economic Impact of Jemalong Irrigation District Modernisation Plan, Summary of Upgrade Scenarios[a]

	Direct (D)	Indirect (I)	Total Industry Impact (D + I)	Consumption Induced (C)	Total Impact (D + I + C)
Scenario 2 (36% AWD)					
Output ($m)	3.0	2.2	5.3	1.9	7.2
Income ($m)	0.3	0.3	0.7	0.2	0.9
Employment (FTE)	16.7	10.7	27.3	5.6	32.9
Value Added ($m)	1.7	1.0	2.6	0.4	3.1

Table 6: Net Economic Impact of Jemalong Irrigation District Modernisation Plan, Summary of Upgrade Scenarios[(a)]

	Direct (D)	Indirect (I)	Total Industry Impact (D + I)	Consumption Induced (C)	Total Impact (D + I + C)
Scenario 4 (10% AWD)					
Output ($m)	2.2	1.6	3.8	1.4	5.1
Income ($m)	0.2	0.2	0.5	0.2	0.7
Employment (FTE)	11.8	7.6	19.4	4.0	23.4
Value Added ($m)	1.2	0.7	1.9	0.3	2.2

Note: (a) Figures represent annual impacts.

It should be noted that the above net impacts are annual figures – over the 20 year project timeframe to 2030, the total additional industry output would be approximately $106.0 million under Scenario 2 ($144.0 million if consumption induced impacts are included), whilst the estimated impact on total output under Scenario 4 would be $76.0 million ($102.0 million including consumption induced impacts).

The impacts under the low water allocation scenario (i.e. 10% AWD) are further enhanced, as under the upgraded infrastructure scenario, viable irrigated production may be possible where previously they may not have been.

The benefits flowing from the proposed modernisation plan are significant and therefore, based on the conservative assumptions presented in this analysis, the net economic impact for the Mid-Lachlan Catchment region is highly positive.

APPENDIX A: DISAGGREGATED INDUSTRY OUTPUT

Table A1: Total Output per Industry, Jemalong Irrigation District Modernisation Plan ($m)

