FINAL REPORT 2018

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Part 1 - Summary Details

Please use your TAB key to complete Parts 1 & 2.

CRDC Project Number: CSE1802

Project Title: A Sprayable water barrier to line irrigation channels – Scoping study

Project Commencement Date: 1/10/2017

Project Completion Date: 30/11/2018

CRDC Research Program: 1 Farmers

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Date Submitted: ______________________________

Part 3 – Final Report

(The points below are to be used as a guideline when completing your final report.)

Background

1. Outline the background to the project.

Irrigation schemes face ongoing problems with seepage/leakage losses from poorly constructed and/or poorly maintained channels, and especially in earthen channels that are used to distribute and deliver water to individual farms and within individual farms. This results in reduced availability of water for on-farm irrigation and hence unnecessary costs to individual growers and the cotton industry. A high level of seepage/leakage losses can also cause environmental problems, including rising water tables, localised water logging and potential salinisation of the root zone.

Objectives

2. List the project objectives and the extent to which these have been achieved, with reference to the Milestones and Performance indicators.

2.1. Understanding potential losses from water distribution channels

Achieved – See Appendix 1

2.2. Engage with key irrigation schemes and consult with water board authorities, grower organisations and growers to find out what benefits and potential problems occur in using channel liners, and if there is interest in developing and commercialising a sprayable polymer channel liner

Achieved – See Appendix 2

2.3. Carry out a literature review to better understand the various types of liners and other associated products that are currently being used as channel liners to reduce seepage/leakage from water distribution channels

Achieved – See Appendix 3

2.4. Develop a list of companies, distributors and installers who manufacture, distribute and install channel liners and include a series of tables to compare and contrast current products and their strengths and weaknesses

Achieved – See Appendix 3

2.5. Provide an outline of a potential CRDC Project Proposal to develop and commercialise a sprayable channel liner

Achieved – See Appendix 4

Methods

3. Detail the methodology and justify the methodology used. Include any discoveries in methods that may benefit other related research.

3.1. Collecting information about channel liners

The main methodology used to assess availability of a sprayable polymer channel liner was a general web search of the literature pertaining to channels, canals and ditch liners and for polymer, concrete and clay as lining materials.

The only company we found that made a sprayable channel liner was one manufactured by Rhino Linings (https://www.rhinolinings.com.au/blogs/Rhino-Linings-Blog/Solutions-for-Water-Waste-Water-Containment-Problems/).

We also found that shotcrete, which is concrete or mortar conveyed through a hose and pneumatically projected at high velocity onto a surface, was used to protect geomembranes.

3.2. Engaging with irrigation schemes

We used our personal contacts and contacts in Irrigation Australia to identify four different but key irrigation schemes across Australia to engage with for this scoping study. Our aim in doing this was to learn from experiences in each of the four irrigation schemes in (i) dealing with seepage/leakage losses from water distribution channels, and (ii) to see if they would be interested in having access to a commercially available sprayable polymer channel liner.

The four irrigation schemes included Harvey Water in the south west corner of Western Australia, the Ord Irrigation Scheme in the north east of Western Australia, the Burdekin Haughton Water Supply Scheme in north Queensland and Murray Irrigation in southern New South Wales.

Results

4. Detail and discuss the results for each objective including the statistical analysis of results.

4.1. General background

Lining of water distribution channels to minimise seepage/leakage losses has been conducted for many years (Lauritzen, 1961). Given that there is interest in a sprayable polymer channel liner it is now important to identify the type of channels that would most benefit from such a product, noting that there is interest in a sprayable polymer channel liner for both large regional and small on-farm water distribution channels and on-farm water storages.

Large regional water distribution channel systems would require a particular type of sprayable polymer to apply to spot repairs (cracks) or limited length repairs once seepage/leaks areas are identified. Whatever product is provided it will be necessary to determine if the cost of repair was economic compared with the amount of water potentially saved and/or yield gained.

Conservation of water is important where this resource is scarce or limited. There are many approaches and products for reducing seepage/leakage from dams and regional, local and on-farm water delivery channels; the question is how to assess the effectiveness of different products. These products invariably also require a long service life, in excess of 10 to 20 years.

Firstly, it is important to identify whether a channel is actually leaking, where the leak is and whether remediation is economically viable (Akbar, 2001, Moavenshahidi, 2013, Pognant et al. 2013).

Types of liners that have been used include exposed liners (PET, PVC, PP, EIA-R, EPDM, HDPE, LDPE, CSPE, PU, Stark and Hynes, 2009), covered liners, re-compacted soil and concrete.

Channel liners fail more frequently compared to dam or reservoir lining failure.

General discussion with growers indicate that a sprayable product that reduces seepage/leakage from on-farm water distribution channels would be useful. They asked whether it would be necessary to apply once only or every year, and this no doubt would depend on the particular sprayable product that is available.

It is not known whether a sprayable product would be effective after wetting and drying, i.e. after the first irrigation cycle, would it be effective for the second, third and following cycles? How persistent would the product be? On-farm channels usually dry out between irrigation cycles depending on the farm layout and which fields were growing cotton that season. Would the whole channel be sprayed, or only those section identified as leaking? This assumes that leaks could be identified prior to the first time the channels were filled with water. Also, would the cost of remediation be worth the effort? This would depend on the amount of water lost being recovered and yield increasing, or potentially a larger area being able to be irrigated when water was available. There needs to be more information about water losses before commenting on this, as it is likely to be seasonally dependent.

If major water distribution channels are being considered the sprayable polymer channel liner would need to be different to that developed for on-farm use in order to accommodate the difference in flow rates through the various distribution channels and height of water in the channels.

Is there any point in competing with current products? Main delivery channels are largely concrete lined or now being replaced with pipelines. On-farm channels tend to be earthen, already in place, and provide flexibility in farm layout.

We have not found that weeds are a major issue, although they are common in farm channels, with growers being encouraged to control and minimise weeds. Weeds tend to grow under water or on banks and are controlled by herbicides. Another issue is weeds floating on the water blocking irrigation infrastructure.

Concrete and geotextiles would seem to be too expensive for on-farm channel lining, especially if only identified leaks were remediated. Also, there would be issues with integration into the current earthen channel network; edge effects could potentially lead to increased scouring resulting in further remediation work.

A sprayable polymer channel liner would need to be resistant to scouring when water flowed through the channel so the thickness would depend on flow rate and head of water in the channel. A thicker polymer would also reduce weed emergence. We also need to think about weed seeds germinating or cotton germinating from bird droppings. This would also vary across farms as large channels are used for moving water around the farm and smaller channels are used for water delivery to specific farm fields. Will the whole network of channels need to be sprayed or only specific areas that a prone to leakages? How much area would need to be sprayed for repair?

Cost will be a critical issue, as the farmer would need to recover the cost of remediation through extra water being available to produce extra yield or water being available for a greater land area.

Prefabricated flexible geomembranes are increasingly being used around the world for irrigation water distribution channels and reservoir liners in place of traditional clay lined or concrete systems.

Clay lined systems typically reduce the amount of seepage/leakage of irrigation water deeper into the soil and at times into the groundwater. Concrete systems are very expensive and subject to cracking and leaks. Using a properly selected geomembrane for a canal or reservoir liner can significantly reduce water loss by helping reduce erosion of embankments and water seepage/leakage. This helps provide valuable water savings and irrigation efficiencies in agricultural and horticultural applications.

Many kilometres of irrigation channels have been built across the country. While many of these irrigation canals are lined with concrete or clay, there are still many channels that are unlined. The methods of lining channels often result in cracking, which causes leaks and extensive water loss. Because water is a precious resource, especially in areas experiencing drought-like conditions, it is important to minimize water losses due to seepage/leakage. Irrigation canal liners made from geomembranes like reinforced polyethylene (RPE) or reinforced polypropylene (RPP) can help prevent water loss and preserve the water supply. However, the performance of different liners need further quantified (Sommerfeldt et al. 1989).

RPE and RPP irrigation canal liners provide a barrier between the water you're trying to transport for irrigation and the walls of the earthen channel. This barrier prevents water from seeping into and through the earthen walls and base of the channels. Seepage/leakage promotes weed growth and erosion, which increase inefficiency in irrigation canals.

Concrete, clay and earthen lined irrigation channels can become damaged from aging and cracking. Geomembrane irrigation channel liners provide a durable passageway between the water and the earthen lined irrigation channels, which helps prevent water loss. Installing a smooth surface like RPE or RPP as irrigation canal liners can reduce the surface area transporting the water, which can result in higher flow rates.

4.2. Understanding potential losses from water distribution channels

Short summary of Appendix 1

Past studies have measured water losses of 3 to 24 mm/day and an instance as high as 50 to 400 mm/day (Akbar, 2001), which are significant losses resulting in a waste of money and a loss in crop production. Seepage/leakage losses can be reduced by lining earthen channels with clay liners, concrete liners, geomembrane and/or other 'plastic' liners. Seepage/leakage is also moderated by siltation of channels, but this can also reduce the volumes of water available and/or delivered to the farmers' fields. Seepage/leakage losses can be different between old and newly constructed channels, with seepage/leakage being less in the older channels. Various methods have been used to identify the locations where seepage/leakage losses occurs and to help quantify losses from water distribution channels. It is important that every effort is made to prevent and at least minimise water losses from water distribution channels and on-farm water storages. See additional details in Appendix 1.

4.3. Engage with key irrigation schemes to consult with Water Authorities, Grower organisations and growers to find out what problems and benefits the use of channel liners may provide, and if there is interest in developing and commercialising a sprayable polymer channel liner

Short summary of Appendix 2

We engaged with water authorities, grower organisations and growers in four different irrigation schemes around the country including Harvey Water in the south west corner of Western Australia, the Ord Irrigation Scheme in the north east of Western Australia, the Burdekin Haughton Water Supply Scheme in north Queensland and Murray Irrigation in southern New South Wales. We learned that all four of these irrigation schemes have some features and interests in common (eg all 4 irrigation schemes have water distribution channels that lose water via seepage/leakage and all 4 schemes want to improve their WUE), and also have different needs and interests (eg Harvey water wants to transition their whole water distribution system from open channels to pipes and they are not particularly interested in getting access to a sprayable polymer channel liner, while the BHWSS would like access to a fit-for-purpose sprayable channel liner). See additional details in Appendix 2.

4.4. Carry out a literature review to better understand the various types of liners and other associated products that are currently being used as channel liners to reduce seepage/leakage from water distribution channels

Short summary of Appendix 3

A literature review has been conducted to determine the extent of liners currently being used. The literature indicates that most activity pertains to construction and repair of major delivery channels for large irrigation schemes utilising concrete and various geomembrane liners with and without protection. The same products were utilised to repair cracks, punctures and tears where necessary with longevity of each system varying from 1 to 20 years. No studies specifically reported on lining or repair of on-farm distribution channels, although studies were undertaken to identify whether on-farm channels were leaking. One problem identified was whether channels were leaking in the first instance and whether the cost of remediation could be justified. See additional details in Appendix 3.

4.5. Develop a list of companies, distributors and installers who manufacture, distribute and install channel liners. Include a series of tables to compare and contrast current channel liner products and their strengths and weaknesses

Short summary of Appendix 3

A list of companies and distributers is provided in Appendix 3. Generally the company/supplier/distributer and installer are one and the same, although there are options for the purchaser to install a liner if the guidelines are followed properly. No mention was made with respect to warranty on longevity of the products. A series of tables provide a summary of PVC and Polyethylene (PE) canal lining case histories; a summary of other canal lining case histories; a summary of Arnold irrigation district geomembrane canal lining systems; a summary of concrete/shotcrete covered geomembrane canal lining systems; a summary of exposed geomembrane canal lining systems; and a summary of soil covered geomembrane canal lining systems. See additional details in appendix 3.

Outcomes

5. Describe how the project's outputs will contribute to the planned outcomes identified in the project application. Describe the planned outcomes achieved to date.

The project outputs may lead to development and commercialisation of a sprayable channel liner to reduce water loss through seepage/leakage from water distribution channels. The challenge is to identify which channels within an irrigation scheme would benefit the most from having access to a sprayable channel liner. The feedback we have obtained through this scoping study indicates that there is strong interest from one irrigation scheme (the BHWSS) in having access to a cost-effective and commercially available fit-for-purpose sprayable channel liner for use on large regional water distribution channels. There is also interest in having access to a sprayable channel liner for use in on-farm distribution channels and on-farm water storages.

6. Please describe any:-

a) technical advances achieved (eg commercially significant developments, patents applied for or granted licenses, etc.);

None

b) other information developed from research (eg discoveries in methodology, equipment design, etc.); and

None

c) required changes to the Intellectual Property register

None

Conclusions

7. Provide an assessment of the likely impact of the results and conclusions of the research project for the cotton industry. What are the take home messages?

The results of this scoping study has confirmed that there is strong interest from one of the four irrigation schemes for a cost-effective commercially available fit-for-purpose sprayable channel liner for use on large regional water distribution channels. There is also interest in other irrigation schemes in having access to a sprayable channel liner for use in small on-farm water distribution channels and on-farm water storages.

If a practical, durable and cost-effective sprayable polymer channel liner was developed and commercialised successfully it would have the potential to increase irrigation water availability substantially and hence improve the cotton industry's water use efficiency and yield potential by minimising seepage/leakage losses from water distribution channels.

