Irrigation Futures

of the Goulburn Broken Catchment

Final Report 4 - Handbook of flexible technologies for irrigation infrastructure

State Government Victoria
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Primary Industries

National Program for Sustainable Irrigation

Goulburn Broken Catchment Management Authority

Goulburn-Murray Water

Cooperative Research Centre for Irrigation Futures

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Provides a brief introduction to the project and how the project objectives have been met.

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Provides an overview of the region, drivers for change, scenarios, implications and strategies.

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Irrigation Futures of the Goulburn Broken Catchment

Final Report 4 – Handbook of flexible technologies for irrigation infrastructure

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Contents

FINAL REPORT

Handbook of Flexible Irrigation Technologies

Prepared for

Department of Primary Industries

Ferguson Road
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Contents

Contents

Contents

Contents

Executive Summary

Introduction

URS Australia was commissioned by the Department of Primary Industries (DPI) to prepare a handbook of technologies that are available to provide flexibility in irrigation delivery systems to deal with the varying irrigation demands which may occur in the future. The project follows on from a process of scenario planning which was used by the Department to develop a vision for the future of irrigated agriculture in the Goulburn-Broken Catchment of Northern Victoria.

Flexibility of irrigation delivery infrastructure may be considered as operational or strategic. The main difference between the two types of flexibility is the time scale for which flexibility is designed:

- operational flexibility is at a fine time scale – ie irrigation events in an irrigation season or over a few seasons;
- strategic flexibility seeks to provide for potential long term changes in irrigation needs, ie over a period of ten years or much longer.

The provision of strategic flexibility is the focus of the handbook.

An early step in developing the handbook was to establish an understanding of how and why the demand changes may evolve, the characteristics of the evolution, and the implications they have on irrigation infrastructure, particularly the need for flexibility and the nature of that flexibility. The early sections of this document provide a Framework of Understanding using discussion based on the Irrigation Futures identified for the Shepparton Irrigation Region (SIR) of northern Victoria. Similar futures may also be relevant to other irrigation regions in Australia, and the example for the SIR is offered as a guide for the reader in judging what circumstances may transpire elsewhere.

The document then proceeds to introduce and describe some technologies that may be considered for use in providing flexibility in irrigation distribution systems. The selection of these technologies has been based on the experience of irrigation system managers and designers of the irrigation systems in northern Victoria, and from consultation with similar professionals in irrigation systems in Australia and overseas. An approach for selecting and comparing options to provide flexibility is offered as part of the discussion on selecting technologies for use.

Associated with this work has been the collection of information on what attention Australian and overseas irrigation system designers and managers may have paid to this subject. The findings of that activity are included in the content of this document. Details of the information collection process and its results are presented in the Appendix: "Experience of Other Agencies".

Scenarios

Four scenarios were developed which summarise the external driving forces, the region's response to those driving forces and the regional impacts that follow. The impacts focus on those factors relevant to irrigation infrastructure planning. The four scenarios are identified as:

- *Moving On* – depicts a steadily changing operating environment for the region; a general decrease of 5 - 10% in the area irrigated followed by moderate to significant recoveries of 10 - 50%.

- *New Frontiers* – agricultural production in the region declines over time because of a number of unfavourable conditions, most notably, the rise in synthetic food production; a decrease up to approximately 70% overall.
- *Pendulum* – describes how large shifts in water policy can dramatically change the face of the region; up to 60% decreases followed by 100 – 300% recovery.
- *Drying Up* – highlights the vulnerability of the region to global economic changes and natural disasters such as drought; decreases up to 95% followed by two- to twenty-fold recoveries.

It is emphasised that the scenarios are not predictions of the future, but are intended to represent a range of possible opportunities and challenges that may be faced over the next 30 years.

Channel System Impacts

Considering the following channel system components, the likely impacts on them under the Scenarios are outlined below:

Carriers – the main carriers of significant volumes of water which pass water to a number of other carriers or trunks. They are and will remain part of the backbone of the irrigation distribution system. It is likely that they will also play a key role in supplying additional areas within and, possibly, outside the established irrigation area. The scale of impact of carriers is likely to be least of all of the components.

Trunks – major channels which generally pass water from the carriers to a number of other trunks or pods. They will also remain as key components in the irrigation distribution system. However, there may possibly be greater variation of impacts across a number of trunk channels because of influences such as:

- the likely spatial and temporal variability of the demand changes;
- the possibility of strategic planning establishing core zones of development that would be less vulnerable to the impacts of the scenario changes; and
- the possible provision of a range of different levels of service than are now offered.

Pods – small, stand alone systems generally made up of 6 to 30 customers and have no water pass beyond them. It is anticipated that individual pod channels will be susceptible to relatively more dramatic impacts under the scenario conditions than the other components, and could include the following, alone or in combination:

- the retirement of complete pods;
- the possible resurrection of retired pods;
- consolidation of properties within pods;
- changing agriculture industries;
- changing standard of service requirements.

Executive Summary

The Need for System Flexibility

The impacts of the Future Scenarios and their implications for the irrigation water distribution system heighten awareness of the likely need for flexibility in the system to meet the changes that could occur. In considering what flexibility may be required, the challenge is that we don't know what changes will eventuate, when they will occur, what their duration will be, how extensive they will be, or what demands, either in terms of system capacities or standards of service, they will place on the system. Two aspects of the anticipated flexibility requirement are:

- Changing capacity requirements:
    - the impacts of the scenarios illustrate that although changes may occur which cause a decline in irrigation demand, it may be that this reduced demand remains for a limited period only and is followed by a recovery, either fully or partly. Thus we need to be aware that not only may capacity requirements change as the extent of development changes, the duration of those changes may also vary.
    - Another factor affecting capacity change may be changes in crop distributions. Demands for water have always varied throughout an irrigation season and peak at certain times during the season depending on the particular crops and the relative areas of each. The Irrigation Futures scenarios highlight that the pattern of these crops may change, and that the changes may also be for a relatively short duration.
- Changing Levels of Service
    - As has been identified in developing the Pyramid-Boort Future Management Strategy (RMCG 2006), the single level of service is not likely to be satisfactory in the future to meet the needs of irrigators in the SIR.

Providing System Flexibility

Some approaches for providing flexibility in the components of the irrigation distribution system would include:

Carriers:

- retain and maintain the current channel waterway to facilitate the recovery of channel capacity following a reduction in demand;
- possibly replacing channel structures which reach the end of their serviceable lives by either building in additional capacity allowance or allowing for staged capacity increase in the future;
- allowing them to operate at higher supply levels (less freeboard) than has been the practice;
- constructing supplementary delivery systems to or from them (pump and pipeline systems);
- construction of off-channel storages;
- combinations of these.

Trunks:

The means of providing flexibility in these trunk components would be similar in concept to those of carriers but at a scale corresponding to their size. Some influencing factors on the choice of flexibility technologies will be:

- their proximity to areas outside the irrigation area identified as prime development zones;
- the risk of pods supplied from them being reconfigured or retired;
- the possibility of spur channel rationalisation being implemented;
- any opportunities to supplement supplies to or from adjacent trunk channels.

Pods:

These components are likely to be most affected by the changes that would occur under the irrigation futures scenarios:

- complete abandonment of some pods as properties are consolidated and can be supplied from an alternative source;
- mothballing for later re-instatement to service;
- varying durations of the requirement for service from these components.