Industry sector	Industry output (direct & indirect)					
	Scenario 1	Scenario 2	Net impact	Scenario 3	Scenario 4	Net impact
Sheep	2.521	2.522	0.001	2.518	2.519	0.001
Grains	21.753	23.722	1.968	17.504	18.876	1.372
Beef cattle	1.093	1.095	0.002	1.089	1.090	0.001
Dairy cattle	0.003	0.003	0.000	0.002	0.003	0.000
Pigs	0.001	0.001	0.000	0.000	0.000	0.000
Poultry	0.001	0.001	0.000	0.001	0.001	0.000
Other agriculture	3.880	5.490	1.610	0.404	1.575	1.171
Services to agriculture; hunting and trapping	2.558	2.910	0.352	1.798	2.050	0.252
Forestry and logging	0.053	0.061	0.008	0.035	0.041	0.006
Commercial fishing	0.004	0.005	0.001	0.003	0.003	0.000
Coal	0.012	0.013	0.001	0.009	0.010	0.001
Oil and gas	0.725	0.799	0.074	0.566	0.618	0.052
Iron ores	0.003	0.003	0.000	0.002	0.003	0.000
Non-ferrous metal ores	0.230	0.256	0.026	0.175	0.193	0.018
Other mining	0.022	0.024	0.002	0.017	0.018	0.002
Services to mining	0.058	0.064	0.006	0.044	0.049	0.004
Meat and meat products	0.016	0.018	0.002	0.012	0.013	0.002
Dairy products	0.007	0.008	0.001	0.005	0.006	0.000
Fruit and vegetable products	0.003	0.004	0.000	0.003	0.003	0.000
Oils and fats	0.005	0.005	0.000	0.004	0.004	0.000
Flour mill products and cereal foods	0.008	0.009	0.001	0.006	0.007	0.001
Bakery products	0.005	0.006	0.001	0.004	0.004	0.000
Confectionery	0.001	0.002	0.000	0.001	0.001	0.000
Other food products	0.114	0.128	0.014	0.083	0.093	0.010
Soft drinks, cordials and syrups	0.001	0.001	0.000	0.001	0.001	0.000
Beer and malt	0.005	0.006	0.001	0.004	0.004	0.000
Wine, spirits and tobacco	0.009	0.011	0.001	0.007	0.008	0.001
Textile fibres, yarns and woven fabrics	0.007	0.008	0.001	0.006	0.006	0.001
Textile products	0.014	0.015	0.002	0.010	0.011	0.001
Knitting mill products	0.000	0.000	0.000	0.000	0.000	0.000
Clothing	0.035	0.039	0.003	0.028	0.030	0.002
Footwear	0.002	0.003	0.000	0.002	0.002	0.000
Leather and leather products	0.003	0.003	0.000	0.002	0.002	0.000
Sawmill products	0.012	0.013	0.001	0.010	0.010	0.001
Other wood products	0.024	0.026	0.003	0.018	0.020	0.002
Pulp, paper and paperboard	0.010	0.011	0.001	0.008	0.008	0.001
Paper containers and products	0.026	0.030	0.004	0.018	0.021	0.003
Printing and services to printing	0.032	0.036	0.004	0.023	0.026	0.003
Publishing; recorded media and publishing	0.054	0.062	0.007	0.038	0.044	0.005
Petroleum and coal products	1.429	1.573	0.143	1.120	1.221	0.101
Basic chemicals	1.534	1.706	0.172	1.161	1.283	0.122
Paints	0.024	0.026	0.002	0.019	0.020	0.002
Medicinal and pharmaceutical products, pesticides	1.026	1.125	0.099	0.812	0.883	0.071
Soap and other detergents	0.015	0.017	0.002	0.011	0.012	0.001
Cosmetics and toiletry preparations	0.002	0.002	0.000	0.002	0.002	0.000
Other chemical products	0.081	0.089	0.007	0.065	0.070	0.005