Extension Opportunities

8. Detail a plan for the activities or other steps that may be taken:
(a) to further develop or to exploit the project technology.
(b) for the future presentation and dissemination of the project outcomes.
(c) for future research.

a) Establish research and development and commercialisation plans to develop a cost-effective, practical, durable and fit-for-purpose sprayable polymer channel liner
b) Present results of this scoping study at the Cotton Collective
c) Investigate potential future formulations for a sprayable polymer channel liner that is fit-for-purpose in lining water distribution channels and on-farm water storages

9. A. List the publications arising from the research project and/or a publication plan. (NB: Where possible, please provide a copy of any publication/s)

None

B. Have you developed any online resources and what is the website address?

No

Part 4 – Final Report Executive Summary

Provide a one page Summary of your research that is not commercial in confidence, and that can be published on the World Wide Web. Explain the main outcomes of the research and provide contact details for more information. It is important that the Executive Summary highlights concisely the key outputs from the project and, when they are adopted, what this will mean to the cotton industry.

Executive Summary

Irrigation currently uses 70% of all the world's freshwater withdrawals. Given the increasing demands for water from all other sectors of the economy, including the environment, irrigation is going to have to give up some of its water and improve its water use efficiency to produce more product with less water. This means that every litre of water made available to irrigated agriculture needs to be used productively and that any potential 'water losses' need to be prevented or at least minimised. Seepage/leakage losses from water distribution channels are variable but have been measured to be 3 to 24 mm/day and as high as 50 to 400 mm/day. These are significant losses that waste money and reduce crop production, but the water losses can be reduced by lining water distribution channels with clay liners, concrete liners, geomembrane and/or other 'plastic' liners. Various methods are now available to identify the locations where seepage losses occur and to help quantify losses from water distribution channels. We have visited and/or held conversations with water authorities, grower organisations and growers in four different irrigation schemes around the country including Harvey Water in the south west corner of Western Australia, the Ord Irrigation Scheme in the north east of Western Australia, the Burdekin Haughton Water Supply Scheme in north Queensland and Murray Irrigation in southern New South Wales. Our aim in doing this was to learn from experiences in each of the four irrigation schemes in (i) dealing with seepage/leakage losses from water distribution channels, and (ii) to see if water managers would be interested in having access to a commercially available sprayable polymer channel liner to help reduce seepage/leakage. We also carried out a literature search and explored the web to gain an understanding of seepage/leakage losses from water distribution channels and the current channel liner products and their use. The results of this scoping study has confirmed that there is strong interest from one of the four irrigation schemes for a cost-effective commercially available fit-for-purpose sprayable channel liner for use on large regional water distribution channels. There is also interest from some of the other irrigation schemes in having access to a sprayable channel liner for use in small on-farm water distribution channels and on-farm water storages. If a cost-effective, practical, durable and fit-for-purpose sprayable polymer channel liner was developed and commercialised successfully it would have the potential to increase irrigation water availability substantially. Use of a technology like this would improve the cotton industry's water use efficiency and yield potential by minimising seepage/leakage losses from water distribution channels.

Appendix 1: Understanding potential losses from water distribution channels

Irrigation Schemes and water loss from water distribution channels
It is now well understood that about 70 percent of all the world's freshwater withdrawals is used for irrigation (Grafton et al., 2018; See also the USGS Website: https://water.usgs.gov/edu/wuir.html). This is a massive amount of water to be used by a single sector of the economy, and as demand for water from other sectors, including the environment, increase, irrigation will have to find ways to produce more product but with much less water. This means that every litre of water made available to irrigated agriculture needs to be used productively and that any potential 'water losses' need to be prevented or at least minimised.

Once water has been allocated to an irrigation scheme water losses can occur via:

(i) evaporation from storage dams, water distribution channels, and irrigated fields
(ii) seepage and/or deep drainage from water distribution channels, storage dams and irrigated fields
(iii) surface runoff from irrigated fields

Any of the above forms of water loss results in less water within the irrigation scheme for productive use. Seepage losses from water distribution channels must therefore be located and quantified to establish their economic and environmental impacts.

Various methods have been used to help identify losses from water distribution channels and to help identify the locations where seepage losses occur. These include:

1. Water balance methods: This can be achieved using some form of supervisory control and data acquisition (SCADA) system to monitor water flows through the channel network to calculate the 'water balance' (water into and out of the irrigation scheme or water into and out of sub-sections of the irrigation scheme). Water managers then use formulas to partition water losses between 'evaporation' and 'seepage'. The Ord Irrigation Scheme for example have used this method to estimate water losses by evaporation to be roughly 5% and water losses by seepage to be roughly 4% of the total water in the system
2. Electromagnetic surveys using EM31 technology have been used to identify critical sections of the water distribution channel system for quantitative seepage measurements (Khan et al., 2008)
3. Inflow–Outflow methods have also been used to measure total water losses in measured lengths of channels using Flow Tracker to determine overall water losses, including evaporation, leakage and seepage (Khan et al., 2008). The Flow Tracker is an Acoustic Doppler Velocimeter (ADV®) that provides accurate, high-precision water velocity measurements under a wide variety of flow conditions and research settings
4. Use of the Idaho Seepage Meter have been used to measure in-situ seepage rates at selected spots identified as having low electromagnetic conductivity and reflected by inflow–outflow measurements (Khan et al., 2008)
5. EM-38 surveys combined with simple field observations of features associated with seepage, for example, wet soil, plant growth, water visible in the channel, water disappearing from the channel (Pognant et al., 2013)

Seepage from water distribution channels and deep drainage from over irrigation of farmer fields can also cause rising groundwater levels and hence water logging and salinisation of the root zone. Water logging and salinisation will impact negatively on crop growth and reduce yields so every effort must be made to control deep drainage to avoid rising groundwater levels. This is a difficult challenge in irrigated systems as we do need some deep drainage to leach salts from the root zone, but not too much drainage that results in rising groundwater levels.

The challenge is no doubt to identify whether channels are leaking in the first place, and if so, to try and quantify the potential volume of water being lost and to get seepage locations fixed as soon as possible. The 'lost water' needs to be quantified in terms of economic cost for the lost water and/or cost in lost production.

The increasing cost of water and reduced water availability will provide greater incentive to reduce seepage and other losses across all water delivery channels as they deliver water from large dams and/or rivers to on-farm fields. A channel may be leaking at one or more locations, or along a considerable length of the channel, so identification of the location and extent of the seepage is critical as this will affect the urgency and cost of repair.

When irrigation water is ordered by individual growers they might estimate supply losses and losses from on-farm water distribution channels and adjust the amount of water ordered to compensate for these losses. Seepage losses will be higher when on-farm water distribution channels are filled with water for the first irrigation of the season and/or re-wet after the irrigation season has commenced. This occurs because on-farm channels lose water through soil evaporation, and if there are weeds growing in the channels, they transpire causing further drying of the soils. When the channels are first wet a significant amount of water is taken up by the dry soil and it is only when the soil surface is relatively wet that less water enters the soil and more water flows down the channel.

Past studies have measured water losses of 3 to 24 mm/day and an instance as high as 50 to 400 mm/day (Akbar, 2001), which are significant losses resulting in a waste of money and a loss in crop production.

The use of particular liners in different sized water distributions channels may be constrained by the form and integrity of the channel, rate of water flows, potential for seepage losses and the cost of maintenance.

The reduction in seepage losses will minimise rising water tables, minimise water logging and salinisation of the root zone, reduce the amount of water required for irrigation, and increase crop productivity.

In rice growing areas seepage losses have been measured across a range of farms with annual estimates of losses ranging from 11 to 62 ML/year, which equated to 1 to 4 % of the total allocation (Akbar, 2001; Tiwari, 1995; Khan et al., 2008). If similar losses to these were experienced by the cotton industry it would result in considerable reductions in cotton yield.

Seepage losses were also different between old and newly constructed channels, with seepage being less in the older channels (Table 1).

Table 1. Cost, life expectancy and effectiveness of seepage control methods

Control method	**Cost ($/m^2)**	**Lifespan (years)**	**Seepage control (%)**
Clay lining	16	15	60
Bentonite grout	40	15	40
Concrete lining	170	30	95
Key trenching	3	5	50
Geo-membrane	7.5	10	30
Geo-membrane/key trenching	22	10	75
Cement+lime+clay	15	10	75

Conclusions:

Seepage losses can be reduced by lining earthen channels with clay liners, concrete liners, geomembrane and/or other 'plastic' liners. Seepage is also moderated by siltation of channels, but this can also reduce the volumes of water available and/or delivered to the farmers' fields.

Based on our experience in undertaking this study it seems that there are very few to no farmers who use liners in their on-farm water delivery channels. This suggests that there are opportunities for new liner products to fill this gap, particularly sprayable polymer liners that are practical to use, effective in reducing seepage losses and cost effective.

We are aware of at least one sprayable product manufactured by Rhino Linings (see https://www.rhinolinings.com.au/blogs/Rhino-Linings-Blog/Solutions-for-Water-Waste-Water-Containment-Problems/) that has the potential to be used on on-farm water distribution channels. There is however room for more sprayable products to cover the range of water distribution channels from large scale regional channels through to simple small scale on-farm water distribution channels.

References:

Akbar, S. 2001. Measurement of losses from on-farm channels and drains. CRC for Sustainable Rice production. 88 p. https://core.ac.uk/download/pdf/41229400.pdf

Grafton, R.Q. et al. 2018. The paradox of irrigation efficiency - Higher efficiency rarely reduces water consumption. Science 361, 748 (2018) (http://dx.doi.org/10.1126/science.aat9314)

Khan, S. et al. 2008. Hydrologic and economic evaluation of water-saving options in irrigation systems. Irrigation and Drainage 57: 1–14. (https://doi.org/10.1002/ird.336)

Pognant, D. et al. 2013. Using EM to verify the presence of seepage losses in irrigation canals. Procedia Environmental Sciences 19: 836 – 845 (http://dx.doi.org/10.1016/j.proenv.2013.06.093)

Sommerfeldt. T.G. et al. 1989. Performance of Four Canal Linings. Canadian Water Resources Journal, 14:2, 29-36 (http://dx.doi.org/10.4296/cwrj1402029)

Tiwari A. 1995. DWR Technical Rep. No. 95/04. Seepage investigation in the MIA. Department of Water Resources, Murrumbidgee Region.

Contact details for a consultant who carries out EM seepage surveys:

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Appendix 2: Feedback from four irrigation schemes across Australia

To determine how four major irrigation schemes in Australia manage water losses from their systems, in particular seepage losses, we carried out a series of interviews with staff involved in managing the schemes.

1. Burdekin Haughton Water Supply Scheme (BHWSS)

Key Contact:
Travis Richards, SunWater (0447 170 774; Travis.Richards@sunwater.com.au)

Summary of conversations with BHWSS SunWater staff; Travis Richards
The core take home message is:
SunWater (via Travis Richards) is very interested in a sprayable channel liner to underpin their channel maintenance program. He believes that a viable and cost-effective sprayable channel liner will reduce maintenance costs and extend the life of most existing channels, saving SunWater millions of dollars over the next 10 to 20 years. Travis also indicated that he was interested in doing trials if and when a prototype product is ready and that he might consider contributing to costs of developing a sprayable channel liner.

The key points from our conversations are summarised below:

1. Concrete lined channels
    - Includes some asbestos that needs attention
    - Subject to cracks – water seeps through the cracks and gets in behind the wall that can lead to collapse of parts of the channel wall
    - In the Burdekin there is a 2 week shut down for maintenance – This is costly for everyone and work is carried out first on the worst parts of the channels
    - A sprayable product would really help with regular maintenance
    - There are >80 km of concrete lined channels in the Dalbeg, Clare and Millaroo regions
    - Channel structures - A sprayable polymer would be very useful for the concrete parts of the channel structures
    - Travis sees significant potential benefits of using a sprayable polymer to support their channel maintenance

2. Rubber liners
    - Don't work that well as they don't sit well in the channels
    - Difficult to get soil out after it has built up on the base of the channel
    - Need a self-cleaning sprayable polymer liner; need a shiny non-stick surface to keep the silt moving with the water so the silt is flushed from the channels rather than building up in the channels
    - Needs to be frictionless (unlined and concrete lined channels incur significant friction and can result in considerable build-up of sediments

3. Urban channels
    - Have similar problems to the rural channels
    - Silt and aquatic weeds can be a big problem – they accumulate in the channels and slow the flow of water, which results in more deposition of silt (negative feedback)
    - They do use excavators to clean the channels but that is difficult and can cause a lot of damage to the channel liners

- Problems with aquatic weeds worsen as silt builds up on the base of the channel. They do use a liquid herbicide called Magnacide H to destroy submersed aquatic weeds in irrigation systems; it 'blasts' the plant structure apart and pulls all oxygen out of the water. It does have a short half-life and is viewed as an "underwater lawnmower"!

