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Adapting to and maximising opportunities from water pipeline projects in dryland regions

Literature Review

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Prepared by:

WIDCORP

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Postal address: PO Box 300
Horsham VIC 3402

Office Location: Horsham Campus
University of Ballarat
Baillie St
Horsham VIC

Telephone: +61 3 5362 2600
Facsimile: +61 3 5362 2603
Email: widcorp@ballarat.edu.au
Internet: www.widcorp.com

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Author: Dr Imogen Schwarz

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Abbreviations

BDRP	Bore Drain Replacement Project
CIE	Centre for International Economics
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DNR	Department of Natural Resources, New South Wales State Government
DPI	Department of Primary Industries, Victorian State Government
DSE	Department of Sustainability and Environment, Victorian State Government
GAB	Great Artesian Basin
GABSI	Grate Artesian Basin Sustainability Initiative
IWRM	Integrated Water Resource Management
NMP	Northern Mallee Pipeline
SMEC	Snowy Mountains Engineering Corporation Pty Ltd
WIDCORP	Water in Drylands Collaborative Research Program
WMP	Wimmera Mallee Pipeline

Literature Review

1 Introduction

This literature review forms part of a collaborative research project with Department of Primary Industries in Horsham titled "Identifying farmer typologies and gauging their attitudes and aspirations and expectations of future benefits and opportunities from the Wimmera Mallee Pipeline". The aim of this review is to identify and document published evidence of how parallel dryland regions have adapted to and maximised opportunities from implementation of a new or additional water regime through pipelines.

A number of underlying assumptions inform the aims of this review. Firstly, 'p*arallel dryland regions'* refer to semi-arid rural areas in Australia, or elsewhere which are similar in composition to the Wimmera-Mallee region – that is a significant proportion of its economic base is in agriculture. Dryland regions make up forty percent of the earth's land surface and Australia has the most dryland of any country in the world (White & Nackoney, 2003). Of central concern to people in these regions are issues of (fresh)water scarcity, variability of supply and future increased water shortages (White & Nackoney, 2003). Uncertainties such as climate change, continued drought years and climate variability have exacerbated the current availability of water in Australia, and the need to secure water supply.

Secondly, '*adapted to and maximised opportunities'* from new water infrastructure refers to the subsequent social, economic and environmental adjustments that will occur in rural communities as a result of a piped water supply in the region. Within the region, the water saved (up to 103,000 ML per year) will not only be available for environmental flows (85,000ML) (RWC, 1991) but also economic and social development (Grampians Wimmera Mallee Water, 2003; Nicol, 2003; RMCG Consultants for Business, Communities & Environment, 2003). How this water will best be maximised is a question raised by local stakeholders and community members.

Furthermore, as water scarcity increases, efficient use of water is becoming a key objective for many countries – "Efficiency in water use means maximising society's benefits over time from the water and technology available" (Easter & Yang, 2005). Water infrastructure must meet demands of population growth, and expanding and changing needs of agricultural and industry sectors, as well as deliver significant water savings. Not only are socio-economic imperatives important but also environmental management of rivers, estuaries and aquifers and addressing the potential impacts of climate change on water resources (DSE, 2005). The replacement of old distribution networks that account for large losses of water with water-efficient schemes is increasingly important for dryland regions, such as the Wimmera-Mallee. The Wimmera Mallee Pipeline (WMP) Project will minimise water wastage through seepage and evaporation by replacement of the existing 16,000km network of highly inefficient earthen channels with close to 9,000 kilometres of pipelines (DSE, 2006b).

Literature was searched to identify similar water pipeline projects from international as well as national sources.[1] Published literature specific to the aim of the review was limited. The search results included literature related to water, as well as oil, gas, waste disposal, sewerage, and desalination pipelines. Much of the focus was about urban as opposed to regional/rural water development projects, except where related to sanitation and drinking water programs in developing countries.

There appears to be little publicly available literature which documents the social and economic impacts of change, such as the public and private benefits and costs for industry, farmers and community of the replacement or addition of pipelines into a region. Conventional searching methods via internet and databases failed to call up current reports on pipeline projects. Contact was made with government agencies and regional water authorities and institutions on a number of Australian based pipeline projects to source information[2], however documents are either not publicly available, are difficult to access, or are not relevant[3] to the aims of this literature review.

The literature identified in the review has been organised into three major sections:

- International themes in literature which pertains mainly to technical aspects of pipeline infrastructure;
- Examples of related pipeline projects in Australia; and,
- Impact studies on the perceived public and private values of pipeline projects.