The Technologies Available

The following is a list of the technologies identified for providing flexibility in irrigation distribution systems. The list includes an indication of the scale of flexibility each could provide and where they could be used in the distribution system in relation to a carrier, trunk or pod. The list should not be considered to be conclusive or exclusive, but includes technologies reasonably considered at the time of preparing this document as being suitable options for providing flexibility in an irrigation system.

Technology	Likely Use
In– Channel and Off– Channel Storages	Are likely to be most useful in association with either main or trunk distribution systems.
Lay Flat Pipe	Replacement of small spur channels in areas where changes in irrigation practices are likely to occur.
Channel Lining	Carrier and trunk infrastructure where the channels operate continuously at their design flow for long periods of time. Channels serving pods do not operate continuously at the design flow for long periods of time and there is less likelihood a need to increase the channel capacity.
Staged development of Supply Systems	When the development is large and undertaken over an extended time and is more likely to be appropriate for carrier and trunk infrastructure.
Supplementary Supply Works	Carrier and trunk supplies, although it could be used for supply to a pod.
Higher Operating Levels/Improved Channel Control	Carriers and trunks where the main channels operate at the design for longer periods of time and, due to their larger capacity, they have a larger freeboard.

Over Sizing pipeline Systems	Should be designed to supply the total area served by the pipeline that is suitable for irrigation, based on crop types appropriate to the area, using modern irrigation practices and taking into account the area occupied by development and access.
Channel System Reconfiguration	This approach can be applied mainly to pods where there is the potential for large changes in the water entitlement.
Short Life Infrastructure	Pods where there is there is likely to be more uncertainty in the continuation of supply.
Groundwater Injection/Aquifer Recharge	When determined to be more cost effective than other storage techniques and the associated operation, environmental and management risks could be mitigated.
Mothballing Channels	Mothballing of channels would only be used where they have significant remaining life and the soil types are suitable for continued irrigation.

Selecting the Technologies

Guidelines are provided to assistance to designers and system managers in selecting the technology that could be used to provide flexibility in a water delivery system for future demand change at a particular site. The guidelines draw the user to consider:

- the characteristics of the site being considered;
- the technologies available for use;
- the factors to be considered in choosing the technology options for more detailed analysis; and
- an approach for analysing the options available to select the most suitable technology for use.

In selecting the most suitable technology, a formal benefit-cost analysis is suggested to be the appropriate methodology for analysing the benefits and costs for options because of the time it can take for full realisation of the benefits of a change.

In general terms, the benefits and costs flowing from the asset replacement fall into the following categories:

- benefits resulting directly from the proposed change;
- any costs associated with the current operation of the system that would not be incurred if the change were made;
- benefits from the current operation of the system that would be given up under the proposed change; and
- extra costs associated with the change.

These benefits and costs should consider impacts at an appropriate level (authority, regional, state) using appropriate discount rates. The benefits and costs might also be considered in a financial analysis for the individual stakeholders.

Executive Summary

Some of the values, particularly those associated with environmental and social benefits and costs will be difficult to value, and expert advice may need to be sought from natural resource economists. Alternatively, priorities might be determined using economic criteria for quantifiable values and ranking criteria for intangibles within a multicriteria analysis. In the situation where the preferred option on economic grounds is inferior on social or environmental grounds, decision-makers from the Authority need to be able to assess these trade-offs and determine the preferred option. In general, this requires that all aspects are considered in the same units and economists tell us that these units are $.

Priorities should be those that maximise the Net Present Value (NPV) of an option's benefits less costs. Benefits are likely to result from:

- additional agricultural productivity from ability to supply additional land or develop land more intensely;
- improvements in level of service (delivery times, flow rates, delivery pressure)
- water savings;
- savings in operations and maintenance costs; and
- change in water quality.

Costs are likely to include:

- capital costs (on-farm & system); and
- new maintenance and operation costs.

Description of the Technologies

The technologies introduced above are presented in more detail Section 5 of the Handbook. This description includes:

- a description of each technology;
- discussion on their respective advantages and disadvantages;
- some comment on their use in the past. In general these uses have not been specifically to obtain flexibility in the same context as the discussion herein, but the their use in providing such flexibility it is evident from the discussion provided;
- the possible use of the technology specifically aiming to indicate in which component of the distribution system the technology might be best suited;
- some discussion on costs and economics. The discussion is general as in most cases there are many variations, combinations and scales in which a technology can be used;
- some suggested references from which further information and examples may be available on the use of the respective technologies.

Section 1 Introduction

URS Australia was commissioned by the Department of Primary Industries (DPI) to prepare a handbook of technologies that are available to provide flexibility in irrigation delivery systems to deal with the varying irrigation demands which may occur in the future. The project follows on from a process of scenario planning which was used by the Department to develop a vision for the future of irrigated agriculture in the Goulburn-Broken Catchment of Northern Victoria.

The scenario planning process highlighted the need for flexibility in irrigation systems in order to meet the potentially profound and rapid changes in operating environment that are anticipated. In order to prepare for this occurrence, it was proposed that a handbook of flexible irrigation infrastructure be developed which could be used by irrigation system designers and provide guidance to them in understanding of the implications of how future changes might impact on their systems and the technological options available to them.

Flexibility of irrigation delivery infrastructure may be considered as operational or strategic. The main difference between the two types of flexibility is the time scale for which flexibility is designed.

The emphasis of operational flexibility is at a fine time scale – ie irrigation events in an irrigation season or over a few seasons. In this context, a flexible water supply system delivers water with flexibility in frequency, rate and duration under the control of the farmer at the point of application (Merriam et al., 2007; Merriam and Freeman, 2007).

Strategic flexibility seeks to provide for potential long term changes in irrigation needs, ie over a period of ten years or much longer. For example, irrigation demand in parts of a system may change significantly, over a number of years, in terms of the volume of water used, irrigation area, and level of service expected. Flexible irrigation infrastructure systems are designed to be adaptive to such large scale changes in the long term, as well as being efficient in the short term. The provision of strategic flexibility is the focus of this handbook.

An early step in developing the handbook was to establish an understanding of how and why the demand changes may evolve, the characteristics of the evolution, and the implications they have on irrigation infrastructure, particularly the need for flexibility and the nature of that flexibility. The early sections of this document provide an understanding of the need for flexibility using discussion based on the Irrigation Futures identified for the Shepparton Irrigation Region (SIR) of northern Victoria. Similar futures may also be relevant to other irrigation regions in Australia, and the example for the SIR is offered as a guide for the reader in judging what circumstances may transpire elsewhere.

The document then proceeds to introduce and describe some technologies that may be considered for use in providing flexibility in irrigation distribution systems. The selection of these technologies has been based on the experience of irrigation system managers and designers of the irrigation systems in northern Victoria, and from consultation with similar professionals in irrigation systems in Australia and overseas. An approach for selecting and comparing options to provide flexibility is offered as part of the discussion on selecting technologies for use.

Associated with this work has been the collection of information on what attention Australian and overseas irrigation system designers and managers may have paid to this subject. The findings of that activity are included in the content of this document. Details of the information collection process and its results are presented in a separate report: “Experience of Other Agencies”.