4. There are some 370 km of channels in the BHWSS – includes main and lateral channels
   - It costs $2 million/9 km to build the main channels
   - Rubber liners will give an idea of what price a sprayable liner needs to be to be cost-effective

5. Pipelines – a highly effective way of distributing water
   - Pipelines are used in the lower Burdekin and there is potential to use a sprayable product on the external and internal surfaces to improve longevity, seal cracks at joints, and reduce maintenance costs
   - They use pipes with 150, 450 and 600 mm diameter

6. Drains – There are approximately 370 km of drains in the BHWSS
   - Drains differ from water distribution channels as they move water that leaves the irrigated fields to recycle pits or back into natural streams and/or rivers
   - There is potential for a sprayable polymer liner to line these drains
   - That would help minimise deep drainage and slow groundwater levels from rising

7. Sprayable Channel Liner – a key role
   - Make it part of the maintenance program/costs
   - Work on worst channels first
   - Extend the life of channels
   - Will help smooth out maintenance costs

8. Problems with silt accumulation
   - Silt accumulation on the bottom of the channel is becoming a big problem
   - General maintenance moves the silt from the bottom of the channel to the outside of the channel, and it continues to accumulate
   - Some channels are >15% under capacity because of silt build up from when the system was established in 1987
   - Silt accumulation along the Haughton main channel is particularly bad

9. Development of a Sprayable Channel Liner and Field Trials
   - SunWater (Travis Richards) is keen to be involved in a project on Sprayable Channel Liners in terms of contributing to:
     - discussions regarding required features/performance of a sprayable channel liner
     - running field trials and
     - contributing to costs

10. Other people who might be interested include:
    - Pat Levings (DRNE), who is working on the Lower Burdekin Ground Water Strategy

AN OVERVIEW OF THE BURDEKIN HAUGHTON WATER SUPPLY SCHEME (BHWSS)
http://www.sunwater.com.au/schemes/burdekin-haughton

History
In the early 1950s the Burdekin River Irrigation Area was established on 7,500 hectares at Clare, Millaroo and Dalbeg, on the levee soils of the lower Burdekin floodplain. Water supplies for this limited area came from the Gorge Weir and Blue Valley Weir. In the 1970s this supply was supplemented from Eungella Dam, on the Broken River behind Mackay.

In March 1980, the Queensland Parliament authorised the establishment of the Burdekin River Project - the largest land and water conservation scheme undertaken in Queensland. The project supplies water for the irrigation of new and existing farms in the lower Burdekin River region, and supplements the urban and industrial needs of the twin cities of Townsville and Thuringowa.

The BHWSS
Uses of Water

Irrigation
The Burdekin's warm winters and ample sunlight enable double-cropping of many field crops. Horticultural crops can be produced in winter for southern markets. The traditional "dry" period from April to October also enables programmed farm management for irrigation and harvest of many crops. For cane growers these conditions also produce the highest yield and sugar content in Australia.

The Burdekin's expanding horticultural sector produces a variety of out-of-season winter vegetables and fruit with crops such as capsicums, eggplant, rockmelons, squash, pumpkins, watermelons and sweet corn being grown in the area.

The Burdekin mango industry has been established for a number of years. The fruit is picked from mid-November to early January for the fresh fruit and processing markets. Several central packing sheds operate during this season.

Urban Water Supplies
In 1988 the Townsville/Thuringowa Water Supply Board (NQ Water) completed construction of a pumping station and pipeline from the Haughton Balancing Storage to the headwaters of the Ross River Dam near Townsville.

Water Boards
A significant proportion of the water from the Burdekin Falls Dam is released from Clare Weir and is directed to the North and South Burdekin water boards to supplement groundwater supplies.

Industrial
SunWater has a number of industrial users including quarries and sugar mills.

Major Storage - Burdekin Falls Dam
The Burdekin Falls Dam is one of the largest dams in Queensland. The dam forms Lake Dalrymple, which covers an area of 22,400 hectares and ponds water 50 kilometres up the Burdekin River. The design of the dam has allowed for future increases in storage capacity and for possible future hydro-electric generation.

Construction of the Burdekin Falls Dam commenced in 1984, with 630,000 cubic metres of concrete used for the dam wall from September 1984 to March 1986. Several earth and rockfill saddle dams were also constructed to prevent water held by the dam escaping through the low areas around the lake during flood events.

The left bank saddle dam is 1,150 metres long, and required 960,000 cubic metres of rockfill material. The Mt Graham saddle dam is 3,500 metres long and required 900,000 cubic metres of earth and rockfill material.

Construction of the Burdekin Falls Dam was completed in 1987. It filled following the wet season in 1988.

The Burdekin Falls Dam operates in conjunction with the existing storages of Clare Weir and Gorge Weir on the Burdekin River, and Val Bird and Giru weirs on the Haughton River at Giru.

Pumping stations are located on the Burdekin River, within the Clare Weir storage, to divert water to the Haughton, Elliot and Barratta Main Channels.

Channel/Pipeline System

Burdekin Channel System Channels have been developed on both sides of the Burdekin River and each section is served by major pump stations located on Clare Weir. The pump stations divert water into main channels on each bank of the river and then to customers by a system of distribution channels.

The Tom Fenwick Pump Station services the Haughton and Barratta Main Channels, which provides water to customers between the Burdekin and Haughton rivers. In addition, the Haughton Main Channel supplements the Haughton River and Giru groundwater area.

On the other side of the river, the Elliot Main Channel services the Leichhardt Downs area and has the potential to be extended eastwards towards Bowen.

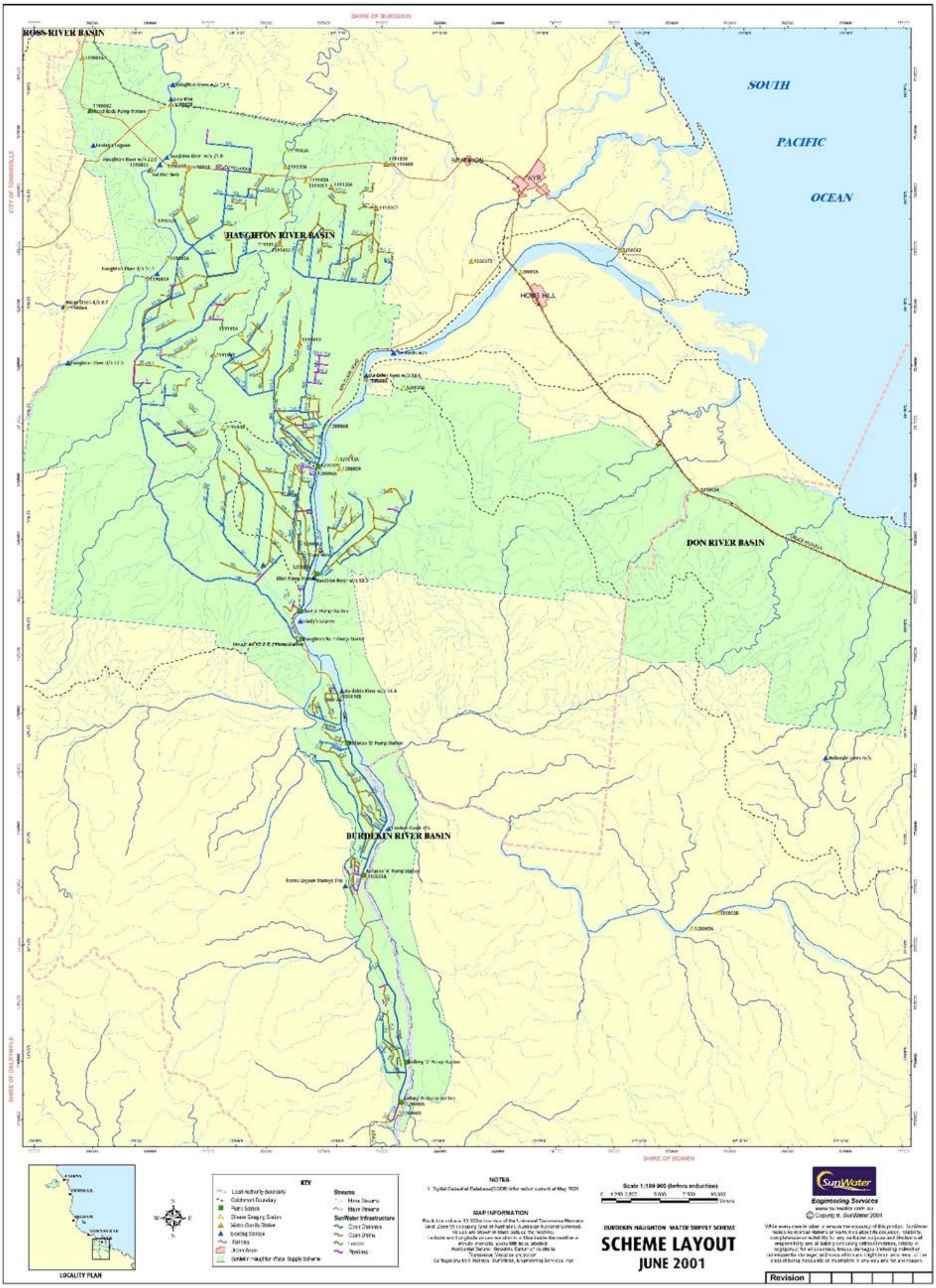


Figure 1: Burdekin Haughton Water Supply Scheme (BHWSS) Irrigation Area

Burdekin Haughton Water Supply Scheme (BHWSS) - Water distribution channels


An unlined earthen water distribution channel


An unlined earthen water distribution channel transporting water


An example of infrastructure associated with unlined earthen water distribution channels

2. HARVEY WATER – WESTERN AUSTRALIA

Key Contacts:

Stephen Cook: Harvey Water, Operations Manager (0427 988 790; scook@harveywater.com.au)
John Ruprecht: Principal, Western Land & Water Consulting (0417 173 826; jruprecht01@gmail.com; https://westernlwc.com.au/). John was previously Director of the Water Resource Management Division, Department of Water, Government of Western Australia

Summary of conversations with Harvey Water staff: Particularly Stephen Cook
The core take home message is:
Harvey Water is not particularly interested in sprayable polymer channel liners as their goal is to transition to a fully piped irrigation system as soon as possible. There were some thoughts that a sprayable polymer liner might be helpful in terms of maintenance of large pipes, as it could be used on the external and internal surfaces to improve longevity, seal cracks at joints, and reduce maintenance costs, but there seems to be less interest in a sprayable liner as time has progressed. Some of the currently remaining Harvey Water earthen channels are lined with concrete but they have not lined any channels with polymer or other plastic products as they are committed to piping the whole system piped.

AN OVERVIEW OF HARVEY WATER:
http://www.harveywater.com.au/

Overview and Corporate Structure:

Harvey Water is a self-funded cooperative which delivers non-potable water to its members and a broad customer base, located 100 km south of Perth, in Western Australia.

Water is sourced from local dams through a licensing agreement with the Department of Water and Environmental Regulation and delivered through gravity flow in a network of channels and pipes to the Harvey, Waroona and Collie River districts. This 112,000 hectare footprint is known as the Harvey Water Irrigation Area (Figure 1).

Water is supplied sustainably and efficiently and delivered to Harvey Water's 720 irrigator members and to more than 350 non-member customers for industrial, mining, construction, hobby farming, garden, fire attenuation and community use.

A unique gravity-fed system provides water under pressure, delivering a more cost effective supply than traditional pumped schemes.

Harvey Water is a dual cooperative which run as separate entities, the South West Irrigation Asset Cooperative (SWIAC) and the South West Irrigation Management Cooperative (SWIMCO).

SWIAC is the custodian of the organisation's assets. It uses its revenues to maintain and develop infrastructure for the benefit of its members and customers.

SWIMCO is the trading entity of Harvey Water. It provides the customer interface and manages the day to day running of the business.

Each cooperative has directors who are members and fellow irrigators. These directors are elected by their peers. The board is also supported by one or more subject matter experts whom bring their expertise to the directorship. Members are encouraged to get involved in the development and success of their company.

Harvey Water maintains a management team which diligently takes care of the interests of the members, customers and ensures we make the best of our financial and natural resources.

Rural Water Services

Rural Water Services is a wholly owned subsidiary of Harvey Water which supplies non-potable water to people living in rural areas for stock and garden use. Customers can be non-shareholders or shareholders of Harvey Water.

Water Supply Network

Harvey Water is licensed to draw 137 GL annually from Waroona, Drakesbrook, Logue Brook, Harvey and Wellington dams as well as the Wokalup Pipe-head. Exploration of additional sources of inflow, including renewable resources is an integral and ongoing part of the business.

Water is piped using gravity pressure through 495 km of closed pipes and 256 km of open channels, supplying water primarily for dairy farming, beef grazing, horticulture and industry.

Water Future

Supplying water to the premium South West growing districts produces significant regional economic benefits, generating $100 million gross value annually from agriculture and horticulture.

Harvey Water's industry-leading approach to water use efficiency, innovative piping projects and ongoing asset development, has allowed it to optimise its water delivery services, helping to facilitate the growth of an important agricultural sector and expand its customer base.

Its capacity to offer a supply of large volumes of non-potable water to customers has enabled Harvey Water to secure contracts to service some of the South West's largest industrial and mining operations.

Flexible commercial models are developed to suit client requirements, including water infrastructure design, construction, maintenance and supply.