2 International themes in literature

Most academic literature on pipelines focuses on the 'supply' side of water management. This reflects the traditional 'command and control' approach on which water management is based (Pahl-Wostl & Sendzimir, 2005). "Technical solutions and supply development" (Pahl-Wostl et al., 2004) dominate the literature discussing aspects about:

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[1] The process included trawling through UB catalogues and other major Australian university catalogues (LaTrobe University, Monash University); and a search of environmental, multi-disciplinary and water-specific databases (including academic search premier, ANR Index Archive, ANR Index, APA – FT, Emerald/Full Text, Elixir, JStor, Master File Premier, and Water Resources Worldwide). Google scholar and IWA publishing (International Water Association publishing) were other online databases accessed. A general search using 'Google' search engine was also conducted. Keywords used to guide the search were 'pipeline', 'pipeline projects', 'water pipeline infrastructure', 'water regime', 'water security', 'water recovery'. More information was sourced from government and private enterprises on related water projects.

[2] The organisations contacted were: Wannon Water – Otway Supply System; Maunsell Australia Pty Ltd – Darling River Water Savings Project; Department of Natural Resources, NSW – Great Darling Anabranch Stock & Domestic Pipeline; SAWater – Virginia Pipeline.

[3] Documents cited as *not* relevant were (environmental, technical, economic) impact assessments pre-construction of pipelines. Economic assessments cited related to benefit-cost analysis of pipeline implementation rather than impacts on regional development opportunities.

- construction and design (eg. Reina, 1999; Wolfe, 1997; Zhuwakinyu, 1997),
- maintenance/diagnosis (eg. Eiswirth & Burn, 2001; Engelhardt et al., 2002; Fraser & Lowdon, 2000; Van Vuuren, van Dijk, & Steenkamp, 2004);
- asset management and decision-support systems (Burn et al., 2003; Burn, 2005; Saegrov, 2004),
- renewal/rehabilitation of water pipeline infrastructure (Dandy & Engelhardt, 2001; Gerodetti & Ruefenacht, 2003;Vickridge, 2002); and,
- water quality and health (Lehtola, Nissinen, Miettinen, Martikainen, & Vartiainen, 2004; Van der Walt, 2002).

Also cited were some 'impact assessments' of pipeline projects, relating namely to environmental factors. Key issues in this body of technical literature on pipelines are described below. These provide some insight into aspects of pipelines that are relevant to farm planning of new piped water on-farm infrastructure.

2.1 Infrastructure replacement issues

Issues associated with the rapid ageing of pipelines, in particular related to urban areas, and the high ongoing costs involved in pipeline rehabilitation are highlighted in literature from Japan, Russia, Germany, South Africa, Switzerland, Hong Kong and the United States. For example, Eiswirth et al. (2001) estimate Germany spends at least $300M (US) in rehabilitation of water mains. High levels of expenditure are also reported by Australian water authorities who spend about $145M (US) per annum (WSAA, 2000, cited in Eiswirth et al., 2001).

In response, scientists are developing new methods to determine strategies for assessment, monitoring and replacement of pipelines that will minimise costs, externalities and is least disruptive (Burn, Davis, DeSilva, Marksjo et al., 2001). Examples of these types of technological innovations are provided in section 2.2.

Whilst there are obvious differences in the scale of water reticulation systems, and disruption to surrounding construction and infrastructure in built-up urban areas as compared with agricultural land, the literature does point to a number of issues of relevance to farming systems. Firstly, the need to consider future maintenance and replacement costs of pipelines in development of supply to farm and on-farm infrastructure planning, and secondly, how to determine the best strategy for maintenance and replacement of water pipelines.

2.2 Asset management systems

In recent years, many water utilities have adopted asset management systems to improve the financial and service performance of water infrastructure. Asset management is defined as "an integrated approach to improving the ability of infrastructure system to deliver water at a defined level of service in the most cost-effective manner" (My Tran, Malano, & Thompson, 2003). Literature cites the role of condition monitoring to assess maintenance, repair and upgrading requirements (Eiswirth, et al., 2001) and costs (Engelhardt, et al., 2002) over the lifetime of pipelines. Decision support systems for pipeline replacement strategies have been developed around the world including WiLCO (Engelhardt et al., 2002), CARE-W (Saegrov, 2004) applied in Norway and, PARMS-PLANNING by CSIRO in Australia (Moglia, Burn, & Meddings, 2006).

These types of assessment models, which are developed into decision support software, are designed to assist in planning and budgeting for pipeline rehabilitation into the future and can be applied at a regional level. These models for asset planning could possibly be applied to on-farm supply systems but evidence of this use is not reported.