Section 2 The Future Scenarios

2.1 The Scenarios

It is critical that irrigation infrastructure planning consider the needs of future irrigated agriculture. However, it is difficult to predict the future as there are many uncertain factors influencing irrigated agriculture. Scenario planning was undertaken as an approach to deal with those uncertainties by considering a plausible range of futures that can be used as planning bases.

Four scenarios were developed which summarise the external driving forces, the region's response to those driving forces and the regional impacts that follow. The impacts focus on those factors relevant to irrigation infrastructure planning. The four scenarios are identified as:

- Moving On – depicts a steadily changing operating environment for the region. The industries in the region evolve successfully in response to international business conditions and moderate climate variability;
- New Frontiers – agricultural production in the region declines over time because of a number of unfavourable conditions, most notably, the rise in synthetic food production;
- Pendulum – describes how large shifts in water policy can dramatically change the face of the region; and
- Drying Up – highlights the vulnerability of the region to global economic changes and natural disasters such as drought.

It is emphasised that the scenarios are not predictions of the future. They are intended to represent a range of possible opportunities and challenges that may be faced over the next 30 years, and to stimulate discussion on the strategic approach to infrastructure planning by considering what the future may hold and how the region can ensure it is robust under a range of possible futures.

2.2 Scenario Drivers

The drivers considered in shaping the scenarios were, in general:

- Water related:
    - Government policy - White Paper, water tariffs, water entitlements;
    - Climatic changes;
    - Water trade; and
    - Other factors such as water demands in Melbourne, resource development in the upper catchment;
- Non water related:
    - General drivers such as the establishment of free trade agreements creating new opportunities, the use of genetically modified organisms, increasing fuel costs, fluctuations in the world economy; and
    - Drivers particular to regional agricultural industries such as horticulture, dairy, livestock, and cropping, and changes in lifestyle and tourism trends.

For each of the four scenarios, the impacts of these drivers on the region in general and on the agricultural industries within it are described in terms of the changes that would occur to the areas irrigated, the requirements for water, production levels, cropping patterns, land use (including farm size changes), social impacts such as employment opportunity changes, agriculture and life style conflicts, and environmental implications.

Details of the scenarios are presented in more detail in *"Perspectives of Irrigation Futures"* available from the Department of Primary Industries.

2.3 Scenario Impacts

2.3.1 Regional Impacts

The regional impacts on the general extent of irrigated agriculture in the Goulburn Broken Catchment, and the associated changes in irrigation water use resulting from the changes driven by these forces are summarised in Table 2-1 for the four scenarios. In developing the scenarios, it was assumed that the changes over each period are relative to the situation at the beginning of that period, not the situation in 2005.

Table 2-1 Summary of Regional Scenario Impacts

Scenario	Period	
	2005 - 2020	**2020 - 2035**
Moving On	• Irrigation area decreases 10% • Water use decreases 8% • Move to more annual crops	• Irrigated area increases 20% • Water use increases 15%
New Frontiers	• Irrigated area decreases 10% • Irrigation water use decreases 10%	• Irrigation area decreases 30% • Irrigation water use decreases 45%
Pendulum	• Irrigated area decreases 30% • Irrigation water use decreases 25%	• Irrigated area increases 70% • Irrigation water use increases 70%
Drying Up	• Irrigation area decreases 80% • Irrigation water use decreases 70%	• Irrigation areas increases 260% • Irrigation water use increase 290%

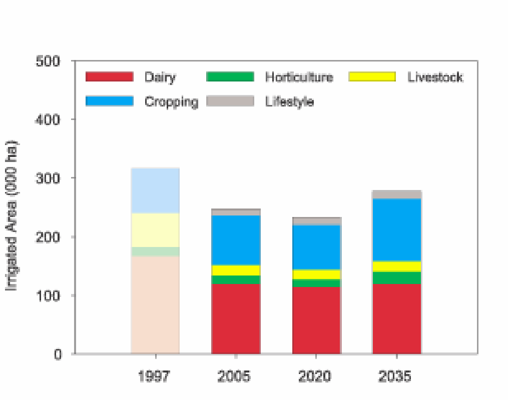
2.3.2 Industry Impacts

Further to the impacts shown on Table 2-1, the scenario planning process also identified impacts on particular agricultural industries within the region:

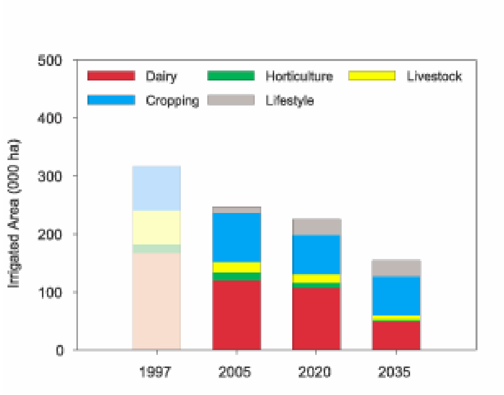
- Dairy;
- Horticulture;
- Livestock;
- Cropping; and
- Lifestyle

The impacts for each of these industries under the four scenarios are illustrated in the following figures.

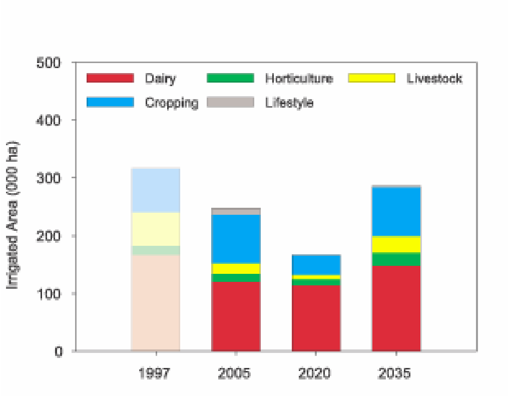
Section 2 The Future Scenarios



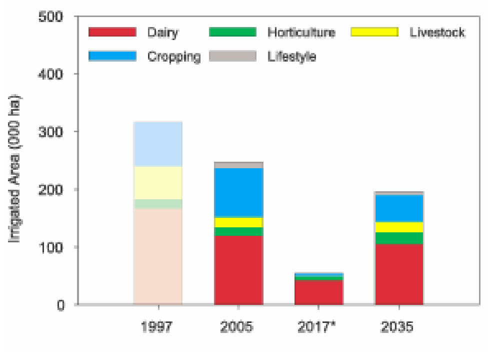
Moving On



New Frontiers



Pendulum



Drying Up

The irrigated area taken into account in the figures above is an estimate of the actual area to which irrigation water is applied rather than the area serviced by the G-MW distribution infrastructure. For 1996/97, this area was approximately 315,000 ha as obtained from irrigated farm census which was found (pers comm. DPI) to concur reasonably well with irrigated area estimates derived from satellite images.

At the time the 'Perspectives of Irrigation Futures" was developed, the irrigated area for 2004/05 was estimated from the water use by each industry in 2004/05, which was the best information available at that time, and the irrigation intensity from 1996/97 for each industry. This gave a total irrigated area of approximately 250,000 ha.

The scale of change on the areas irrigated within the catchment associated with these impacts can be summarised as:

- *moderate change* - Moving On: general decreases of 5 - 10% followed by moderate to significant recoveries of 10 - 50%;
- *significant, long term abandonment* - New Frontiers: up to approximately 70% decrease overall;
- *significant swings* - Pendulum: up to 60% decreases followed by 100 – 300% recovery;

- *dramatic swings* - Drying Up: decreases up to 95% followed by two- to twenty-fold recoveries.