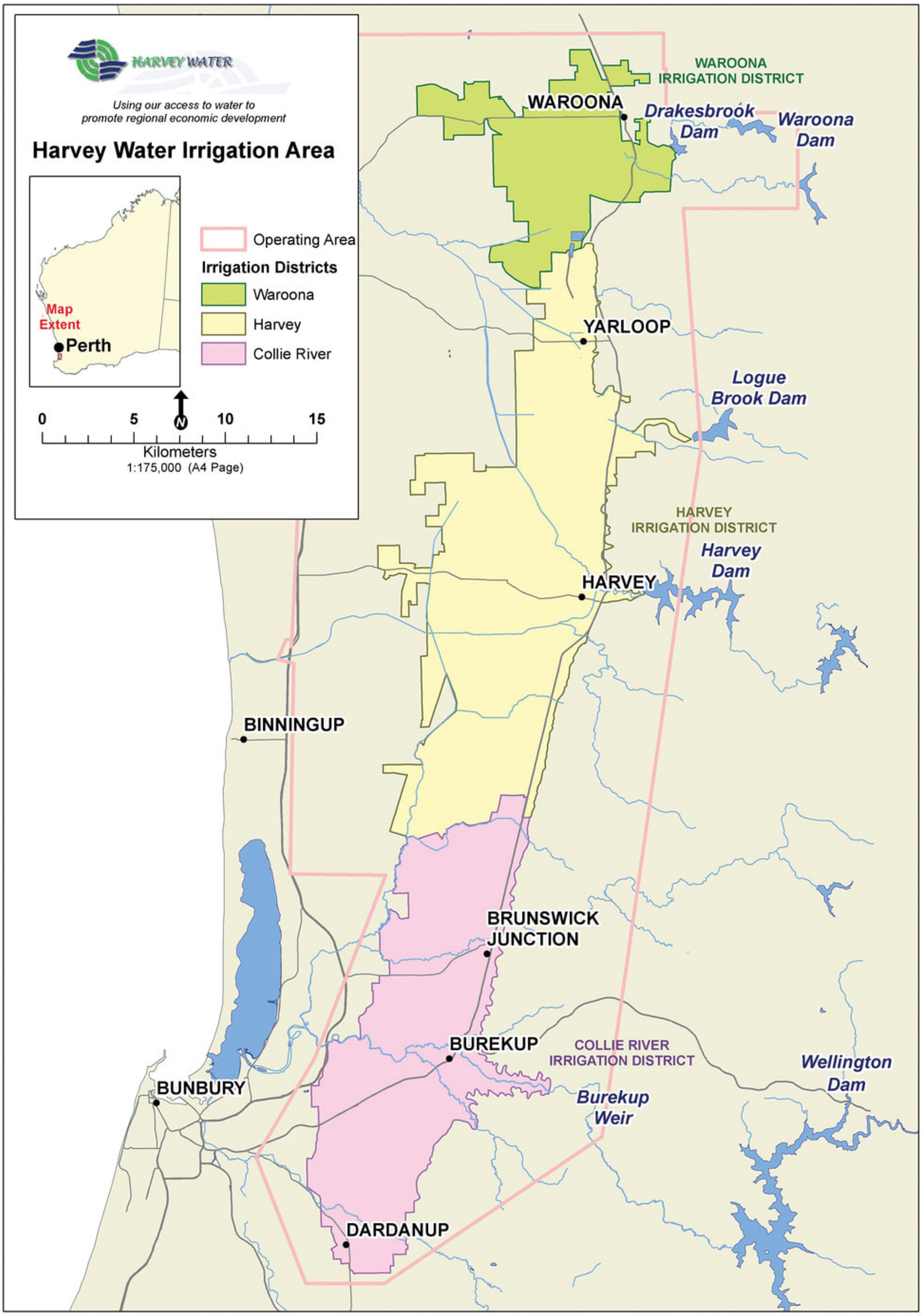


Figure 2: Harvey Water Irrigation Area

3. MURRAY IRRIGATION

Key Contacts:
Michael Pisasale: 03-5898 3341
Nick Warne: 0429 645 317
Adelaide Austin: 0408 448 367

Summary of conversations with Murray Irrigation staff: Particularly Michael Pisasale, Nick Warne and Adelaide Austin. I met with Michael at the IAL Conference in Melbourne and Nick and Adelaide in Finley. I've also talked with them by phone.

The core take home message is:
There is interest in a sprayable channel liner but there were doubts/questions about the durability of a 'sprayable polymer channel liner' and its cost-effectiveness, especially for the big regional water distribution channels. They also see costs associated with having to do additional preparation work on the channels to obtain a good coverage when applying a sprayable channel liner. They also worry about the liner peeling and causing problems downstream (for example, getting caught in and blocking various bits of infrastructure). Other challenges Murray Irrigation face include:

(i) build-up of silt in the channels
(ii) weeds that need to be sprayed using herbicides 2 to 3 times a year. They don't think a polymer channel liner will be able to control weeds better than the herbicides they are already using
(iii) yabby holes
(iv) stock damage to the channels
(v) damage around concrete structures
(vi) cost of channel repairs

Murray Irrigation currently has a large maintenance program that is effective in looking after their water distribution channels and it seems it will take some effort to change current thinking and to explore alternative technologies.

Having said this, Murray Irrigation did say that they thought on-farm water storages (OFWS's) would be a good target for a sprayable liner product. Most of the OFWS's are between 50 and 100 ML in size, and they full and empty each year. This means they would need to be sprayed each year to minimise seepage losses.

MURRAY IRRIGATION – BACKGROUND
https://www.murrayirrigation.com.au/water/services/water-delivery/

Murray Irrigation provides irrigation water to over 2,400 farms owned by 1,700 family farm businesses in southern NSW. Water is supplied through almost 3,000 km of energy efficient, gravity fed, earthen channels to an area of almost 750,000 ha.

Service levels
We provide a seven-day water delivery service to customers. This means that our customers are able to make starts, finishes, increases and reductions to water deliveries on all days including weekends and public holidays.

New infrastructure installed as part of the PIIOP project now allows us to deliver two types of service levels to customers.

1. Remote Control – Standard Level of Service – Two changes per day.

2. Automation – High Level of Service – multiple changes per day.

Customers are being notified of their ability to access these improved levels of service as part of our operationalising and testing. Outlets not upgraded as part of the PIIOP program are now referred to as Manual Outlets and will require a different management regime under automation.

As such the following service level will be provided to Manual Outlets:
One change per day (the change time will likely be different each day)

Water ordering
Customers should ensure that water orders are placed at least four days in advance to guarantee delivery. This means that orders lodged after 6.30am effectively require at least five days' notice.

Examples include:

- A water order lodged at 6.17am (i.e. before 6.30am) on Tuesday to start an outlet will result in the outlet being started four days later on Saturday
- A water order lodged at 2.27pm (i.e. after 6.30am) on Tuesday to start an outlet will result in the outlet being started five days later on Sunday

During channel refilling at the start of the irrigation season, irrigation water may not be available within the normal four-day notice period due to the need to fill empty and/or low sections of channel.

Customers are encouraged to provide as much notice as possible about their requirements in order to limit the risk of our team not being able to deliver water on the day it was ordered.

The requirement for a four day advance order time is due to the fact that it takes four days for water that is released from Hume Dam (upstream of Albury) to arrive at Lake Mulwala where our Mulwala Canal Offtake is located (note: the four-day advance water order requirement also applies to the Wakool Canal Offtake).

Water may be ordered via logging into the water ordering system or using the IVR telephone system.

Restriction of supply
In some circumstances, it may be necessary for us to apply restricted supply rates to customer water orders as a result of operational constraints and/or need such as channel capacity limits.

When we needs to apply restricted supply rates we will do so in accordance with our Distribution Rules Policy (unless otherwise negotiated with customers (e.g. rescheduling)).

Key aspects of these arrangements include:

- The distribution of available water in proportion to flow shares
- The application of flow rate limits (for outlets)
- Landholdings are generally entitled to one flow share, except in cases where subdivisions and amalgamations have been carried out, or a reconfiguration has occurred

System maintenance
Planned maintenance:
Where we are required to conduct planned maintenance to our water distribution system that may cause an interruption of service delivery, we will inform affected customers of the time and duration of any planned service delivery interruption at least seven days in advance.

System faults:
Customers who have concerns regarding the condition of their channels and our ability to meet their irrigation supply requirements are encouraged to contact our Customer Support team on 1300 138 265.

Unplanned maintenance:
Where we are required to conduct any form of unplanned maintenance to our water distribution system, that may cause an interruption of service delivery to customers, we will aim to rectify the situation as soon as reasonably possible to ensure service delivery interruption is minimised.

PIIOP Round 2

A funding agreement between our company and the Australian Government was signed in 2012 for the modernisation of the water delivery system

The PIIOP is an asset renewal project which involves upgrading ageing infrastructure across our entire footprint to benefit our customers by improving our water delivery service. Our focus was on providing our customers with infrastructure that would last into the future and support increased need for efficiency, innovation and resilience.

Project summary
Extensive planning and consultation with customers was undertaken after the funding agreement between our company and the Australian Government was signed in 2012. In 2013, works began to upgrade network regulators and farm outlets with automated and/or remote-controlled technology.

Customers now have improved water efficiency, ordering flexibility and the opportunity for higher on-farm productivity.

The PIIOP Round 2 project received $169.2 million in funding from the Australian Government.

Improving service at Murray Irrigation

PIIOP future focus

Outlet meters
The outlet program involved the upgrade of more than 2,200 farm outlets with modern and efficient Rubicon FlumeGate™ and SlipMeter™ outlets. These outlets offer a greater ability to examine and control water flows. These are across the operational footprint and can be an on-farm outlet or larger outlets that feed to smaller channels. The outlets feature telemetry-enabled systems that allow us to control them remotely. For our farmers and landholders, this means that they can place more water orders per day with less notice, giving them a greater flexibility in their farming practices.

Regulators
The regulator program upgraded concrete infrastructure along the channel system with Rubicon regulators or refurbished existing AWMA regulators. These sites speak to our network of communications towers, known as nodes. This enables us to remotely control them and change water flows and levels throughout the footprint from the office. The regulator program was completed in September 2017 and comprised 1,404 sites.

System reconfigurations
The reconfigurations program kept customers connected to our channel system but altered their supply point and reduced the length of channels.

Reconfiguration project assessments were based on merit and to date:

88 projects have been completed

- 2,012ML in water savings has been achieved (exceeding the target of 1,800ML)
- 144km of footprint has been reduced
- 199 outlets have been decommissioned
- 103 regulators have been decommissioned.

Blighty project
This project brought the High Level of Service option to our farmers. It enabled customer consultation throughout the whole project and sought to prove a number of plans and targets we had as a company.

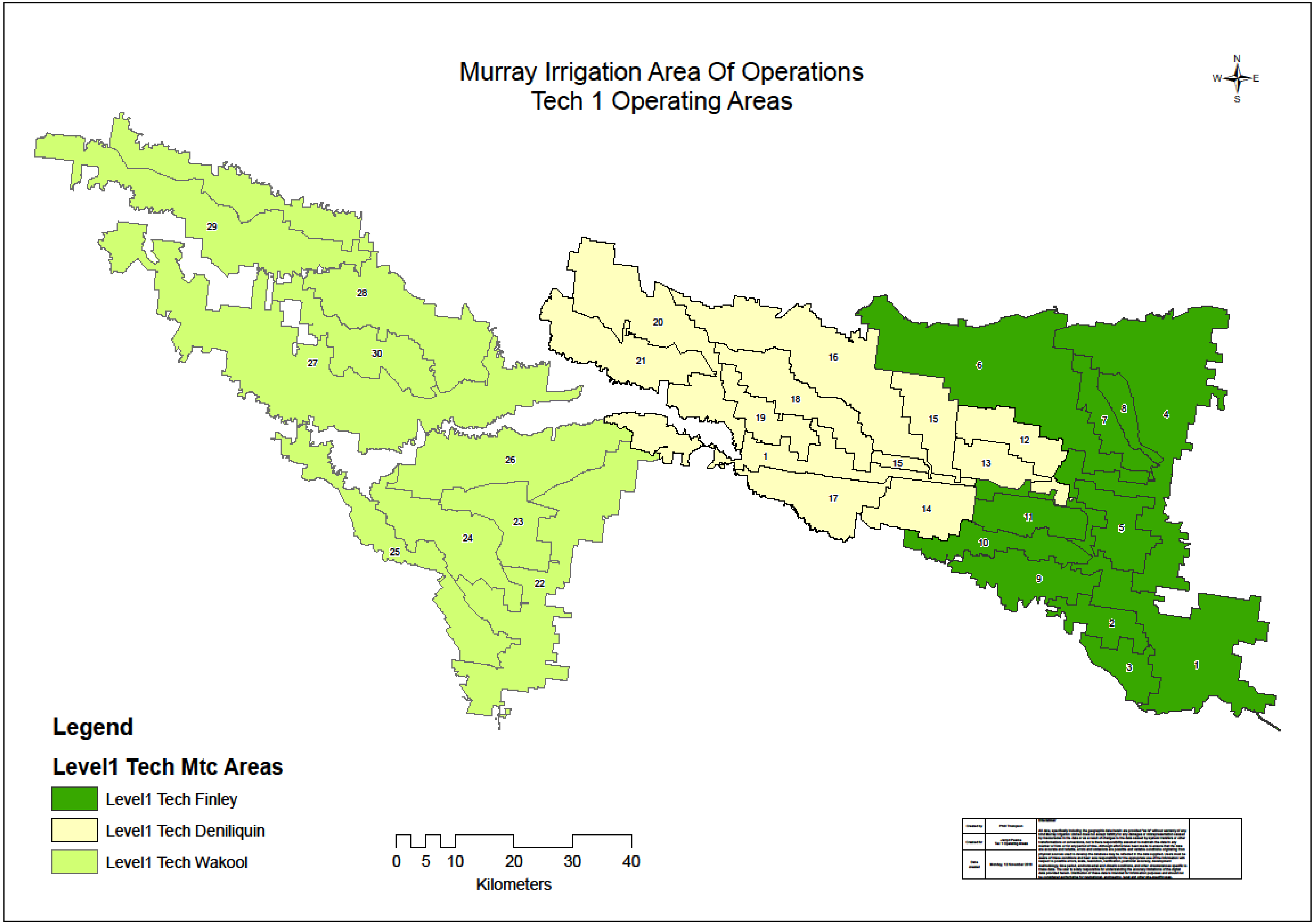
The biggest impact is on improving the customers' on-farm operations. Initially, the aim was to expand HLOS over our footprint, but was readjusted to SLOS as most of our farmers do not need four water order changes per day.