2.3 Current knowledge gaps in international literature

Relatively absent from international pipeline literature is the relationship between the 'human-technology-environment systems' (Pahl-Wostl & Sendzimir, 2005) which is driving current water management needs and practices. For example, current literature on integrated water resource management (IWRM) focuses on issues of water efficiency, and considers social, economic, and political implications of water use and water management (Ali, 1999; Dolatyar & Gray, 2000; Trottier, 1999; Turton, 1999). In addition IWRM literature also examines environmental concerns such as climate change (Vorosmarty, Green, Salibury, & Lammers, 2000), salinity (Goss, 2003; Nielson, Brock, Rees, & Baldwin, 2003) and, clean water and sanitation issues (Benabdallah, El Mghari, & Echiabi, 2000; Molden & de Fraiture, 2004) associated with managing our water resources. However where literature considers these issues, it does not specifically focus on pipeline projects; rather pipelines are mentioned as one component of a whole water resources management system, if at all.

3 Overview of related water pipeline projects and derived benefits

This section provides a brief overview of literature on water pipeline schemes, and their potential benefits and limitations to the affected regions. In the international literature, a number of major projects in dryland regions were cited. These are:

- *Red Sea-Dead Sea pipeline* (Jordan, Israel, Syria) – Pipeline supplies water from the Red Sea in order to raise the level of the Dead Sea (Gavrieli, Bein, & Oren, ; Hattar, 2002) and supply desalinated drinking water to communities (Beyth, 2002) located in one of the most water-limited regions of the world (Harding, 2005).
- Koffiefontein emergency pipeline project, South Africa – Faced with water shortages this water supply development project delivers water to the dryland region of Koffiefontein, a diamond mining town and sheep farming district (Koffiefontein emergency pipeline project.2001).
- Clarens-Johannesburg pipeline, South Africa – to supply water to the Guetung region (Human, 2001).

Given the recent attention to water pipeline delivery infrastructure across much of Australia it is surprising the limited published literature on these projects and less on the benefits and limitations of water pipelines applied to a rural dryland setting. Table 1 provides an overview of these projects where this information was accessible (via related websites and 'google' search).

Table 1 Related water pipeline projects in Australia

Water pipeline project	Region	Description	Potential benefits/limitations
Great Artesian Basin Sustainability Initiative (GABSI); Bore-Drain Replacement Program (BDRP) (Completed 1998)	Areas within the Great Artesian Basin (GAB), Queensland	Infrastructure efficiency project to address loss of pressure from aquifers resulting in decreased water supply, with many artesian bores slowing or ceasing to flow. Involved replacement of bore drains with pipelines, as well as bore capping and rehabilitation. Commenced in 1994-95.	• Increase security and better quality supply of water for farm and domestic use • Increased land productivity through closure of bore drains • Maintenance of pressure in town water supplies that are reliant on artesian waters • More flexible water system allows for efficient and flexible farm management • Retain value of artesian waters for future opportunities and use. • Restore environmental flows to springs, having tourism value. • Reduce pest plants and animals, and salinity issues on-farm, whilst improving natural vegetation through closure of bore drains. • Elimination of bore maintenance and associated costs *Source:* CIE , 2003; Pegler, Moore, Bentley, 2001.
Virginia Pipeline Scheme (Completed 1999)	Northern Adelaide Plains, South Australia	A waste-water reuse scheme includes150km of pipeline distribution network to supply recycled water to 200 square kilometres of horticultural land. The Virginia Pipeline project one of the first of its type in South Australia, and consequently, a similar scheme has been completed, south of Adelaide.	• Plays a significant role in reducing pollution into marine environment by 70% • Provides opportunity to secure access to water, a particularly limited resource in the context of a semi-arid climate where existing groundwater resources were facing overuse. • Provides about 250 vegetable growers with reliable supply of water, to a quality suitable for irrigation use. • Estimated volume of recycled water = 22,500 ML per year (which represents over 50% of annual plant flow). *Source:* Kracman, Martin, & Sztjanbok, 2001; http://www. environment. sa.gov.au/coasts/mpas/pdfs/mpa_report/part_3.pdf