2.3.3 The Context of Scenario Changes

As an example of applying the regional scenario impacts summarised on Table 2-1 to the total areas irrigated within the SIR, the scale of changes would be as shown on Table 2-2.

Table 2-2 SIR Areal Changes Resulting from Scenario Impacts

Scenario	Period					
	2005 - 2020			2020 - 2035		
	Change	Impact		Change	Impact	
			Within SIR			Within SIR
Moving on						
Land Use Area	- 10%	From To	250k ha 225k ha	+ 20%	From To	225k ha 270k ha
New frontiers						
Land Use Area	- 10%	From To	250k ha 225k ha	- 30%	From To	225k ha 158k ha
Pendulum						
Land Use Area	- 30%	From To	250k ha 175k ha	+ 70%	From To	175k ha 298k ha
Drying up						
Land Use Area	- 80%	From To	250kha 50k ha	+ 260%	From To	50k ha 180k ha

2.4 Channel System Impacts

2.4.1 Channel System Components

A notion of looking at a system in terms of discrete components was developed by Goulburn-Murray Water during the development of the “Future Management Strategy – Facilitating the Restructure of the Pyramid-Boort Irrigation Area” (RMCG 2006). The components identified comprise carriers, trunks and pods defined as follows:

- **Carriers** – the main carriers of significant volumes of water (over 2,000 ML/day). Carriers pass water to a number of other carriers or trunks.
- **Trunks** – major channels which generally pass water from the carriers to a number of other trunks or pods (carry between 100 and 2,000 ML/day). Trunks generally serve at least two Pods.
- **Pods** – small, stand alone systems generally made up of 6 to 30 customers and have no water pass beyond them (generally less than 100 ML/day).

2.4.2 Channel System Impacts

Carriers

Carriers are and will remain part of the backbone of the irrigation distribution system. It is likely that they will also play a key role in supplying additional areas within and, possibly, outside the established irrigation area. The scale of impact of carriers is likely to be least of all of the components.

Trunks

Trunk channels will also remain as key components in the irrigation distribution system. However, there may possibly be greater variation of impacts across a number of trunk channels because of influences such as:

- the likely spatial and temporal variability of the demand changes;
- the possibility of strategic planning establishing core zones of development that would be less vulnerable to the impacts of the scenario changes; and
- the possible provision of a range of different levels of service than are now offered.

Pods

Comments similar to that offered for the trunk channels could also apply to pods, but it is anticipated that individual pod channels will be susceptible to relatively more dramatic impacts under the scenario conditions than the other components. The impacts on the scenario changes on pods could include the following, alone or in combination:

- the retirement of complete pods;
- the possible resurrection of retired pods;
- consolidation of properties within pods;
- changing agriculture industries;
- changing standard of service requirements.

Section 3 Providing Flexibility

3.1 The Need for System Flexibility

The impacts of the Future Scenarios developed for the Goulburn-Broken Catchment with their implications for the irrigation water distribution system heightens awareness of the likely need for flexibility in the system to meet the changes that could occur. In considering what flexibility may be required, the challenge is that we don't know what changes will eventuate, when they will occur, what their duration will be, how extensive they will be, or what demands, either in terms of system capacities or standards of service, they will place on the system.

In preparing for this situation, the Handbook of Flexible Irrigation Infrastructure aims to provide irrigation system designers with an understanding of how the changes might impact on the systems, the technologies available to them to deal with this, and some guidelines to applying or developing those technologies to suit future cases as they develop.

3.1.1 Changing Capacity Requirements

The discussion in Section 2 highlights the impacts that future changes might have on components of the distribution system ranging from enhancement of capacities from what they are now in some cases, to retirement in others. However, the impacts of the scenarios illustrate that although changes may occur which cause a decline in irrigation demand, it may be that this reduced demand remains for a limited period only and is followed by a recovery, either fully or partly. Thus we need to be aware that not only may capacity requirements change as the extent of development changes, the duration of those changes may also vary.

Another factor affecting capacity change may be changes in crop distributions. Demands for water have always varied throughout an irrigation season and peak at certain times during the season depending on the particular crops and the relative areas of each. The systems in the SIR support a variety of cultures including pastures, lucerne, cereals, and horticulture. The principal crop has been pasture which in the form of perennial and annual varieties have constituted up to 85% of the irrigated area. The peak demand by farms for water for perennial and annual pastures occurs in January and March respectively. At the peak, perennial pastures require more water per unit area than annual pastures, and delivery rates which have been based on the peak demands for perennial pasture have adequately accommodated the peak demands for most mixtures of pastures and other crops. The Irrigation Futures scenarios highlight that the pattern of these crops may change, and that the changes may also be for a relatively short duration.

3.1.2 Changing Levels of Service

As has been identified in developing the Pyramid-Boort Future Management Strategy (RMCG 2006), the single level of service is not likely to be satisfactory in the future to meet the needs of irrigators in the SIR. Some of the range of services that were identified as possibly being required would have implications for the distribution system:

- water on demand – this will only be available where the system can supply it or it can be added without impacting adversely on other irrigators;
- special services such as a pressurised supply – could be provided to meet a particular demand for an appropriate fee.

A key aspect to offering a range of levels of service apart from having or providing system capacity is having tariff arrangements to support or encourage their uptake by customers. It may be that adoption of levels of service that distribute peak demands over longer periods than now occur would provide more flexibility in the existing infrastructure.

3.2 Providing Flexibility

3.2.1 Carriers

Carriers are expected to continue in their current role to a substantial degree as long as the distribution system remains in place. These large water carriers may see some reduction in capacity need as circumstances change, but a recovery should be considered as a possibility. They are also expected to retain their key role in the distribution system if the area of land irrigated retracts from the extremities of the distribution system towards these carriers.

Some approaches for providing flexibility in the Carriers would include:

- retain and maintain the current channel waterway to facilitate the recovery of channel capacity following a reduction in demand;
- possibly replacing channel structures which reach the end of their serviceable lives by either building in additional capacity allowance or allowing for staged capacity increase in the future;
- allowing them to operate at higher supply levels (less freeboard) than has been the practice;
- constructing supplementary delivery systems to or from them (pump and pipeline systems);
- construction of off-channel storages;
- combinations of these.

3.2.2 Trunks

Trunks are also expected to continue to fill their existing role, although the variation of demands on them might be more pronounced than that on Carriers. This could be particularly experienced in downstream reaches of trunks and where trunks are secondary spur channels supplying pods that are retired from the system.

The means of providing flexibility in these trunk components would be similar in concept to those of carriers but at a scale corresponding to their size. Some influencing factors on the choice of flexibility technologies will be:

- their proximity to areas outside the irrigation area identified as prime development zones;
- the risk of pods supplied from them being reconfigured or retired;
- the possibility of spur channel rationalisation being implemented;
- any opportunities to supplement supplies to or from adjacent trunk channels.

3.2.3 Pods

These components are likely to be most affected by the changes that would occur under the irrigation futures scenarios:

- complete abandonment of some pods as properties are consolidated and can be supplied from an alternative source;
- mothballing for later re-instatement to service;
- varying durations of the requirement for service from these components.