Sub-system retirements
The sub-system retirement project was the strategic voluntary retirement of landholdings from our area of operations by disconnecting them from the system.

Funding is being provided to enable these landholders to convert to dryland farming and to assist with the installation of an alternate stock and domestic water supply.

Under the project, landholders transferred their water entitlements to the Commonwealth and terminated their delivery entitlements and associated shares in our company. In total, 29 of 30 landholdings participated in this project.

The PIIOP project is really about higher flows for us. We wanted to be able to command more water when we're irrigating. We were really happy with the whole process, from consultation to installation it was all pretty smooth, there were no issues at all. We are certainly looking forward to the benefits of remote control.


Murray Irrigation Area Of Operations
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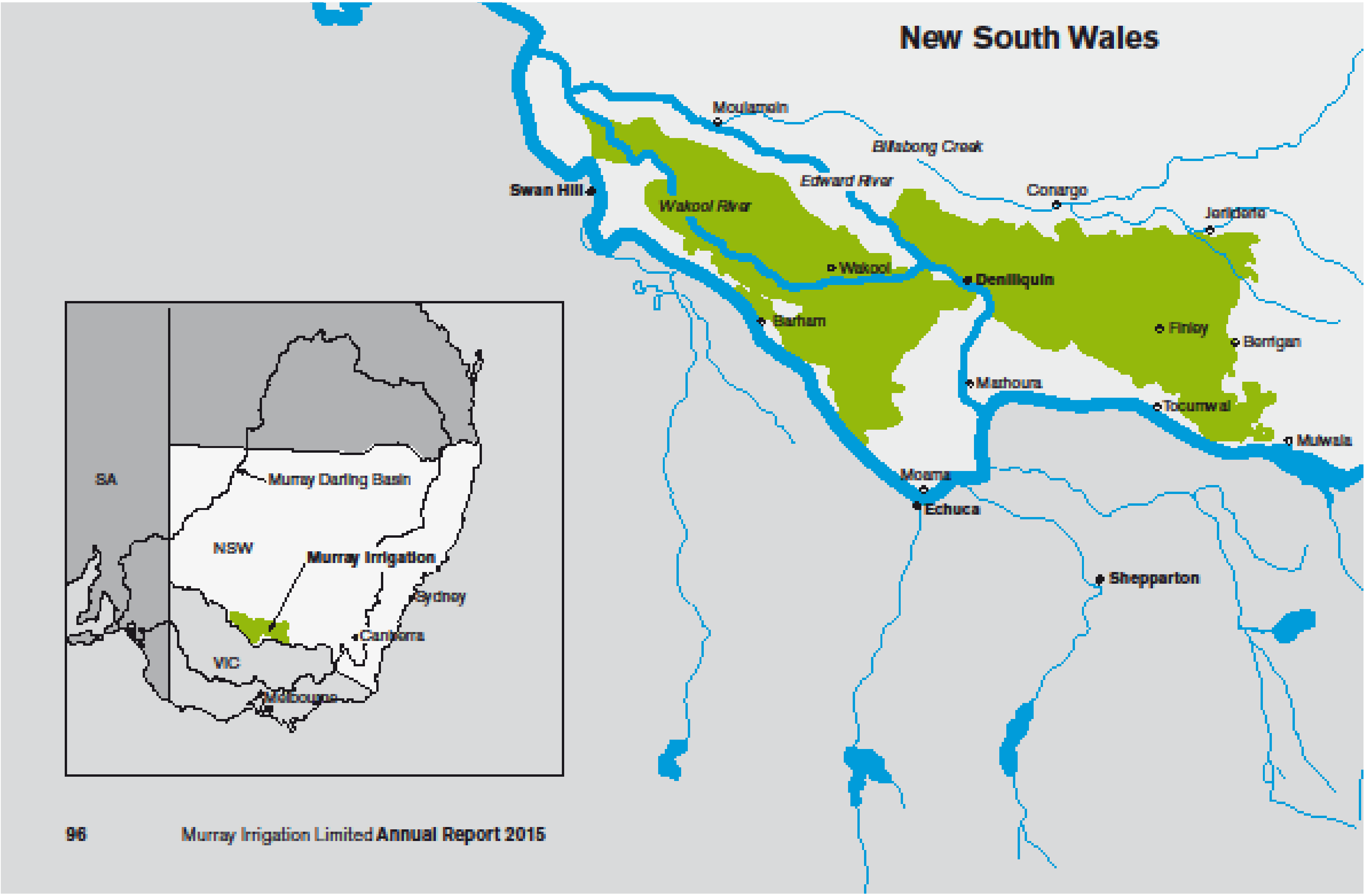
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Billabong Creek
Edward River
Conargo
Jerilderie
Swan Hill
Wakool River
Wakool
Deniliquin
Barham
Finley
Berrigan
Mathoura
Tocumwal
Mulwala
Moama
Echuca
Shepparton
SA
Murray Darling Basin
NSW
Murray Irrigation
Sydney
Canberra
VIC
Melbourne
96
Murray Irrigation Limited Annual Report 2015

Murray Irrigation – Photos of large Regional Water Distribution Channels

Full channel transporting water with a velocity that can be as high as 0.4 to 0.6 m s^{-1} (equivalent to 1.44 km h^{-1} to 2.16 km^{-h})

Draining the channel for repairs and maintenance

An example of different materials used in the channels

Murray Irrigation - On-farm water distribution channels on a farm near Finley, NSW.

Note the growth of weeds in the channel

Piping used to get the water from the channel onto the field

A relatively well maintained water distribution channel that could benefit from a cost-effective sprayable polymer liner to prevent weed growth and reduce seepage losses

Murray Irrigation - On-farm distribution channels on farms around Finley, NSW

An on-farm water distribution channel damaged by animals

An on-farm water distribution channel showing significant vegetative cover and typical infrastructure

An on-farm water distribution channel showing typical infrastructure

Murray Irrigation - Newly made on-farm distribution channels around Finley, NSW

These on-farm water distribution channels shown below could benefit substantially from a sprayable channel liner that is practical to use, reduces weeds, minimises seepage losses and is cost-effective

(1)

(2)

(3)

4. THE ORD IRRIGATION SCHEME

Key Contacts:

Mathew Dear (General Manager); 0408 683 300; ceo@ordirrigation.com.au
John Ruprecht: Principal, Western Land & Water Consulting (0417 173 826; jruprecht01@gmail.com; https://westernlwc.com.au/). John was previously Director of the Water Resource Management Division, Department of Water, Government of Western Australia

Summary of conversations with ORD Irrigation staff: Particularly with Mathew Dear and John Ruprecht

The core take home message is:
There is, as with some of the other irrigation schemes, interest in a sprayable channel liner but doubts/questions about the (i) potential durability and effectiveness of a 'sprayable polymer channel liner', and (ii) strong doubts about the cost-effectiveness of a potential channel liner.

There is currently plenty of water available to Ord Irrigation Cooperative (OIC) who manage the Ord Irrigation Scheme, so water is cheap and there are no economic incentives to really drive adoption of new technologies to improve water use efficiency. This could change though as irrigation expands in the Ord Irrigation Scheme and further irrigation expansion takes place into the Northern Territory.

ORD IRRIGATION COOPERATIVE (OIC) - BACKGROUND

www.ordirrigation.com.au

The Ord Irrigation Cooperative (OIC) was formed in 1996 to operate and manage the business of providing water and drainage services to the farms within Stage I of the Ord River Irrigation Area (ORIA) as part of the transfer of the irrigation assets and business from the State to the growers.

The ORIA project first began back in 1941 with an experimental farm in the region. In 1958 the Kimberley Research Station was established on Ivanhoe Plain, as a joint Commonwealth venture. By 1958 the WA Government was convinced of the viability of an irrigation scheme and the initial development was completed in 1963.

By 1966, 31 farms irrigated from the Diversion Dam had been allocated. Construction of the Ord River Dam, only 99 metres high and only 341 metres long the dam is by no means impressive on a global scale, however its construction resulted in Australia's second largest inland reservoir called Lake Argyle. Its operating storage capacity is 11, 000, 000 megalitres or 204, 719, 140, 000 cubic feet (5, 797, 000, 000 cubic metres) it is said to comparable to 21 times the size of Sydney Harbour.

Of the reliable storage of 11, 000 gigalitres in Lake Argyle, 335 gigalitres are allocated to Stage 1 of the Ord River Irrigation Area.

Water is released from Lake Argyle through the Oral hydro power supply and through controlled releases through the Water Corporations regulating valves at the base of the dam. An additional flow is also released through the Spillway Plug into Spillway Creek to provide dry season flow.

These combined releases comprise the inflow into lake Kununurra which, through the operation of the Kununurra Diversion Dam (built 1962), provides the head required to supply the gravity channel network of the Ivanhoe Plains system and the Packsaddle pumping station.

The Ord Stage 1 area is 15, 150 hectares of agricultural land, which currently has over 300 kilometres of irrigation channels and drains, over 120 regulators, 1200 service meters, and 61 individual customers. Water is gravity fed to farms via a series of earth lined open supply channels, using a range of flow regulator structures.

The Ord Expansion Project is currently investing over $300 million on developing additional agricultural land and supporting infrastructure, including supply channels, drains, and roads. The development will be the most significant addition of agricultural land in Kununurra in over 35 years. The ORIA sees the expansion as a long needed addition to the existing irrigated land, to improve economies of scale within the Region.

Ord River development and irrigated agriculture
https://www.agric.wa.gov.au/assessment-agricultural-expansion/ord-river-development-and-irrigated-agriculture?nopaging=1
(Page last updated: Thursday, 12 July 2018 - 1:46pm)

Tropical agriculture on the Ord River in Western Australia's Kimberley region began in 1941. Fourteen thousand hectares of irrigated farmland started with the opening of the Kununurra Diversion Dam in 1963. Lake Argyle – the largest freshwater storage on mainland Australia – was created in 1971.

We supported tropical agricultural development by assessing land and water suitable for irrigation: 13 400 ha of land in Ord Stage 2, nearly 9000 ha in Ord Stage 3, and about 9000 ha in the Mantinea Development area.

Ord Irrigation Scheme - Lake Argyle

Ord Irrigation Scheme - M2 irrigation channel

Ord Irrigation Scheme – Dethridge Wheel

Ord Irrigation Scheme - Diversion Dam

Development history of the Ord River area

The Durack family made the first attempts at tropical agriculture on the Ord River in 1941 with an experimental farm. 'The Frank Wise Institute of Tropical Agriculture, formerly known as the Kimberley Research Station (KRS) started in 1945 from the original Carlton Reach Research Station, set up by Kimberley Michael Durack with help from his brother William Aiden Durack in 1941, and support from the WA Department of Agriculture and the WA Public Works Department, being the first serious attempt at tropical agriculture on the banks of the Ord River' (**Wikipedia** viewed 21 June 2017).

In 1963, the Kununurra Diversion Dam across the Ord River was built, marking completion of the first stage of the Ord Irrigation Scheme.

This investment also led to the establishment of the town of Kununurra, built as the service centre for the scheme.