Table 1 continued…

Water pipeline project	Region	Description	Potential benefits/limitations
Northern Mallee Pipeline Project (Completed 2002)	Northern Mallee, Victoria	Provision of an alternative water distribution system: Conversion of earthen channels to 2500 km pipelines for stock and domestic water supply system in agricultural region. Project commenced in 1991 and completed 2002.	*Benefits* • Security of water supply on farms for stock, and increased effectiveness of pesticides & spray units • Increased flexibility of water systems on farms • Increase productivity of land through channel decommissioning • Improved quality of farm life and increased financial security • Estimated volume of water recovered = 50, 000 ML per year • Increased environmental flows (Allocation of 34,000ML per year) *Limitations* • Farm operating costs and on-farm set up costs • Few new agricultural enterprises have been developed Source: WIDCORP, 2006
The Tungamah Pipeline, Lake Mokoan project (Completed 2006-07)	Near Benalla, Victoria	A water recovery scheme involving decommissioning of Lake Mokoan and installation of 360km of pipelines to replace 520km highly inefficient earthen channels. The Tungamah pipeline links the Tungamah domestic and stock system between Shepparton and Yarrawonga.	• Provide reliable water supply to irrigators • Estimated volume of water recovered = 18,000 ML per year for environmental flows to the Snowy River. • Also help to restore flows to Broken and Goulburn Rivers. *Source*: http://www.waterforrivers.org.au/projects/past/200721518394.htm ; http://www.dse.vic.gov.au
Woorinen Pipeline Project (Completed – date not specified)	Northern Mallee, near Swan Hill, Victoria	Irrigation infrastructure efficiency project include replacement of 53km of concrete and earth channels with 60km of pipeline in the Woorinen Irrigation System which originally serviced 200 properties.	• More reliable water supply for users including those with farming enterprises such as stone fruit, vine, market garden, crops and pasture. • Estimated volume of water recovered = 1,500 ML per year for environmental flows *Source*: http://ww.dse.vic.gov.au

Table 1 continued…

Water pipeline project	Region	Description	Potential benefits/limitations
Normanville Pipeline Project (Completed – date not specified)	Mallee-North Central, Victoria (Between Kerang, Quambatook & Boort)	Irrigation infrastructure efficiency project in the Normanville District Stock and Domestic Water Supply System. Involved replacement of 335km of earthen channels with closed piping to deliver about 400ML to around 150 properties within the region.	• More reliable supply and better quality of water to farm and town users. • Reclaim productive use of land through installation of underground pipelines • Estimated volume of water recovered = 3,600 ML per year for environmental flows. *Source*: http://ww.dse.vic.gov.au
The Great Darling Anabranch stock and domestic pipeline (under construction)	Murray-Darling region, southern New South Wales	Provision of an alternative more efficient supply system for stock and domestic water via a pipeline to Anabranch landholders. Estimated cost of $54 million.	• Estimated volume of water recovered in the Menindee Lakes = 47,000 ML per year • Return 460km of ephemeral creek to a more natural flow regime • To protect water security for users *Source*: http://www.dnr.nsw.gov.au/water/recovery.shtml#cpbp
Darling River Water Savings Project (Under planning phase & community engagement process)	Murray-Darling region, New South Wales	Water savings project that reduces water losses from the Menindee Lakes system, to improve security of supply and environmental flows. Option may include alternative supply options to Broken Hill and other users around lake from Anabranch Pipeline or pipeline from Murray River.	• Improve operational flexibility of river and water storage management to better meet the needs of water users and the environment • To protect environment and riverine ecology • To protect water quality and water security for users • To contribute to economic development in the Region *Source*: http://www.webmckeown.com.au/watersavings

Whilst the WMP is the largest pipeline infrastructure project in Australia and is also one of the most significant water management schemes, other projects are comparable. Project description and benefits of the WMP are summarised in Table 2. Of particular relevance to the project objectives of the Wimmera Mallee Pipeline, are pipeline infrastructure developments and other water saving actions under the concept of 'water recovery'[4] (DNR; The Living Murray, 2007) and 'water saving' (DSE, 2006a) projects such as those located in the Murray Darling River Basin. The 'Living Murray Initiative' (2007) is one such program focusing on improving recovery of water, in this case the primary reason being for environmental benefit. Inadvertently, creating water savings to provide additional environmental water, involves delivering water more efficiently to water users. The Northern Mallee Pipeline and Wimmera Mallee Pipeline also have allocated large volumes of water recovered to environmental flows, in addition to other social and economic development objectives.

Despite other pipeline projects being smaller in scale than the Wimmera Mallee Pipeline, these projects have a number of similarities which include a significant

Table 2 Wimmera Mallee Pipeline Project profile

Region	Description	Potential benefits/limitations
Wimmera Mallee, western Victoria.	Water infrastructure efficiency project. Involves replacement of 16,000 km earthen channels with 9,000 km of underground pipelines to supply stock and domestic water to 6,000 rural customers and 36 towns across the region. Project covers 10% of Victoria and costed at $501 million. Commenced in 2006. Expected completion in 2010.	• Provide sustainable water supply to the region for the next 100 years • Minimise massive losses of water (up to 85%) through seepage and evaporation • Provide regional growth such as on-farm diversification, commercial opportunities, tourism. • Provide estimated economic benefit of 4,900 full time jobs and add $710 million to regional economy. • Provide approximately 80,000 ML water per annum for environmental flows to rivers and lakes with flow-on benefits for community. • Estimate volume of water recovered = 103, 000 ML per year

Source: DSE, 2006b; Grampians Wimmera Mallee Water, 2003; Nicol, 2003; RMCG Consultants for Business, Communities & Environment, 2003; Wagner, 2004.