Section 3 Providing Flexibility

The means of providing flexibility in pod components include:

- mothballing channels;
- use of short life infrastructure – lay flat pipes;
- portable farm outlets.

Section 4 Selecting the Technologies

4.1 The Guidelines

The following guidelines provide broad assistance to designers and system managers in selecting the technology that could be used to provide flexibility in a water delivery system for future demand change at a particular site. The guidelines draw the user to consider:

- the characteristics of the site being considered;
- the technologies available for use;
- the factors to be considered in choosing the technology options for more detailed analysis; and
- an approach for analysing the options available to select the most suitable technology for use.

4.2 Site Characteristics

These should be identified and sufficiently developed to clearly describe the location and nature of the site, and the issues associated with it which define the scale of flexibility required. It is suggested that the following be identified.

The characteristics of the land to be served.

- Where it is located:
    - Locality maps.
    - Aerial photography.
- Its size.
- Current land use.
- Soil types.
- Topography.
- Contour mapping.
- Current land tenure.
- Geomorphology.
- Groundwater conditions.
- Its proximity to water supply sources:
    - Pods.
    - Trunks.
    - Carriers.
    - Natural waterways.

Current service arrangements

- Irrigation water source:
    - Channel.
    - Pipeline.

  - Natural watercourse.
- Level of service available:
  - Supply capacity.
  - Supply frequency.
  - Land commandability.
- Condition of supply assets.
- Current issues:
  - Supply limitations.
  - Asset condition.
  - Remaining life of assets.
  - Environmental.
- On farm works:
  - Watering method.
  - Farm layouts and works.

Anticipated change

- Drivers for change:
  - Changed crop type.
  - Changing crop intensity.
  - Water trading.
  - Changing on-farm management practices.
  - Consolidation of properties.
  - Private investment.
  - Water availability.
- Scale of change:
  - Increase/decrease in area.
  - Intensity change.
  - Usage volume.
- Life of change.

Implications of change for supply infrastructure

- Change in supply capacity requirements.
- Change in command requirement.
- Change in location of service point(s).

Flexibility requirement

- Extent of requirement.
  - Change in delivery capacity – range in ML/d.

- Change in command requirement – range in metres of delivery head.
- Change in asset life requirement – years (approximately).

Risks of providing flexibility

- Change to water availability – trade out, supply restriction (drought).
- Change to required life of system.
- Change to infrastructure condition.
- Change to length of irrigation season.

The issue of uncertainty (in terms of what flexibility will actually be required in the future) raises the fundamental issue of who will take the risk of providing that flexibility now, and meet the costs associated with that provision. This is not a simple issue. The assessment of risk, and the costs and benefits involved, has to be made at a project level. It is not possible to provide generalised guidance in this area.

4.3 Technologies Available

The following is a list of the technologies identified for providing flexibility in irrigation distribution systems. The list includes an indication of the scale of flexibility each could provide and where they could be used in the distribution system in relation to a carrier, trunk or pod. The list should not be considered to be conclusive or exclusive, but includes technologies reasonably considered at the time of preparing this document as being suitable options for providing flexibility in an irrigation system. Further details and discussion of the technologies are provided in Section 5.

Technology	Likely Use
In– Channel and Off–Channel Storages	Are likely to be most useful in association with either main or trunk distribution systems.
Lay Flat Pipe	Replacement of small spur channels in areas where changes in irrigation practices are likely to occur.
Channel Lining	Carrier and trunk infrastructure where the channels operate continuously at their design flow for long periods of time. Channels serving pods do not operate continuously at the design flow for long periods of time and there is less likelihood a need to increase the channel capacity.
Staged development of Supply Systems	When the development is large and undertaken over an extended time and is more likely to be appropriate for carrier and trunk infrastructure.
Supplementary Supply Works	Carrier and trunk supplies, although it could be used for supply to a pod.
Waterway Enlargement	Waterway enlargement is an alternative method of increasing the capacity of a supply system to improved hydraulic efficiency and supplementary supply. It is therefore likely to be used for carrier and trunk channels.
Higher Operating Levels/Improved Channel	Carriers and trunks where the main channels operate at the design for longer periods of time and, due to their larger

Control	capacity, they have a larger freeboard.
Over Sizing pipeline Systems	Should be designed to supply the total area served by the pipeline that is suitable for irrigation, based on crop types appropriate to the area, using modern irrigation practices and taking into account the area occupied by development and access.
Channel System Reconfiguration	This approach can be applied mainly to pods where there is the potential for large changes in the water entitlement.
Short Life Infrastructure	Pods where there is there is likely to be more uncertainty in the continuation of supply.
Groundwater Injection/Aquifer Recharge	When determined to be more cost effective than other storage techniques and the associated operation, environmental and management risks could be mitigated.
Mothballing Channels	Mothballing of channels would only be used where they have significant remaining life and the soil types are suitable for continued irrigation.

4.4 Choosing and Developing the Options for Analysis

Before considering what options might be available or suitable to meet a flexibility requirement, it will be necessary to define that requirement, primarily in terms of:

- at what location that flexibility is needed;
- the scale (flow range) required;
- the proximity of the site to current supply sources or potential supply sources;
- the duration of the likely requirement;
- the standard of service needed.

Many of the factors listed under the section on Site Characteristics may be off assistance in establishing a clear understanding and definition of the flexibility requirements.

Knowing what is to be achieved, attention can then be directed to selecting the technologies that might be suitable. These technologies might represent stand alone approaches, or there could possibly be a need to consider combinations of two or more technologies. The identification of these options could involve consultation with system managers and operators, system designers from either within the Authority or elsewhere, possibly from the proponents of a particular development or scheme, experience elsewhere, and other stakeholders.

The selection of the technology options for assessment would substantially take into account the flexibility requirements determined as listed above to identify what options might be available, generally considering:

- the proximity of the site to supply sources;
- the scale of flexibility required;
- the capacity availability or limitations of the supply sources;
- the estimated life required;
- the condition and estimated remaining life of the existing supply sources; and

- the works options available for obtaining the supply from the supply sources identified.

Having established a range of the options for analysis, it will be further necessary to establish a comprehensive description of each option for use in comparing them and selecting the preferred option. This description would include:

- the physical characteristics of the option – based at least on preliminary sizing and siting of the components of the options. This would be supported by appropriate layout drawings to give a clear illustration of the option;
- estimates of cost – capital and operating for the anticipated life of the works.
- economic benefits and costs of each option – as applicable to the level (authority, region, state) at which the economic merit of the options is being assessed. Some further comment on economic benefit and cost items are provided later;
- the social impacts of the options – these might be in terms of the customer affordability of the respective options or the social merit as assessed on the regional basis. They may also involve identification of any heritage or cultural issues that might influence the choice of the preferred option;
- any environmental issues associated with the respective options.

4.5 Selecting the Preferred Technology

An approach for selecting the preferred option is presented below. In doing so, it is acknowledged that authorities may have their own procedures for such an analysis. The general approach offered may be considered where a specific authority approach has not been established.

Formal benefit-cost analysis is suggested to be the appropriate methodology for analysing the benefits and costs for options because of the time it can take for full realisation of the benefits of a change. Benefit-cost analysis, through discounting procedures, converts future flows of benefits and costs to a comparable basis at a common point in time.