Irrigated agriculture development
Some of the developments are:

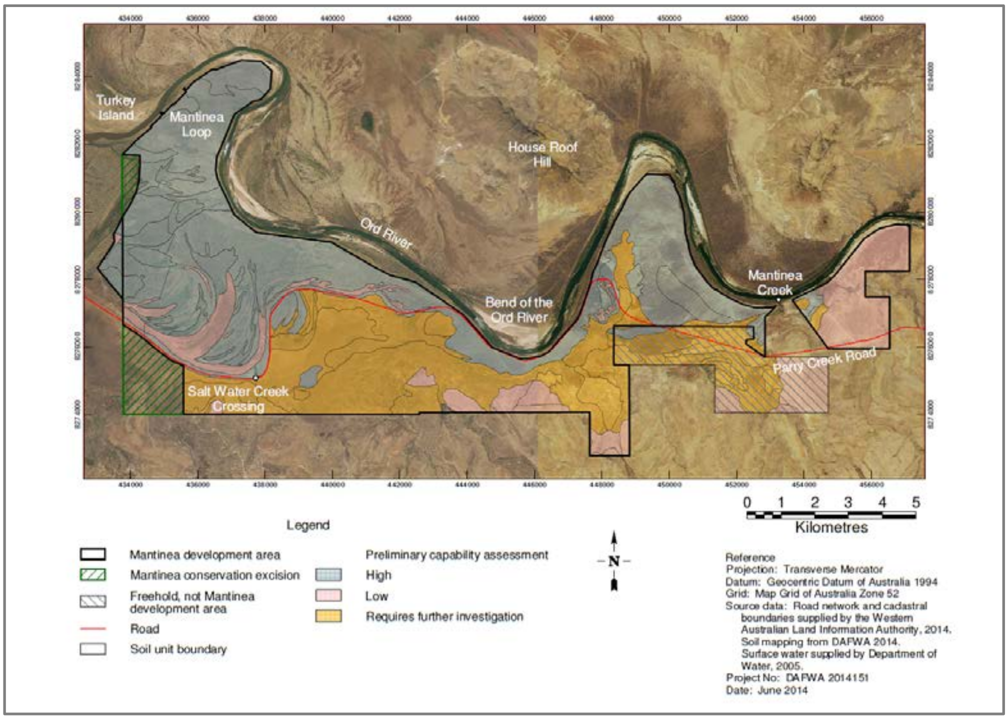
- Lake Argyle was created in 1972 to support irrigation expansion and is the largest freshwater storage on mainland Australia. Its storage capacity is 10,760 million cubic metres or nearly 20 times the water volume of Sydney Harbour. Lake Argyle was formed where the Ord River enters the Carr-Boyd Ranges, 40 kilometres south of Kununurra.

- Ord Stage 1 – 14 000 hectares (ha) of irrigated farm land. Existing irrigated farmland is being used for a variety of agricultural crops including mango, citrus, watermelon, rockmelons, pumpkin, chickpeas, sandalwood and chia.

- **Ord River Irrigation Expansion Stage 2 – Goomig Farmlands**. Following the 2012 release of an additional 7400 ha of Goomig lands for irrigated agriculture, we supported development of the region’s agricultural industries by assessing the land and water resources, farming system research and crop trials.

- **Ord River Irrigation Expansion Stage 3 – Cockatoo Sands**. In 2012, we started soil and water investigations of the Cockatoo Sands (red loamy sands) near the Ord River Irrigation Area, Kununurra. The investigations identified about 6500 ha of Cockatoo Sands and about 2400 ha of Pago Sands on Carlton Hill Station suitable for fodder or perennial crops. The Cockatoo Sands have great potential because they are well-drained and have capacity to support agriculture throughout the wet season. As part of the Water for Food government program, we investigated an additional 30 000 ha of Cockatoo soils north of Kununurra for possible expansion.

- **Ord River Irrigation Expansion: Mantinea Development area**. In 2014, we contributed to the expansion of irrigated agriculture in the Kimberley by providing resource assessment information for 9070 ha of the Mantinea Development area, 30 kilometres north-west of Kununurra.



Mantinea Development area

Appendix 3: Information on current channel liner products

This section includes a list of suppliers of various lining products taken from company/re-seller web sites.

It is difficult to obtain indicative costs for these products as quotes are usually based on individual circumstances and size of remediation projects. We have therefore not included costs for the various products listed and/or discussed.

(1) Plastic and Geomembrane Liners

- HDPE (High Density PolyEthylene)
- LLDP (Linear Low Density Polyethylene)
- PP (Polypropylene)
- RPP (Reinforced Polypropylene)
- PVC (Polyvinyl Chloride)
- CSPE (Hypalon)
- TPO (Thermoplastic Poly Olefin)

Plastic and Geomembrane Advantages: Low Co-efficient of Friction, High Chemical Resistance, Excellent Impact Resistance, Does not absorb water, excellent abrasion resistance, FDA approved for food contact (natural only), light weight, excellent UV resistance. Uses: Water Catchment Areas, Lagoons, Dam Liners, Reservoirs, Irrigation Channel Liners, Canals.

Plastic and Geomembrane Liners Available From:
GeoLine http://geoline.com.au/
FABTECH: https://www.fabtech.com.au/products/agricultural-products/geomembrane-liners

(2) LiningSolutions

20 Bridge Road, Griffith, NSW. 2680
http://liningsolutions.com.au/
Telephone: +61 (02) 7903 7129
Email: info@liningsolutions.com.au

Lining Solutions Specialisation

- Provides technical support to best apply EPDM & take full advantage of its excellent features
- Specialised experience will ensure maximum water savings on your lining project
- Professional technical support, advice & our innovative Quality Assurance system – backed by Firestone's extended product warranty
- Provides Firestone training to installers, engineers, designers and specifiers
- Keeps stock of materials and accessories in regional areas

(3) Canal$^{3®}$ Geocomposite lining

http://www.titanenviro.com/products/geosynthetics/canal3-geocomposite-lining/

Canal$^{3®}$ is a lining solution for irrigation canals and other water containment applications. The top and bottom layers of non-woven material not only provide increased puncture protection, but also increased interface friction. This product is not affected by changing temperatures or frost, which typically cause cracks in concrete lining solution, nor by animals which often cause damage to geomembrane liners. This innovative canal liner can be installed in exposed or buried applications. Shotcrete can also be applied onto Canal³® for additional vandalism and ultraviolet light protection.

It is manufactured using varying weights and types of non-woven materials that are adhered to a polyethylene liner of varying thickness. It is normally supplied in widths of 5.2 m and 7.6 m and roll lengths up to 91.4 m. Special roll sizes can also be produced to minimize waste on large projects.

Advantages: Flexible lining solution offering improved reliability by protective nonwoven layers, no over excavating required for a protective sand bedding, faster installation as you save at least one step compared to other membrane lining solutions: no installation of additional non-woven layers for puncture protection required, inert to biological degradation and naturally encountered chemicals, alkalis, and acids.

Uses: Irrigation Ponds, Canals, Reservoirs and Ditches, agricultural applications, municipal applications, liners & covers, landfill liners, covers, & caps, liquid containment, secondary containment, wastewater lagoon liners, solid waste containment, water & wastewater treatment & containment, industrial applications, environmental containment.

(4) Rhino Linings

Rhino Linings Australasia Pty Ltd
39 Activity Crescent
Molendinar Qld 4214

Local call Australia-wide: 1300 88 77 80
Telephone: +61 7 5585 7000
Email: info@rhinolinings.com.au

https://www.rhinolinings.com.au/blogs/Rhino-Linings-Blog/

https://www.rhinolinings.com.au/blogs/Rhino-Linings-Blog/Solutions-for-Water-Waste-Water-Containment-Problems/

Experiencing Difficulty When it comes to Containing Waste Water?
Inferior sealants and lining alternatives for your water channels require constant and costly monitoring and maintenance. Look beyond those short-term solutions and join thousands of satisfied customers in more than 65 countries that have utilised the innovative products of Rhino Linings Australasia to contain their waste-water and avoid time-consuming and costly spillages.

Rhino Linings Australasia Pty Ltd is a trusted brand, best known as the manufacturer and supplier of spray applied membranes used in road vehicle and marine vessel protection as well as a wide range of industrial applications. However, what you may not be aware of is the cost-effective, long-term containment solutions that we can provide for the water and waste-water industries.

The Coliban Water Authority Case Study

The Coliban Water Authority in Victoria had a problem. Large volumes of precious water were escaping through the old, deteriorated concrete base and earthen irrigation channels in the Bendigo and Ballarat regions. The location of the channels was also proving to be a challenge, as they wound through the delicate National Parks and specialised farmlands of North Eastern Victoria.

With sensitive environmental considerations and difficult terrain preventing vehicular access, it appeared that Coliban would be drawn into a long and costly channel restoration process while absorbing the cost of water draining from the compromised channel system. What a waste of time and money!

Fortunately, Rhino Linings Australasia Pty Ltd had the solution. Our polyurethane spray system was perfect for lining the failed water channels.

Lightweight and durable application equipment meant that the remote location and difficult terrain proved no problem for our product technicians.

With just one application of our remarkable elastomer, the integrity of the channels was restored, effectively preventing further loss of valuable H_2O and increasing the transfer flow rate considerably.

The Coliban Water Authority was so impressed that Rhino Linings has since been their first choice when confronted with other wastewater concerns.

Protect your investments!
Rhino Linings is ideal for protecting your tanks, channels, bunded structures and containment zones. Our innovative polyurethane and polyurea lining systems are chemically resistant, potable water approved and wet area membrane approved. The one coat spray-on application means the process of protecting your investments with a seamless membrane to any thickness is swift and cost-effective, leaving you with more time and capital to direct to other areas of your business.

Rhino Linings Australasia Pty Ltd is a leading international manufacturer and supplier of high-performance elastomeric lining systems, has proven products ready to solve the most challenging and costly water / wastewater containment problems.

Our products are:
- Seamless, impervious spray applied lining
- Designed for long-life under extreme environmental conditions.

- Versatile: Formulations can be sprayed to virtually any substrate including concrete, steel, metals fibreglass, wood and geo-textile surfaces
- Can be sprayed to any desired thickness
- Tack free within minutes of application with modifiable cure times available.
- Efficient: Costly downtime is significantly reduced compared to other lining methods ultimately saving you money

Rhino linings is ready to provide a solution for your business
Rhino spray applied polyurethanes and pure polyureas delivers superior corrosion protection and resistance against adverse chemistries such as fuel, diesel, crude oil, condensates, brine water, hydroxides, solvents, peroxides, salts, lye and various forms of other harsh chemicals.

(5) Water$ave Plug Range

https://www.polymerinnovations.com.au/product/watersave/plug-range/

Water$ave Plug Range is the world's best polymer based earthen dam or water catchment sealant. Whether the leak is in the base, wall, through rock or any soil type Polymer Innovations has the specific Water$ave Plug dam sealant to put an end to your water losses.

The best time to treat your leaking dam with Water$ave Plug is when there is water in the dam, especially after recent rain. While there is water about & your dam is filling, stop those dam leaks before it costs you more money by putting your crops, stock & livelihood at risk.

There are other ways of sealing your dam using such products as bentonite clay, lime or with a lining. Most of these solutions have to be implemented when the dam is built.

Even then due to time or money restrictions these dams are not built as well as they should be where such things as soil conditions, council specifications & seasonal changes are not considered.

When applied at the correct application rate most cases require only one application to permanently seal your dam or pond.

Water$ave Plug & Water$ave Seep is available in 10 kg, 15 kg or 19 kg pails

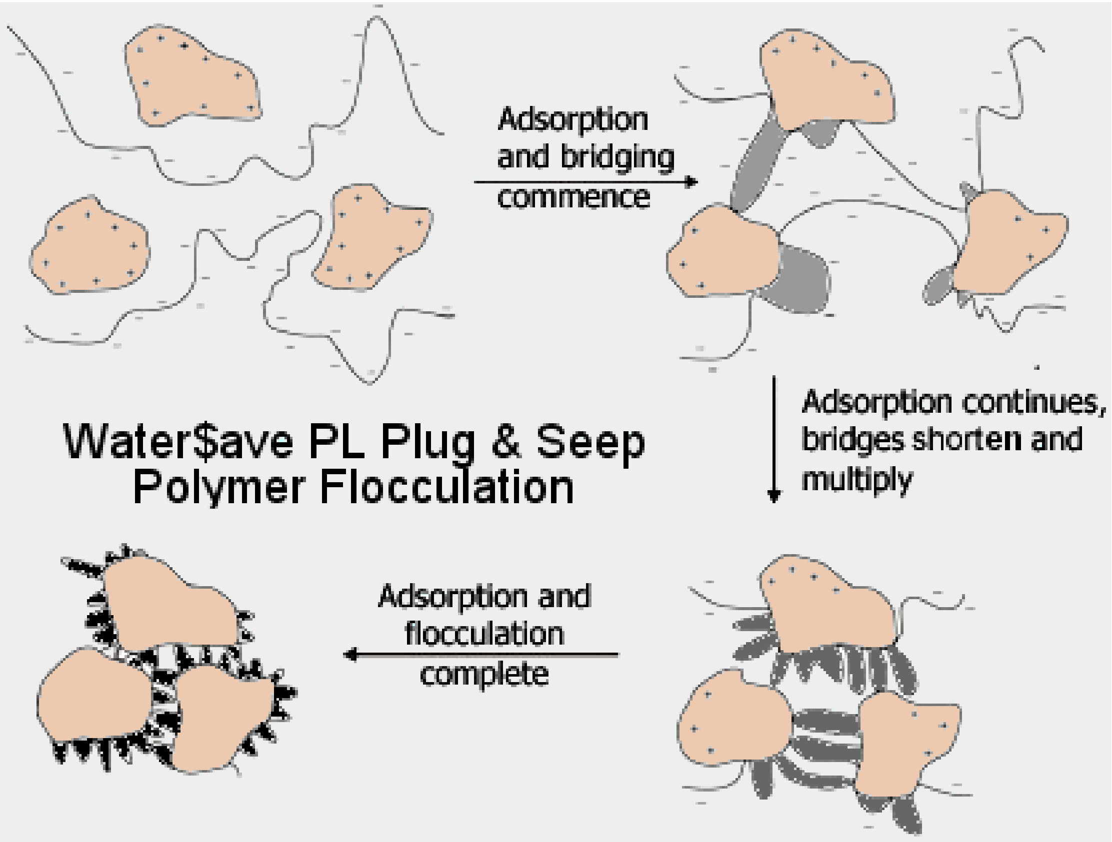
Just sprinkle over the surface of the water. On a quiet day with no wind or rain. Apply at 100gm/m2 for a fast leak or 75gm/m2 for a slow leak. A fast leak is a noticeable reduction over days & weeks. A slow leak is a noticeable reduction over months.