[4] A further search of 'water recovery' projects on the international level resulted in information/literature focusing on more sophisticated means of water recovery other than conversion from open earthen channels to pipelines. The term 'water recovery' related to water recycle and water reuse methods for use in industry, for urban water supply and for manned space infrastructure. Desalination of seawater via reverse osmosis is one such example of 'water recovery' technology used in countries located in the Middle-East, the Caribbean and elsewhere.

focus on addressing water security through recovery of waster water, return of water to ecosystems through environmental flows, and provision of a reliable and better quality water supply for farms and towns.

However, there is limited focus on the potential social and economic benefits of water recovered. There is a dearth of public documents (including accessible and publicly available) which examine the socio-economic impacts of change in water infrastructure schemes to pipelines. One of the key issues identified by stakeholders of the Darling River Water Savings Project was the importance of water for local tourism and regional development and the flow on effects to wider economy. The consulting group plans to assess these socio-economic changes to the region (Maunsell Australia, 2006). These types of assessments are the focus of the following section of the literature review.

4 Related socio-economic studies on water pipeline projects

Water management has become an important issue in recent years and an integrated approach which considers equitable distribution, water conservation, environmental flows, and economic and social development is more prominent in the literature (Gunningham & Sinclair, 2002; IRRR, 2004; Liquid assets, 2003). Whilst this approach is becoming established, socio-economic data of water piping schemes is only beginning to emerge.

Recent research about public perceptions of impacts of water pipeline projects in the Great Artesian Basin (CIE, 2003), particularly in South West Queensland (Pegler et al., 2001), and in the Northern-Mallee region of Victoria (WIDCORP, 2006b) are beginning to be published. Research has also been conducted on community attitudes and aspirations of the Wimmera Mallee Pipeline, prior to installation (WIDCORP, 2006a). The Queensland studies (CIE, 2003; Pegler et al., 2001) examines mainly farming impacts of change in water delivery from bore drains to pipes, as well as some public values. The more recent Victorian studies document

Table 3 Summary of community/ farm evaluation studies of water pipeline projects

Authors	Year of study	Project/ Area of study	Total respondents	No. of farm respondents[1]
Pegler, Moore and Bentley	2001	Bore-Drain Replacement Project, South West Qld	31	31
CIE	2003	Great Artesian Basin Initiative, Qld, NSW, SA	40	40
WIDCORP	2006	NMP Project, North West VIC	54	44
SMEC	1999	NMP Project, North West VIC	14	14
WIDCORP	2006	WMP Project, West VIC	630	189

[1] *Farm respondents* refers to landholders (CIE; Pegler, et al.), farmers (WIDCORP, 2006b) or those “who personally worked or had family members working in farming or primary production industries” (WIDCORP, 2006a, p. 29).

both community and farmer's perceptions of a change in delivery of water from a channel to piped system in relation to social, environmental and economic impacts on their lives, livelihoods and farming practices. Table 3 provides a brief profile of these studies. Whilst it is recognised that other studies possibly exist, this is the only literature available from a desk-based review.

Bringing together this information will provide an initial base for other literature to be added as these approaches to water management become the subject of more research. Three aspects of these three pipeline projects have been identified in the literature: impact evaluation studies; their public and on-farm benefits; and how farmers have adapted to installation of on-farm water piping systems, in terms of personal and on-farm adjustments.

The following sub-sections summarises the identified opportunities of piping projects in terms of public and on-farm benefits.

4.1 Public benefits

The public benefits from bore drain and channel/dam replacement are outlined in Table 4. In general public benefits ranged from "economic and ecological impacts to social change" (Pegler et al. 2001).