In general terms, the benefits and costs flowing from the asset replacement fall into the following categories:

- benefits resulting directly from the proposed change;
- any costs associated with the current operation of the system that would not be incurred if the change were made;
- benefits from the current operation of the system that would be given up under the proposed change; and
- extra costs associated with the change.

These benefits and costs should consider impacts at an appropriate level (authority, regional, state) using appropriate discount rates. The benefits and costs might also be considered in a financial analysis for the individual stakeholders.

Some of the values, particularly those associated with environmental and social benefits and costs will be difficult to value, and expert advice may need to be sought from natural resource economists. Alternatively, priorities might be determined using economic criteria for quantifiable values and ranking criteria for intangibles within a multicriteria analysis. In the situation where the preferred option on economic grounds is inferior on social or environmental grounds, decision-makers from the Authority need to be able to assess these trade-offs and determine the preferred option. In general, this requires that all aspects are considered in the same units and economists tell us that these units are $.

Priorities should be those that maximise the Net Present Value (NPV) of an option's benefits less costs. Benefits are likely to result from:

- additional agricultural productivity from ability to supply additional land or develop land more intensely;
- improvements in level of service (delivery times, flow rates, delivery pressure)
- water savings;
- savings in operations and maintenance costs; and
- change in water quality.

Costs are likely to include:

- capital costs (on-farm & system); and
- new maintenance and operation costs.

It is suggested that the Authority use a decision support model to establish the overall priorities of the options considered. An example of such a model is provided in Table 4-1. In using this model:

- all "Musts" are to be met for an option to be considered further;
- in this example, a ranking system is used to establish comparison between options for specific attributes This could comprise a ranking range (e.g. "1" to "6" or -4 to +4) to provide a measure of comparison between the options for an attribute.
- it is also possible to use a weighting system. However, as different weighting could be applied to different analyses and such weighting would largely depend on stakeholder values, this approach has not been included in the example as it is considered that decision makers can place more reliance on "the answer" rather than the process used to develop "the answer."
- if a weighting system is used, it is expected that the maximisation of NPV would be given a high weighting in the analysis;
- the narrative outlines the background to the score assigned for respective attributes. Blanks in the "narrative" would suggest further data gathering is required.

Table 4-1- Decision Support Tool for Establishing Option Priorities

Factor		**Option 1**		**Option 2**		**Option 3**	
Objectives and characteristics of the planned flexibility							
The option must .... **Does it achieve this?** (go/no go)							
ATTRIBUTE	**SCORE RANGE**	**Score**	**Narrative**	**Score**	**Narrative**	**Score**	**Narrative**
NPV		$		$		$	
Social:							
Affordability							
Culture/Heritage							
Stakeholder acceptance							
Environmental							
Degree to which flexibility is provided							
Other attributes							
Total weighted scores							

Section 5 The Technologies

5.1 Information Provided

The technologies introduced in Section 4 are presented in more detail in the following. In doing so, the discussion on the technologies includes:

- a description of each;
- discussion on their respective advantages and disadvantages;
- some comment on their use in the past. In general these uses have not been specifically to obtain flexibility in the same context as the discussion herein, but the their use in providing such flexibility it is generally evident from the discussion provided;
- the possible use of the technology specifically aiming to indicate in which component of the distribution system the technology might be best suited;
- some discussion on costs and economics. The discussion is general as in most cases there are many variations, combinations and scales in which a technology can be used;
- some suggested references from which further information and examples may be available on the use of the respective technologies.

Whilst the technologies presented in the following sections can be used individually or in combination, they can also be used in conjunction with other asset maintenance initiatives such as the Advanced Maintenance Program operated by Goulburn-Murray Water and other authorities. This program is aimed at lengthening the life of assets by 10 to 20 years by implementing a number of timely rehabilitation techniques such as rock armouring channel batters, reinstating eroded beaching at channel structures, repairing cracks in concrete structures, and reinstating eroded bank material. This extension of time provides flexibility through deferral of capital expenditure until future requirements are clearer.

5.2 In- and Off-channel Storages

5.2.1 Description

In and off channel storages are storages situated at strategic locations either within or adjacent to the channel system. Scheduled flows or excess flows, which occur due to rain rejection or operational surpluses, are directed to the storage and later returned for use in the channel system in response to increased demand. A supervisory control and data acquisition (SCADA) system can be used to monitor and control diversions to and from the storage.

The difference between an in and off-channel storage is that with an in channel storage the storage is within the channel and usually operates under gravity conditions, whereas an off channel storage is located adjacent to the channel and is designed for gravity inflow and pumped outflow or visa versa.

5.2.2 Advantages and Disadvantages

The storage capacity provided within the distribution system by in channel and off-channel storages can reduce the requirements for increasing the capacity of carrier and trunk channels, provide flexibility in meeting varying demands over time, smoothing the fluctuations that can occur through channel regulation, and facilitate water saving by capturing rejected flows.

A significant degree of planning is required in developing the concept for in channel and off channel storages, particularly in establishing its optimum size. This includes the prioritisation of its functions, such as providing system flexibility, saving outfalls, or smoothing regulation. Depending on the extent to which demand varies over time, there could be periods when the storage is under committed and other times when it would be limited in the flexibility it provides. Another key issue in developing a storage concept is locating the storage to ensure that the flexibility it is designed to provide is realised.

There are also environmental issues that would need to be considered including the possibility of increased seepage losses to the water table and the energy requirements in having to pump water either into or out of the storage.

5.2.3 Past Experience

Goulburn-Murray Water uses some large off-channel storages for regulation purposes. These large storages are designed to assist with channel regulation and to overcome channel capacity problems. These include:

- Tandarra Pondage, a 2,860 ML capacity in-channel storage, and Greens Lake, a 32,750 ML off-channel storage on the Waranga Western Channel (WWC); and
- Kow Swamp, a 51,700 ML capacity off-channel storage, and Kangaroo/ Racecourse Lakes, 39,200 ML capacity in-channel storage in the Torrumbarry supply system.

Tandarra Pondage is a man-made storage controlled by inlet and outlet regulating structures on the Pyramid No 1 Channel. It assists with the provision of peak flows to the Pyramid Boort Irrigation Area during the spring and autumn periods. The pondage is filled during the low demand periods in the early spring and summer, smooths the fluctuations in the carrier channel flow caused by regulations, and stores surplus flow after rain rejections.

The Greens Lake Scheme also provides supplementary flow to WWC during the periods of peak demand and to assist regulation of this carrier. When excess water is available in the WWC, water is passed by gravity flow to Greens Lake. This water is then used in peak demand times to supplement flows in the channel. This storage assists with supply to the Rochester and Pyramid Hill-Boort Irrigation Areas during periods of peak demand in the spring and autumn. Water store in Greens Lake has to be pumped to the WWC. An issue with Greens Lake is that it is subject to natural inflows from a large catchment and it does not have a well defined natural outlet. Consequently the filling of the lake from the channel in the late winter and early spring has to be carefully managed to avoid the flooding of adjacent lands.

There are other examples of the use of this technology. Murrumbidgee Irrigation have recently constructed off channel storages near Yenda and in Barren Box Swamp. This Yenda storage is located adjacent to the Main Canal at approximately its halfway point in the system (upstream of the intensively developed horticulture area near the City of Griffith) to:

a) capture surplus flows resulting from rainfall rejection;

b) provide flexibility in meeting downstream peak demands when there is high demand on the system overall.