Table A1: Total Output per Industry, Jemalong Irrigation District Modernisation Plan ($m)						
Industry sector	**Industry output (direct & indirect)**					
	Scenario 1	**Scenario 2**	**Net impact**	**Scenario 3**	**Scenario 4**	**Net impact**
Rubber products	0.020	0.022	0.002	0.015	0.017	0.002
Plastic products	0.056	0.063	0.007	0.040	0.045	0.005
Glass and glass products	0.010	0.011	0.001	0.007	0.008	0.001
Ceramic products	0.002	0.003	0.000	0.002	0.002	0.000
Cement, lime and concrete slurry	0.014	0.016	0.002	0.011	0.012	0.001
Plaster and other concrete products	0.004	0.004	0.000	0.003	0.003	0.000
Other non-metallic mineral products	0.007	0.008	0.001	0.005	0.006	0.001
Iron and steel	0.080	0.088	0.008	0.062	0.068	0.006
Basic non-ferrous metal and products	0.024	0.026	0.002	0.019	0.020	0.002
Structural metal products	0.034	0.037	0.004	0.026	0.028	0.002
Sheet metal products	0.013	0.014	0.001	0.010	0.011	0.001
Fabricated metal products	0.102	0.112	0.010	0.080	0.088	0.007
Motor vehicles and parts; other transport equipment	0.085	0.095	0.010	0.062	0.070	0.007
Ships and boats	0.001	0.001	0.000	0.001	0.001	0.000
Railway equipment	0.028	0.031	0.003	0.022	0.024	0.002
Aircraft	0.039	0.044	0.004	0.030	0.033	0.003
Photographic and scientific equipment	0.019	0.021	0.002	0.015	0.016	0.001
Electronic equipment	0.085	0.094	0.009	0.066	0.072	0.006
Household appliances	0.012	0.013	0.001	0.009	0.010	0.001
Other electrical equipment	0.040	0.044	0.004	0.031	0.034	0.003
Agricultural, mining and construction machinery, lifting and material handling equipment	0.173	0.191	0.018	0.135	0.148	0.012
Other machinery and equipment	0.080	0.088	0.008	0.063	0.068	0.006
Prefabricated buildings	0.004	0.004	0.000	0.003	0.003	0.000
Furniture	0.003	0.004	0.000	0.002	0.003	0.000
Other manufacturing	0.009	0.010	0.001	0.006	0.007	0.001
Electricity supply	0.192	0.214	0.022	0.144	0.160	0.016
Gas supply	0.021	0.024	0.002	0.016	0.018	0.002
Water supply; sewerage and drainage services	0.320	0.354	0.034	0.246	0.270	0.024
Residential building construction	0.000	0.000	0.000	0.000	0.000	0.000
Other construction	0.054	0.060	0.006	0.041	0.045	0.004
Construction trade services	0.120	0.133	0.014	0.091	0.100	0.010
Wholesale trade	0.734	0.838	0.104	0.509	0.584	0.074
Wholesale mechanical repairs	0.055	0.060	0.005	0.043	0.047	0.004
Other wholesale repairs	0.054	0.060	0.006	0.041	0.046	0.004
Retail trade	0.069	0.081	0.012	0.044	0.052	0.008
Retail mechanical repairs	0.171	0.194	0.023	0.121	0.138	0.016
Other retail repairs	0.051	0.055	0.005	0.040	0.044	0.003
Accommodation, cafes and restaurants	0.173	0.195	0.023	0.124	0.140	0.016
Road transport	0.464	0.529	0.065	0.323	0.370	0.047
Rail, pipeline and other transport	0.156	0.173	0.016	0.121	0.132	0.012
Water transport	0.031	0.034	0.003	0.024	0.026	0.002
Air and space transport	0.046	0.052	0.005	0.035	0.039	0.004
Services to transport; storage	0.372	0.412	0.040	0.284	0.313	0.029
Communication services	0.204	0.227	0.024	0.153	0.170	0.017
Banking	0.281	0.314	0.034	0.208	0.232	0.024
Non-bank finance	0.138	0.154	0.016	0.104	0.115	0.011
Insurance	0.074	0.082	0.009	0.055	0.061	0.006
Services to finance, investment and insurance	0.269	0.296	0.027	0.210	0.229	0.019

Table A1: Total Output per Industry, Jemalong Irrigation District Modernisation Plan ($m)						
Industry sector	**Industry output (direct & indirect)**					
	Scenario 1	**Scenario 2**	**Net impact**	**Scenario 3**	**Scenario 4**	**Net impact**
Ownership of dwellings	0.000	0.000	0.000	0.000	0.000	0.000
Other property services	0.413	0.461	0.048	0.308	0.343	0.034
Scientific research, technical and computer services	0.150	0.169	0.019	0.110	0.124	0.013
Legal, accounting, marketing and business management services	0.330	0.368	0.039	0.246	0.274	0.027
Other business services	0.234	0.261	0.026	0.177	0.196	0.019
Government administration	0.072	0.081	0.009	0.052	0.059	0.007
Defence	0.000	0.000	0.000	0.000	0.000	0.000
Education	0.050	0.056	0.006	0.037	0.042	0.004
Health services	0.014	0.015	0.001	0.011	0.012	0.001
Community services	0.000	0.000	0.000	0.000	0.000	0.000
Motion picture, radio and television services	0.035	0.039	0.004	0.026	0.029	0.003
Libraries, museums and the arts	0.014	0.015	0.001	0.011	0.012	0.001
Sport, gambling and recreational services	0.005	0.006	0.000	0.004	0.005	0.000
Personal services	0.005	0.005	0.001	0.004	0.004	0.000
Other services	0.004	0.004	0.000	0.003	0.003	0.000
Total	**43.737**	**49.016**	**5.279**	**32.342**	**36.094**	**3.752**