Table 4 Public benefits from conversion to piped water systems

Public benefits	Explanation
Improved water quality and security	Hindmarsh residents believed this benefit would be a major strength of the WMP for towns and farms in the region (WIDCORP, 2006a). Security of supply and reduced amount of water wasted were perceived as major strengths of the NMP by community respondents (WIDCORP, 2006b).
Value to landscape and ecosystems	Conversion to piped water system has resulted in significant water savings, which contributes to environmental flows to the Wimmera and Glenelg rivers and the subsequent improvement to in-stream quality and habitat of these rivers (SMEC 1999). This benefit was supported by Hindmarsh residents as a major strength, from pre-assessment of WMP (WIDCORP, 2006). Similar ecosystem protection benefits in GAB studies were reported. This included improved quality of waterways due to reduction of bore water flowing into them (Pegler, 2006; Jones, 1995). There are possible environmental costs to bore-drain replacement (CIE, 2006), and channel decommissioning, such as cost to wildlife that use the artificial wetlands (CIE 2006; Starks, 2006; WIDCORP, 2006).
Existence and option value	WIDCORP (2006b) reported that there was limited evidence of attracting new users, business and tourism to the region, as proposed pre-construction. Furthermore WIDCORP (2006a) reported mixed reactions from residents about these possible economic benefits of the pipeline. Studies on bore drain replacement (Pegler et al. 2002; Jones, 2005) found that even if water from GAB is under utilised, people still place a value on the water available for potential future use.
Recreational and aesthetic use	NMP resulted in improvements to local gardens and landscapes, and use for recreational water bodies (SMEC, 1999). However there was community concern over loss of water in dams/channels for recreational activities such as swimming and yabbying and loss of wildlife (WIDCORP, 2006b).
Improvement to regional and social economy	Many respondents (66%) believed NMP had improved the region's economy, particularly those on earlier rather than later stages of project. Positive changes related to increased household income (WIDCORP, 2006b). WIDCORP (2006b) reported that improved community spirit, quality of life and reduced levels of stress and anxiety were considered the main social benefits for the region.

4.2 Farm benefits

Potential farm benefits are outlined in Table 5.

The studies by Pegler (2001), CIE (2003) and WIDCORP (2006b) recorded similar benefits for farmers as a result of conversion to a piped water system. Closure of bore drains and channels, better distribution of water around properties, increased security of supply and better water quality had major implications for on-farm management systems. Previous related studies (Christiansen, 1991; Crisp, Kellaway, Madden, & Batterham, 1994; Jones, 1995; Rose, 1997) that have also evaluated farming benefits of piping of existing uncontrolled bores in the Great Artesian Basin, found similar advantages, in addition to increased the value of landholder's properties (Benson & Chewings, 1980).

Table 5 On-farm benefits from conversion to piped water systems

Private benefits	Explanation
Return on investment	CIE (2003) and Pegler et al (2001) found that with government assistance of up to 80%, the on-farm benefits of piping outweighed the costs to landholders. Benefit cost ratios varied from 0.6 to 12.8. An incentive for encouraging uptake of piping was not part of NMP – however Kinhill (1995) found a benefit cost ratio of 1.4 to 2.5 for Stage 1. Qualitative analysis of benefits of NMP (Stages 1-7) highlighted that overall conversion had been positive (WIDCORP, 2006b). Pegler (2001) reported that landholders believed piping had increased property values.
Reduced management costs	Ongoing costs of piped systems in GAB areas were significantly lower than costs involved with open bores (CIE, 2003). This benefit was recorded as the most significant benefit by Pegler et al. (2001) that identified reduction in total on-farm operating costs of about 90% per annum. SMEC (1999) also note the NMP has reduced farm operating costs, this is possibly due to savings in operation, maintenance and capital expenditure costs on redundant channel systems as proposed by RWC (1991).
Improved water quality and security	As a result of drain breakouts, seepage and evaporation, there was poor water security to GAB and NMP farmers. However, conversion to piped water led to improved security and provision of better water quality for domestic and farm use (stock, fire-fighting, sprays. Pegler et al. (2001) reported that 68% of farmers nominated improved domestic water quality as a benefit.
Decreased land degradation	Bore drains prior to installation were leading to major farm management problems in the GAB region. Landholders identified unreliable water supply, water wastage through evaporation and seepage, excessive land degradation including weeds, severe erosion and salinity problems, pollution of natural water courses and reduced vegetation coverage (CIE, 2003; Jones, 1995; Pegler et al., 2001). Pegler et al. (2001) noted 58% of farmers observed improvements to natural resources following closure of bore drains.
Improved livestock conditions	Pegler et al. (2001) identified that once livestock adjust to new water arrangements, a consistent supply of water is a significant benefit for better livestock management. Similarly, WIDCORP (2006b) reported that security of water supply, in addition to a flexible on-farm water system, were the main reasons for stock improvements. A secure water system enabled retention of stock, particularly during dry conditions, and a flexible system meant troughs could be located at optimal sites to minimise tramping on pasture and walking distances to water, and to maximise use of shade. Most farm respondents (59%) observed improved livestock condition, particularly those (73%) connected to the pipeline for longer (Stages 1-3).
Improved land management and agricultural production	Replacing channels with underground pipelines was a significant benefit reported by all studies (SMEC 1999; WIDCORP, 2006b; Pegler et al., 2001; CIE, 2003) as this increased productivity of reclaimed – such as more efficient mustering and increase in land for cropping – as well as reduced water wastage and improved efficiency of farming practices and equipment. Wimmera Mallee pipeline catchment area respondents view increased agricultural production as an important benefit as a result of the WMP, however expectations vary from low to high (WIDCORP, 2006a).
Improved application of pesticides and sprays	WIDCORP (2006b) found that quality water from pipeline reduced the need to use rainwater for pesticides and herbicides and is a significant benefit. 77.3% of NMP farm respondents noticed improvements in effectiveness of pesticides and spray units as a result of access to improved quality water (WIDCORP, 2006b).
Flexible water supply	With the introduction of a piped system, issues of water availability no longer constrained stock and farm management decisions as tapping points could be located anywhere on the property allowing new land to be serviced and maximising benefits for stock (WIDCORP, 2006b). Most NMP farm respondents (92%) agreed the pipeline had increased the flexibility of supply, and 91% had implemented on-farm water systems. This was the most significant benefit of the NMP, and was a reported benefit of GAB projects (CIE, 2003; Pegler, et al. 2001).