The Barren Box Swamp is used to harvest drainage flows and system outfall flows for irrigation and domestic stock supply to the west of the swamp. The new off stream storage is a reconfiguration of the swamp to reduce water loss through evaporation and enhance its environmental value.

5.2.4 Use of the Technology

In channel and off channel storages are likely to be most useful in association with either main or trunk distribution systems.

5.2.5 Costs and Economics

The preparation of estimates of cost and economic justification for this technology is site specific and will need to be assessed according to the defined function, size, topography of the site, operation procedure, and the benefits and disbenefits provided by the storage. It will also be necessary to consider any environmental and social issues associated with constructing and operating the storage at a particular site, and in comparing the options for the storage as suggested in the assessment guidelines provided earlier.

5.2.6 References

- Sustainable Water Resources Management and Farm Dams- Discussion Paper (Dept. of Natural Resources and Environment - April 2000),
- Design Considerations for Night Storage in Irrigation Systems (Mankarious, Delta Barrage, Egypt - American Society of Civil Engineers -August 2001),
- Design of On-Farm Irrigation Ponds (Mehta et al. - American Society of Civil Engineers 1992),
- Murrumbidgee Irrigation website for the Barren Box Swamp Project:

  http://www.mirrigation.com.au/BBS

- Goulburn-Murray Water website for a Fact Sheet on greens Lake:

  http://www.g-mwater.com.au/article.asp?ContentID=greens_lake

- Water Systems Infrastructure Operational Review (GMW 2002).

Section 5 The Technologies

Section 5 The Technologies

5.3 Lay Flat Pipe

5.3.1 Description

Lay flat pipe is a low cost flexible textile tube that is inflated by the water flowing through it. Unlike traditional pipes the pipe cannot be buried and therefore needs to be manufactured using a UV stabilised material. When the pipeline is drained it can be recovered and relocated.

Photo Courtesy Bartlett Water Services

Major irrigation water supply systems comprise open channels that operate at relatively flat longitudinal grades. Pipes can therefore only be used for the replacement of small spur channels, which generally operate at very low pressures.

The low pressures allow the use of lay flat pipes.

5.3.2 Advantages and Disadvantages

The advantages of lay flat pipe are that it is cheaper to install than the traditional pipes used for gravity irrigation supply due to the lower pipe supply cost and installation cost as the pipe is laid on the ground or in the abandoned channel. Since the pipe is not buried, in the event of changes in irrigation practices, it can be relocated.

The disadvantages of the pipe are that the pipe is not as robust as traditional pipes and has shorter expected life. With the pipe not being buried the pipe will impact on farm operations and not provide flexibility with location. While the pipe will have to pass through culverts at road and farm crossings, the culverts will not require rubber ring joints. Although the pipe will not be buried, in the relatively flat irrigation areas, laying the pipe on the natural surface may not locate the pipeline below the pipeline hydraulic grade line (HGL), and require the laying of the pipe in the abandoned channel or a trench, thereby reducing some of the flexibility of the technology that is provided by buried pipelines.

5.3.3 Past Experience

Lay flat pipes were trialled in the Goulbourn Murray Irrigation District (GMID) in the early 1990s for the replacement of small spur channels. The pipelines were laid in the existing channels to provide the required hydraulic characteristics for the pipeline. The channel beds were smoothed to provide an even surface for the pipe. The fact that it has not been widely used for the replacement of spur channels in the GMID would indicate that it is not favoured by system managers, due to the lack of robustness of the technology and difficulties in obtaining fittings.

Significant development has been undertaken as part of the Pratt Water Murrumbidgee Project into the manufacture of a 10 metre working head lay flat pipe and fittings. An 880 metre long pipeline was installed in Murrumbidgee Irrigation Area (MIA) 2003 and is undergoing testing by the CSIRO.

5.3.4 Use of the Technology

Lay flat pipes are most likely to be useful for the replacement of small spur channels in areas where changes in irrigation practices are likely to occur. The lower cost may also allow the pipeline replacement of channels that are not economic to replace using traditional pipelines.

5.3.5 Costs and Economics

Some cost information is provided in the references listed below. However, as there is such a wide range variables for different cases of application of this technology, it is necessary to look at individual cases in assessing the costs, required life, and economic, environmental and social merits of proposed works or the options for such.

5.3.6 References

- The Pratt Report for saving water in the Murrumbidgee Valley

  http://www.napswq.gov.au/publications/pubs/pratt-water-main.pdf

  http://www.napswq.gov.au/publications/pubs/pratt-water-appendices.pdf
- Website of CE Bartlett of Ballarat. Information on their lay flat pipe product.

  http://www.bartlett.net.au/fluming.php
- Information on using lay flat pipe in the Murrumbidgee Irrigation Area

  http://www.napswq.gov.au/publications/pratt-water/working-papers/pubs/laterals-mil.pdf

5.4 Channel Lining to Reduce Friction Loss

5.4.1 Description

The capacity of a channel is a function of the channel waterway cross sectional area of the, longitudinal slope and surface roughness. Reducing the surface roughness will increase the channel capacity as a direct proportion. The roughness coefficient of earthen channels ranges from 0.02 for carrier channels to 0.0275 for small spur channels. The roughness coefficient of channel liners ranges from 0.013 for concrete to 0.011 for synthetic liners. Therefore channel lining has the potential to increase the capacity of carrier channels by 67 percent and spur channels by 130 percent.

Channel lining requires the reshaping of the waterway to a formal shape and the installation of the channel liner and connection to the channel structures. (*Photo Courtesy Goulburn-Murray Water)*

5.4.2 Advantages and Disadvantages

The advantages of channel lining are that it significantly reduces leakage, eliminates seepage and the erosion of the channel bank, thereby extending the bank life and allows the construction of the channel bank using material of lower water retaining quality. Although the use of channel liners can allow a smaller channel waterway and the use of smaller banks, this may increase relative construction costs because of the need to use smaller, less efficient construction equipment, and the possible need to borrow more material for construction where there is insufficient material obtained from the excavation to form the channel.

The main disadvantage is the additional cost for the installation of the channel liner. Channel liners also need to be proactively maintained to ensure their integrity and prevent failure, particularly where supported by material of lower water retaining quality. Lining failures will be more expensive to repair and difficult to carry out while the channel is in operation. Irrigation areas are subject to high watertable and provision needs to be made to relieve pore water pressures when channels are dewatered for maintenance. With the limited use of channel lining in Australia there is no specialised equipment available to automate construction and reduce costs.

5.4.3 Past Experience

Concrete lined channels where commonly used in the construction of small irrigation supply schemes in the early 1900s when low cost labour was available and precast concrete pipes were a relatively new product with limited application. Plastic liners have been used for the rehabilitation of concrete lined channels or for seepage control in earthen channels. Where it has been used in concrete lined channels it required the removal of sharp edges in the channel and the use of rigid HDPE sheeting to maintain the channel shape. The flow improvement characteristics are negligible given the small difference in roughness coefficient between the concrete and HDPE. The use of plastic liners for seepage control has involved the covering of the liner with earth for UV protection and to hold the liner in place. This arrangement has no hydraulic advantage.