Remove any livestock & dense reeds. They impede the polymers ability to get to the outflows. Allow 12 - 48hrs. To hydrate, expand & sink towards the outflows. Then allow 2 - 10 days. Depending on the rate of leak for the polymers to start incorporating into the soil structures.

Water$ave Plug Range is a blend of lineal & cross linked polymers that are 99% insoluble, non toxic & biodegradable. It will not harm any plants or animals like fish, yabbies, your pets or livestock.
This polymer is known as a Polyacrylamide. Its charge density & molecular weight can be controlled by the ratio of Acrylamide & Potassium Acrylate. This allows us to customise its charge depending on the soil to be bonded. This is known as flocculation, where soil solids are bonded into 'flocs'.
The hydrating polymers expand & create a 'net' that carry the polymers & solids toward the leaks.
This creates a 'plug' & will continue to expand filling holes, cracks & crevices to become part of the

soil structures. Water$ave Plug & Seep locates the leak & seals it! Even if you don't know exactly where the leak is our polymers will locate the outflows.

Water$ave Plug & Seep - How does it work?



(6) Damit™ Dam Sealer

https://www.shalex.com.au/damit-dam-sealer/

DamIt™ Dam Sealer is an advanced, non-toxic, polymer powder which can be used to seal leaking dams and ponds. The polymer is applied to a leaking dam or pond by scattering the powder across the surface of the water. DamIt Dam Sealer is designed with a positive charge which draws it downward through the water toward the bottom of the dam or pond. The water pressure (hydrostatic pressure), which causes the dam or pond to leak, forces the polymer down into cracks and crevices as it sinks to the bottom of the pond or dam. Once activated with water, the polymer will expand in size and bind to other polymer particles to form larger groups of particles, which effectively slows and stops the leak. The polymer will continue to expand over a number of hours and forms a flexible plug that withstands water pressure. The positive charge of the particles will also attract any silt and suspended matter in the water downward to the bottom, which acts to embed the polymer within the soil structure and minimise any disturbance or movement of the polymer that may be caused by future water inflows.

DamIt™ Dam Sealer is insoluble and will form a long term plug in cracks and porous soils. The polymer stays active when wet and can withstand continuous wet/dry cycles to accommodate rising and falling water levels due to seasonal water level variations in the dam or pond. The polymer is totally safe and approved for use with potable water and will not harm humans, fish, aquatic plants or animals. DamIt™ Dam Sealer will eventually break down to form a harmless mix of water and carbon dioxide over time.

DamIt™ Dam Sealer is a rapid, cost effective solution for sealing water leaks and does not require earthmoving equipment or the emptying of dams and ponds; allowing you to save valuable water and keep the dam or pond in use while repairs are undertaken.

DamIt™ Dam Sealer works on a wide range of soil types; from clays to sandy loams and in a wide range of water types; from clear, pure drinking water through to saline water with high levels of suspended clays typically found in rural stock dams. One application is can stop leaks permanently.

DamIt™ Dam Sealer is applied over the surface of the dam/pond at a rate of 1 litre of DamIt™ Dam Sealer powder per 10 square meters (or 107 square feet) of dam. If you have obvious signs of the leak (eg wet walls or water trickling out of ground), or you feel you know the general area causing the leak then DamIt™ Dam Sealer can be applied just to those areas of the dam/pond and a smaller amount of DamIt™ Dam Sealer will be required.

Uses: Farm dams, garden & park ponds, golf courses, levee banks, irrigation channels/ponds, artificial wetlands, storage reservoirs, water features, tailing dams (not for high acid or alkaline tailings), fish ponds & aquaculture.

(7) LIQUID DAMSEAL

http://www.rstsolutions.com.au/products/liquid-damseal

LIQUID DAMSEAL is a blend of high molecular weight polymers that when applied to dry dam walls, seals the surface to stop water seeping into the walls.

LIQUID DAMSEAL is applied to empty dams to reduce or eliminate seepage loss. LIQUID DAMSEAL is applied during dam construction to ensure that leaks won't occur after completion.

Most dams have a certain amount of water loss due to seepage so it is recommended that LIQUID DAMSEAL is applied to all dams exposed surfaces prior to filling with water to prevent leaks and to conserve water.

Benefits; Seals leaking dams to greatly reduce water loss, small quantities required and very easily applied, instant results, environmentally safe, effective in water conservation.

(8) AQUA BEN'S HYDROSORB

http://aquaben.com/resources/
http://aquaben.com/ditch-pond-sealing/

Aqua Ben's Hydrosorb division stops leaks in canals and ponds using our Soilfloc® Sealant

Our low cost method of canal and pond sealing greatly reduces water loss without requiring the excessive capital expense of concrete or plastic liners. Seal the leaks with Soilfloc® Sealant and stop losing water. Soilfloc® Sealant is an Anionic Polyacrylamide polymer, also known as PAM.

Soilfloc® Sealant is the best polymer sealant available for your pond, ditch, canal or lake. If your leak is on the floor, wall or through rock formations -our customizable **Soilfloc®** Sealant will seal the leak in any soil type. No water source is too big or too small, we customize for your specific needs!

Soilfloc® Sealant is a non-toxic, biodegradable custom two part blend of linear and cross-linked polymers for your specific needs. It does not harm plants, fish or livestock.

Soilfloc® Sealant can be applied during construction to prevent leaks or when the pond is actively leaking. Soilfloc® Sealant finds its way into the cracks and crevices, seals the leaks and saves water.

Soilfloc® Sealant is used by recreational pond owners, Metropolitan districts, homeowners associations, agriculture, irrigation districts, cattle ranches, homeowners and many more satisfied customers. Soilfloc® Sealant has sealed leaks in fire ponds, dams, irrigation canals (needs to be 1.2m deep to effectively work), ditches, settling ponds, koi ponds, swimming ponds.

(9) SUMMARY

Most reported studies on channel/canal/ditch lining have been undertaken on large irrigation distribution networks (Haynes, 2011), which pose different issues compared to on farm networks, where the benefit to growers would be greatest.

The loss from large networks are considered to be distribution losses, which result in larger volumes of water to deliver the required amount to growers. The on-farm channel network also results in loss of delivered water, reducing the volume of water available for on-farm irrigation, which could reduce crop yield and/or the area of crop grown.

Since most products in the market are targeted to large delivery channels for use during construction or for localised maintenance and/or repair and the fact that many large channels are being replaced with buried pipes there is little to no information with respect to small scale distribution via on farm channels.

The tables included below are taken from the USA Bureau of Reclamation as they are involved in construction of dams and delivery water channels and the maintenance of these facilities in the western USA. References are listed below the Tables.

The various liners used in the reported studies were mostly effective in reducing the seepage from the channels (ranging from 30 – 100% reduction) and varied in visual condition (poor to good) depending on the time since placement (See Tables 1-6 and Riaz and Sen, 2005). The plastic liners alone had a higher failure rate than those covered with soil and concrete liners. The estimated service life of the various liners varied from 1 to 20 years, which reflected the type and thickness of the lining material.

The specification for a new spray-on polymer liner will depend on the target channel(s). The use in major distribution channels may not be feasible due to the flow and head characteristics of such channels: deep and high flow results in scouring which reduces longevity of liners.

The potential of a spray-on polymer liner will largely be for on farm distribution channel networks, where depth and flow tend to be lower compared to major distribution networks. Also, the product use may be greater in repair of sections of leaking channel(s) as it will be easier to spray a section rather than line the whole section with, for example, geomembranes. Another possible use could be in on-farm storages to reduce water loss from leakage and deep drainage. Different polymer formulations may be needed for the different channels to optimise cost and performance.

Table 2: Summary of PVC and Polyethylene (PE) Canal Lining Case Histories

ID No.	Location/Section	Material	Date Installed	Cost (per m^2)	Seepage (m^3/m^2-day) [Reduction]	Status	Reference
	Arnold Canal Section A-4	Exposed 0.75 mm PVC w/ geotextile UV cover	Mar-92	$11.30	0.012 [96%] in 1998	2002 - Some stiffening and cracking. Some seams above water table are separated.	Swihart and Haynes (2002)
PVC-2	Arnold Canal Section A-7	1.0 mm PVC w/ 3" grout filled mattress	Nov-91	$27.30	0.015 [95%] in 1998	2002 - A few small holes in mattress. Overall excellent	Swihart and Haynes
PVC-3	Helena Valley Canal	0.25 mm PVC w/ sand and gravel cover	1968	N/A	0.015 in 1983	1989 - Very good performance, some damage from animal hooves. 50% loss in plasticizer	Morrison and Comer (1995)
PVC-4	East Bench Canal	0.25 mm PVC w / soil cover	1969	N/A	0.015 in 1974	1984 - Shows stiffening and 40% loss in plasticizer	Morrison and Comer
PVC-5	Bugg Lateral	0.25 mm PVC w/soil cover	1961	N/A	N/A	1980 - Some stiffening and root penetration damage and 40% loss in plasticizer	Morrison and Comer (1995)
PVC-6	Main Canal	0.20 mm PVC w/soil cover	1959	N/A	N/A	1991 - Significant stiffening has occurred. Field reports indicate still providing satisfactory seepage	Morrison and Comer (1995)
PVC-7	Fivemile Lateral	0.25 mm PVC w/soil cover	1978	N/A	0.002 in 1983	1985 - Some small mechanical tears and holes. 12-30% plasticizer	Morrison and Comer
PVC-8	Black Sea Canal Section 1	0.25 mm PVC w/sand and gravel cover	1977	N/A	[60%] in1978	1979 - Some soil sloughing	Timblin et al. (1984)
PVC-9	Black Sea Canal Section 2	0.25 mm PVC w/concrete cover	1977	N/A	[81%] in 1978	1979 - Minor hairline cracking	Timblin et al. (1984)
PVC-10	Black Sea Canal Section 3	0.25 mm PVC w/shotcrete cover	1977	N/A	[70%] in 1978	1979 - Some shrinkage cracking	Timblin et al. (1984)
PVC-11	Coachella Canal	0.75 mm PVC w/ concrete cover	1989	N/A	0.003 [98%] in 1994	1994 - No major problems	Kepler and Comer
PE-1	Arnold Canal Section A-1	0.10 mm PE geocomposite liner w/shotcrete cover	Feb-92	$26.20	0.015 [95%] in 1997	2002 - Some small holes in shotcrete	Swihart and Haynes (2002)
PE-2	Arnold Canal Section A-2	0.75 mm textured VLDPE w/ 540 g/m^2 geotextile	Oct-92	$27.10	0.034 [89%] in 1993	2002 - Only minor cracking found	Swihart and Haynes (2002)

		cushion					
PE-3	Arnold Canal Section A-3	Exposed 2.0 mm textured HDPE	Oct-92	$14.90	0.030 [90%] in 1997	2002 -Moderate stiifening and some small tears.	Swihart and Haynes
PE-4	Arnold Canal Section A-9	Exposed 1.5 mm VLDPE w/ 405 g/m^2 geotextile cushion	Nov-92	$19.30	0.021 [93%] in 1993	1995 - Removed from study due to whales in liner	Swihart and Haynes (2002)
PE-5	Arnold Canal Section A-10	Exposed 1.5 mm HDPE w/ 405 g/m^2 geotextile cushion	Nov-92	$19.30	0.021 [93%] in 1994	1995 - Removed from study due to whales in liner	Swihart and Haynes (2002)
PE-6	Ochoco Main Canal Section O	Exposed 0.75 mm LLDPE	Nov-99	$8.40	0.003 [99%] in 2001	2002 - A few small tears from animal traffic	Swihart and Haynes
PE-7	Buffalo Rapids Section BU-1	Exposed 1.5 mm textured white HDPE w/ 338 g/m^2 Geotextile cushion	Apr-07	$13.60	N/A	2002 - Minimal problems	Swihart and Haynes (2002)
PE-8	South Canal Belle Fourche	0.75 mm VLDE w/ soil cover	Apr-87	N/A	N/A	1992 - No problems	Morrison and Comer
PE-9	Black Sea Canal Section 4	0.25 mm PE w/soil cover	1977	N/A	[30%] in1978	1979 - Some soil sloughing	Timblin et al. (1984)
PE-10	Black Sea Canal Section 5	0.25 mm PE w/concrete cover	1977	N/A	[80%] in 1978	1979 - Minor hairline cracking	Timblin et al. (1984)
PE-11	Toshka Canal	1.5 mm textured HDPE w/ concrete	2003	N/A	N/A	2005 - No problems	Yazdani (2005)