4.3 Adapting to a changed water supply – farmer perspectives

Studies on bore drain replacement (CIE, 2003; Pegler, 2001; WIDCORP, 2006) and piping in the Northern Mallee highlighted the personal adjustments as well as changes to properties of farmers in order to adapt to a new water regime. Table 6 summarises farmers' adaptation to piped water systems. Pegler et al. (2001), CIE (2003), and WIDCORP (2006b) noted that farmers' had experienced improvements in quality of life. In addition, WIDCORP (2006b) found community expressed concern about loss of recreational opportunities in on-farm dams and channels and had ongoing concerns about associated costs of water and water infrastructure. However, findings from WIDCORP (2006b) study also suggest that attitudinal changes occur over longer time horizons. Respondents on earlier stages (1-3) were generally more positive about changes than those on latter stages (4-7).

Findings from WMP pre-assessment (WIDCORP, 2006a) correlate with actual changes to farming recorded in the Northern Mallee study (WIDCORP, 200b) as a result of conversion to piped water. Farm respondents from Hindmarsh survey (WIDCORP, 2006a) identified that overall their expectations of the pipeline related to specific on-farm improvements rather than longer-term business developments. In particular, they rated specific farm benefits such as a flexible water supply and increased agricultural opportunities of high importance, whereas developing new businesses were rated as low (WIDCORP, 2006a).

Table 6 Farmer adaptation to piped water systems

Aspects	Explanation
Attitude change over time	In relation to benefits of piping, Northern Mallee community perceptions varied over short to longer time horizon, from somewhat sceptical to very positive (WIDCORP, 2006b).
Quality of life	GAB (CIE, 2003; Pegler et al., 2001) and WIDCORP (2006b) studies reported similar improvements to quality of life for farm families as a result of advantages of piped water systems. Social benefits reported by CIE, (2003) and Pegler et al. (2001) include better quality domestic water supply, reduced mental stress by being able to manage properties better, and the ability to leave the property for short periods of time. WIDCORP (2006b) reported that most farmers had a more positive outlook towards their future as a farmer, their personal and farm financial security and living on the farm. One of the major social disadvantages expressed by many respondents in Northern Mallee (71.4%) was changes to on-farm recreation water use, particularly loss of swimming and yabbying in channels/dams. This was more significant for respondents on later rather than earlier stages of the pipeline, and again relates to attitudinal changes over time (WIDCORP, 2006b).
Ongoing concerns	The cost of water and infrastructure costs in accessing water from the pipeline were major concerns for residents prior to construction of NMP and WMP (WIDCORP, 2006a; WIDCORP, 2006b). Similar concerns conveyed in WIDCORP (2000b) study post-construction of NMP t, in 37% of open-ended responses, and by 51% of survey respondents who agreed the pipeline had led to excessive water costs.
Changes to on-farm management	SMEC (1999) as well as Pegler et al. (2001) identified that farmers experienced time savings as a results of bore drain and channel closures and installation of piping. Pegler et al. (2001) reported that time saved by landholders was directed towards more general property management, and also fencing and reduced off-farm labour requirements. WIDCORP (2006b) reported that piping made farmers implement some changes to current broad-acre farming practices related to updating on-farm water systems and reclaiming land for cropping from filled in channels. However the uptake and development of alternative farming enterprises has been limited. (Refer Appendix A for more detail)

5 Conclusion

This review has highlighted the similar objectives and benefits of pipeline projects to the Wimmera Mallee Pipeline, based on water recovery and water efficiency - though the scale of these projects is smaller, and locations are limited within Australia. Whilst these projects exist, there is a dearth of published or accessible data of actual socio-economic impact evaluations, after installation of new piping water distribution networks. Upon contacting water authorities to identify possible impact studies, whilst some data may exist, it is not organised in a way which is accessible. The sum of all these factors means it is difficult to build up a knowledge base of the ways parallel regions have adopted to and maximised opportunities from new water piping infrastructure developments.

One of conditions necessary for uptake of innovations by farmers is trialling the innovation (Pannell, 1999), or at the very least having evidence of the perceived effectiveness of similar innovations in other regions (Miller, 2004). However, there is a clear lack of dependable social and economic data on pipelines, and other areas of water management. Pannell sees that “neglect of economic and social issues” as a primary cause of low uptake of innovation.[5] Furthermore, unless information is accessible to the public arena we are not optimising our learning. This literature review begins to build an evidence base that demonstrates the benefits, limitations and adjustments for farmers and the public of major water pipeline infrastructure projects.

The availability of research literature related to socio-economic impacts in the context of major water infrastructure improvements, is limited to research led by WIDCORP on Northern Mallee (WIDCORP, 2006b) and Wimmera Mallee Pipeline (WIDCORP, 2006a), in addition to research on piping in the Great Artesian Basin (CIE, 2003; Pegler et al., 2001).

Therefore the DPI and WIDCORP farming styles research will complement and further build upon these previous studies, for the following reasons:

- This research will provide baseline data and a prospective as compared to retrospective insight (as in Northern Mallee survey & Great Artesian Basin piping surveys) into farmer’s attitudes and aspirations of the benefits of a piped water supply.

- Whilst the study examining attitudes and aspirations of residents on the first leg of the WMP (WIDCORP, 2006a) has begun to build a picture of public perceptions before its instalment, this current study will specifically focus on farmer perspectives’ prior to connection of the pipeline on farm properties. This will provide the opportunity to track on-farm changes over time and in conjunction with the water reform process.

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[5] Pannell, D. (no date). Sourced from http://www.crcsalinity.com/pages/program05.asp. Cooperative Research Centre for Plant Based Management of Dryland Salinity, University of Western Australia. Cited in IRRR (2004).

- This research has a significantly larger sample size, than previous social surveys of water pipeline projects(CIE, 2003; Pegler et al., 2001; WIDCORP, 2006a; WIDCORP, 2006b) which will contribute to a more robust dataset for analysis.

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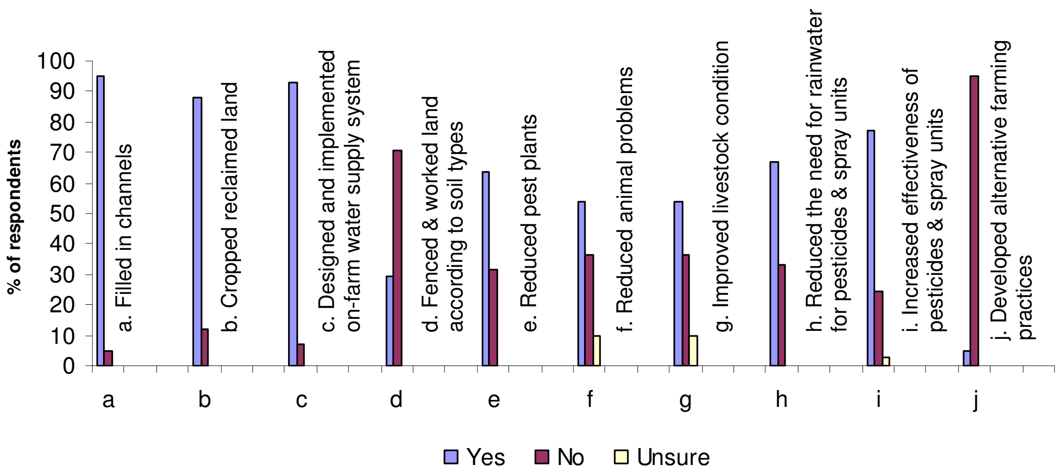
Appendices

Appendix A

Changes on farms, nominated by farmers, as a result of conversion from channels to pipeline in the Northern Mallee



Source: Data was extracted from WIDCORP, 2006b.