Table 3: Summary of Other Canal Lining Case Histories

ID No.	Location/Section	Material	Date Installed	Cost (per m^2)	Seepage (m^3/m^2-day) [Reduction]	Status	Reference
HYP-1	Arnold Canal Section A-5	Exposed 1.1 mm Hypalon w/ 540 g/m^2 geotextile cushion	Mar-92	$11.90	0.012 [96%] in 1998	2002 - Numerous large L-shaped tears	Swihart and Haynes (2002)
HYP-2	Arnold Canal Section A-6	Exposed 1.1 mm Hypalon w/ 270 g/m^2 geotextile cushion	Mar-92	$11.10	0.012 [96%] in 1999	2002 - Numerous large L-shaped tears	Swihart and Haynes (2002)
SPF-1	North Unit Canal Section NU-1	Spray-applied Polyurethane Foam (SPF) w/ Futura 500/550 Coating	Oct-92	$46.60	N/A	1998 - Half of the foam had washed out. Removed from study	Swihart and Haynes (2002)
SPF-2	North Unit Canal Section NU-2	SPF w/ Geothane 5020 Coating	Oct-92	$42.20	N/A	1998 - Half of the foam had washed out. Removed from study	Swihart and Haynes (2002)
SAG-1	North Unit Canal Section NU-3	Geoxtile w/ Spray-applied Geothane 5020 membrane	Oct-92	$14.90	N/A	Complete failure after first filling	Swihart and Haynes (2002)
SAG-2	North Unit Canal Section NU-4	Geoxtile w/ Spray-applied Geothane 5020 membrane	Oct-92	$19.30	N/A	Complete failure after first filling	Swihart and Haynes (2002)
GCL-1	Ochoco Main Canal Section O-1	Soil Covered Bentomat GCL	Apr-99	$8.83	0.033 [89%] in 2001	2002 - No problems	Swihart and Haynes (2002)
GCL-2	Ochoco Main Canal Section O-2	Exposed Bentomat GCL	Apr-99	$8.18	0.024 [92%] in 2001	2002 - Some crackng above waterline	Swihart and Haynes (2002)

GCL-3	Eberswalde Turnout	Riprap covered GCL	1997	N/A	N/A	2000 - No major problems	von Maubeuge et al. (2000)
EPDM-1	Ochoco Main Canal Section O-3	Exposed 1.1 mm EPDM w/ geotextile cushion on side slopes and soil on invert	Nov-99	$9.15	0.003 [99%] in 2001	2002 - No problems	Swihart and Haynes (2002)
EBG -1	Ochoco Main Canal Section O-5	Exposed 4.0 mm Coletanche NTP 2 ES elasometric bitumen geomembrane	Nov-00	$16.30	0.003 [99%] in 2001	2002 - No problems	Swihart and Haynes (2002)
EBG -2	Lugert-Altus West Canal Section LA-1	Exposed 4.0 mm Teranap elasometric bitumen geomembrane	May-94	$14.70	0.0 [100%] in 2002	2002 - Minor aligator cracking	Swihart and Haynes (2002)
EBG -3	Juniper Flat Main Ditch Section J-1	Exposed 4.0 mm Teranap elasometric bitumen geomembrane	Oct-97	$14.50	N/A	2002 - Minimal alligator cracking, several punctures from cow hooves	Swihart and Haynes (2002)

Table 4: Arnold Irrigation District Geomembrane Canal Lining Systems

ID No.	Thickness	Material	Cost (per m^2)	Seepage Reduction (%)	Rating at Time of Last Inspection	Service Life at Time of Last Inspection
PVC-1	0.75 mm	PVC w/ geotextile UV cover	$11.30	96%	Good	10 yr
PE-1	0.10 mm	PE geocomposite liner w/ shotcrete cover	$26.20	95%	Good	10 yr
PVC-2	1.0 mm	PVC w/ 3" grout filled mattress	$27.30	95%	Good	10 yr
PE-3	2.0 mm	Textured HDPE	$14.90	90%	Good	10 yr
PE-2	0.75 mm	VLDPE w/ 540 g/m geotextile cushion	$27.10	90%	Good	10 yr
HYP-1	1.1 mm	2 Hypalon w/ 540 g/m geotextile cushion	$11.90	96%	Fair	10 yr
HYP-2	1.1 mm	2 Hypalon w/ 270 g/m geotextile cushion	$11.10	96%	Fair	10 yr
PE-4	1.5 mm	2 VLDPE w/ 405 g/m geotextile cushion	$19.30	93%	Poor	3 yr
PE-5	1.5 mm	2 VLDPE w/ 405 g/m geotextile cushion	$19.30	93%	Poor	3 yr

Table 5: Concrete/Shotcrete Covered Geomembrane Canal Lining Systems

ID No.	Thickness	Material	Cost (per m^2)	Seepage Reduction (%)	Geomembrane Rating at Time of Last Inspection	Service Life at Time of Last Inspection
PE-1	0.10 mm	PE geocomposite liner w/ shotcrete cover	$26.20	95%	Good	10 yr
PVC-9	0.25 mm	PVC w/ concrete cover	N/A	81%	Good	1 yr
PVC-10	0.25 mm	PVC w/ shotcrete cover	N/A	70%	Good	1 yr
PE-10	0.25 mm	PE w/ concrete cover	N/A	80%	Good	1 yr
PE-2	0.75 mm	VLDPE w/ 540 g/m2 geotextile cushion	$27.10	90%	Good	10 yr
PVC-11	0.75 mm	PVC w/ concrete cover	N/A	98%	Good	5 yr
PVC-2	1.0 mm	PVC w/ 3" grout filled mattress	$27.30	95%	Good	10 yr
PE-11	1.5 mm	PE w/ concrete cover	N/A	N/A	Good	2 yr

Table 6: Exposed Geomembrane Canal Lining Systems

ID No.	Thickness	Material	Cost (per m^2)	Seepage Reduction (%)	Geomembrane Rating at Time of Last Inspection	Service Life at Time of Last Inspection
PVC-1	0.75 mm	PVC w/ geotextile UV cover	$11.30	96%	Good	10 yr
PE-6	0.75 mm	LLDPE	$8.40	99%	Good	2 yr
HYP-1	1.1 mm	Hypalon w/ 540 g/m2 geotextile cushion	$11.90	96%	Fair	10 yr
HYP-2	1.1 mm	Hypalon w/ 270 g/m2 geotextile cushion	$11.10	96%	Fair	10 yr
EPDM-1	1.1 mm	EPDM w/ geotextile cushion on side slopes	$9.15	99%	Good	3 yr
SPF-1	1.25 mm	SPF w/ Futura 500/550 Coating	$46.60	N/A	Poor	5 yr
SPF-2	1.25 mm	SPF w/ Geothane 5020 Coating	$42.20	N/A	Poor	5 yr
PE-4	1.5 mm	VLDPE w/ 405 g/m2 geotextile cushion	$19.30	93%	Poor	3 yr
PE-5	1.5 mm	HDPE w/ 405 g/m2 geotextile cushion	$19.30	93%	Poor	3 yr
PE-7	1.5 mm	Textured white HDPE w/ 338 g/m^2 Geotextile	$13.60	N/A	Good	1 yr
SAG-1	1.5 mm	Geoxtile w/ Spray-applied Geothane 5020	$14.90	N/A	Poor	1st Filling
SAG-2	1.5 mm	Geoxtile w/ Spray-applied Geothane 5020	$14.30	N/A	Poor	1st Filling
PE-3	2.0 mm	Textured HDPE	$14.90	90%	Good	10 yr
EBG -1	4.0 mm	Coletanche NTP 2 ES elasometric bitumen	$16.30	99%	Good	2 yr
EBG -2	4.0 mm	Teranap elasometric bitumen geomembrane	$14.70	100%	Good	8 yr
EBG -3	4.0 mm	Teranap elasometric bitumen geomembrane	$14.50	N/A	Good	5 yr
GCL-2	N/A	Bentomat GCL	$8.18	92%	Good	3 yr

Table 7: Soil Covered Geomembrane Canal Lining Systems

ID No.	Thickness	Material	Cost (per m²)	Seepage Reduction (%)	Geomembrane Rating at Time of Last	Service Life at Time of Last Inspection
PVC-6	0.20 mm	PVC	N/A	N/A	Fair	21 yr
PVC-4	0.25 mm	PVC	N/A	N/A	Good	14 yr
PVC-5	0.25 mm	PVC	N/A	N/A	Fair	19 yr
PVC-8	0.25 mm	PVC	N/A	60%	Good	1 yr
PE-8	0.25 mm	PE	N/A	30%	Good	1 yr
PVC-7	0.25 mm	PVC	N/A	N/A	Good	15 yr
PE-9	0.75 mm	VLDPE	N/A	N/A	Good	15 yr
GCL-1	N/A	Bentomat GCL	$8.83	89%	Good	3 yr
GCL-3	N/A	GCL w/ Riprap cover	N/A	N/A	Good	3 yr

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Appendix 4: Outline of a CRDC Project Proposal to develop a sprayable channel liner

Here we provide a draft outline for development of a full research proposal (3 year project) to develop a degradable/biodegradable sprayable channel liner/s for use in irrigated cotton cropping systems.

The problem:
The loss of water from irrigation water distribution channels via seepage/deep drainage

The Objective:
Develop and initiate commercialisation of a sprayable channel liner/s to minimise water loss from water distribution channels

The Outcome:
A reduction in seepage and/or deep drainage from irrigation channels to maximise delivery of water to irrigated cotton resulting in improved crop yields (increased water use efficiency (WUE)), better profitability (through potential to increase cropping area) and longer-term sustainability

The 3 year project will include the following stages:
(The project team will liaise with CRDC Managers in refining and finalising this project proposal)

(1) Ideate the ideal properties of an on-farm water distribution channel liner

(2) Laboratory scale R&D to develop a number of potential polymer formulations for a sprayable channel liner

(3) Selection and scale up of the most promising polymer formulation (MVP: minimum viable product)

(4) Development of laboratory/glasshouse scale 'soil based channels', applicators and protocols to monitor application, performance, effectiveness and degradability/biodegradability of the preferred sprayable polymer formulation (the MVP)

(5) Undertake a number of short term small scale 'indicative field trials' on actual on-farm water distribution channels (Will assess performance by monitoring the water balance of a short section of the test channel)

(6) Evaluate the performance of the preferred sprayable polymer and discuss what modifications are required to further improve the sprayable polymer formulation

(7) Optimise and further develop formulations and sprayable application technologies

(8) Selection of second generation materials and application technology

(9) Manufacture larger batches of the prototype formulation polymer – Pilot scale-up and carry out an assessment of economic feasibility

(10) Production of prototype delivery equipment (we will work with farmers to assess use of on-farm sprayers and if need be engage a contractor to help with this work)

(11) Undertake larger scale, longer duration field trials to assess application and to monitor effectiveness of the sprayable polymer, interactions with and the effects of environmental variables (eg soil type, pH, salinity, soil water, soil temperature et cetera) on the lifespan and degradation profile of the channel liner system

(12) Using the information gained from (9) a model will be developed to help predict what changes will be required in the polymer formulation and/or delivery system to address the needs of different cotton farming environments

(13) Identification and preliminary engagement with regulators and potential companies to produce the polymer and delivery and monitoring systems

(14) Production and submission of the Final Project Report

This project will build on past investment from CSIRO in work on sprayable degradable and biodegradable polymers; controlled degradable coatings for fertilisers; controlled degradable polymers for biomedical applications, et cetera…

Key activities will deliver:

(1) Knowledge about different types of channels and which channels we target to maximise returns for farmers

(2) A new sprayable polymer formulation

(3) The delivery system to apply the sprayable polymer to the channel surface

(4) Monitoring and modelling degradation/biodegradation of the sprayable polymer

(5) Estimates of loading rates and frequency of application

(6) A commercialisation strategy for the sprayable channel liner/s that will benefit the farmers, CRDC and CSIRO (to be discussed in more detail while developing this project proposal)

(7) Amongst other things….

Potential Project Team Members:

(1) Keith L. Bristow – Project Leader, CSIRO
Irrigated farming systems; hydrology; engagement with farmers, water service providers, agribusinesses et cetera

(2) Raju Adhikari – Polymer Chemist, Biora Pty Ltd
Ex CSIRO; Has worked on sprayable degradable/biodegradable polymers, controlled release fertilisers, degradable coatings,Biomedical degradable polymer spin out company (PolyNovo), polymer systems in market – Aortech – Implantable biomedical polymers

(3) Mike O'Shea – Polymer Chemist, Biora Pty Ltd
Ex CSIRO work on controlled release fertilisers, degradable coatings, PolyActiva – Biomed degradable polymer drug delivery spin out; Renewable chemicals / polymers experience, taking polymer technologies from the Laboratory to Pilot scale to Market. Mike also has considerable industrial experience

For this project we propose a 50:50 investment from CSIRO and CRDC.

Depending on how the project progresses we could consider engaging with others, including CRC-Polymers, Innovation Funding, a Startup Company, the Advanced Manufacturing Growth Centre (https://www.industry.gov.au/strategies-for-the-future/growth-centres) et cetera.

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