5.4.4 Use of the Technology

The use of this technology is suited to where land is limited or too valuable for the enlargement of the channel or for increasing the capacity of medium size channels where the cost of the channel liner will be less than cost of the construction of a new channel bank. Hence it is more likely to be suitable for carrier and trunk infrastructure where the channels operate continuously at their design flow for long periods of time. Channels serving pods do not operate continuously at the design flow for long periods of time and there is less likelihood a need to increase the channel capacity.

5.4.5 Costs and Economics

Some cost information is provided in the references. It is considered most likely that individual cases will need to be considered on their own merits. Channel lining techniques to-date have been mostly used in association with water savings projects. It may therefore be appropriate to consider the joint flexibility and seepage reduction merits of channel lining in assessing the merit of the using such liners.

5.4.6 References

- Information on using channel liners in the Murrumbidgee Irrigation Area:

  http://www.napswq.gov.au/publications/pratt-water/working-papers/pubs/laterals-mil.pdf
- Flexible membrane lining techniques:

  http://www.ancid.org.au/seepage/4_2_16_flexMembrane.html
- Water Systems Infrastructure Operational Review (GMW 2002). Discussion on the use of channel ling in the context of saving water.
- LWRRDC Guide to Best Practice for Construction and Refurbishment of Earthen Channels.
- ANCID Channel Seepage Project – Stage 2 Channel Seepage Remediation.

5.5 Staged Development of Supply Systems

5.5.1 Description

Irrigation water supply infrastructure is costly. New irrigation development is generally undertaken in stages and does not require the full capacity of the supply system until the development is well advanced. It is possible to stage the provision of capacity in the major infrastructure. Below ground channel excavation would be undertaken and the structures would be constructed with a lower interim capacity and enlarged when the development matches that interim capacity. Where the channel has banks the height of the channel banks is determined from the flow level in the channel is, which dictated by the topography of the area. The capacity of the channel is varied by varying the depth and width of the waterway. Staged development of the channel is not practical as the larger channel capacity is provided by a wider and possibly deeper waterway, which results in the banks being wider apart. The larger channel capacity also provides a greater opportunity to obtain sufficient material for the construction of the banks from the excavated part of the channel waterway.

5.5.2 Advantages and Disadvantages

The greatest advantage with staged development of the infrastructure is lower initial investment and resource requirements for the construction. The disadvantages are likely to be higher ultimate costs associated with increasing the capacity of the initial works because of construction complexities in integrating the initial and later works and changes in construction standards, and infrastructure components with different remaining lives.

5.5.3 Past Experience

The construction of the Burdekin Irrigation Scheme's (Queensland) Main Haughton Canal, which has a design flow of 20 cumecs, was staged with channel having the ultimate capacity and the major siphons, comprising two-rows of three metre diameter pipes, having end structures for the ultimate design and only one of the two barrels. The second barrel was installed some time later and had to be fitted between stub pipes fixed to the end structures.

In designing the Robinvale pipeline system the ability for the system to be upgraded some time in the future or to deliver more water when required was considered. The ability to do this would be at a cost either in dollar terms or as a lower standard of delivery service.

For example, the pumping station could have been designed to cater for possible future pumps to be installed. This may simply be a larger pump station building than would otherwise be required for servicing the agreed design capacity. This additional space comes with an associated cost.

With the pipeline distribution system, the pipelines are designed to cater for a particular flow at a particular pressure. Depending on the layout of the distribution system, the opportunity for future 'looping' of pipelines to increase pipeline capacity may be possible.

Given an agreed and set design, the system is designed to deliver a specified maximum flow at a specified minimum pressure at the property boundary. If for some reason a lower standard of delivery service is accepted, a higher flow rate may be delivered at a lower pressure head. The quantum of additional flow able to be delivered is dependent upon the system hydraulic characteristics, the acceptable reduction in pressure and the ability of the pumps to deliver additional flow without being limited by other factors such as net positive suction head.

5.5.4 Use of the Technology

The use of staged development is only suitable when the development is large and undertaken over an extended time and is more likely to be appropriate for carrier and trunk infrastructure.

5.5.5 Costs and Economics

The costs of the works will depend on the situation in which they are being used, and the nature of the works. Some considerations of the economic merit of proposed works or the options for such will include the costs and required life of the works at the various stages of implementation, and the condition and remaining life of the assets to which a subsequent stage of development is being added.

5.5.6 References

None were identified.

5.6 Construction of Supplementary Supply Works

5.6.1 Description

Irrigation supply systems are designed to meet the peak water demand of the area served and generally there is no spare capacity in the system for new development. Increasing the development served requires either upgrading the capacity of the supply system or the construction of supplementary supply works. The supplementary works may make use of natural carriers from which water is injected further downstream in the system. This will require either a diversion weir or pump station with a pipeline or channel to inject water into the supply system in the vicinity of the new development. This will free up capacity in the system to allow the supply of the new development.

5.6.2 Advantages and Disadvantages

The advantage of supplementary supply works is that it can avoid the upgrading of long lengths of channel to allow the development of irrigation new areas. The construction of the works is generally remote from the irrigation system and can be undertaken during irrigation when conditions are better for construction. Upgrading the capacity of an existing channel is limited to the short period between irrigation seasons (over winter) when the system is shut down for maintenance and conditions are generally not ideal for construction. The disadvantage is that it generally requires major infrastructure on a natural waterway, with potential environmental issues to be addressed. It may also require the extended use of natural carriers, which have transmission and operation losses.

5.6.3 Past Experience

The expansion of irrigation in the Sale and Nuntin areas of the Macalister Irrigation District (MID) was achieved by the construction of Maffra Weir and the Main Eastern Channel connection to the Main Sale Channel. This avoided the enlargement of the Main Northern Channel, which has a number of large siphons and tunnels as well as a pipe chute that drops approximately 25 metres. Supply to the Nambrok-Denison area of the MID is supplemented by supply from the Thompson River via Cowwarr Weir.

The Cattanach Canal was constructed to supplement flow from Goulburn Weir to Waranga Basin and follows a more direct route than the original channel, the Stuart Murray Canal. Construction of the Cattanach Canal involved depths of cut up to 20 metres for a three metre deep waterway.

Supply to the GMID system is also supplemented by pumping stations on the Campaspe River and River Murray that discharge to the WWC for the Rochester and Pyramid Boort Irrigation Areas and the Little Murray River Weir Pool for the Torrumbarry Irrigation Area respectively. Supplementary works in the form of pumping stations on the River Murray have allowed the abandonment irrigation channels that were encroached on by urban development in the towns of Cobram and Swan Hill.

5.6.4 Use of the Technology

Supplementary supply works are used where alternative supply with adequate capacity is available. This may be from a natural waterway or a part of the channel system where the permanent transfer of water entitlement has resulted in spare capacity in the channel. The technology is more likely to be associated with carrier and trunk supplies, although it could be used for supply to a pod.

5.6.5 Costs and Economics

Some examples of the application of this approach are provided in the first of the references listed below. These cases are assessed individually, not only in terms of cost and economic merit, but also take into account drainage and flooding, hydrogeological and other environmental aspects in defining the overall merit of the options and comparing them.

5.6.6 References

- Identification of Likely Prime Development Zones in the Shepparton Irrigation Region (SKM 2000). Includes example of using supplementary supply works within and adjacent to an existing irrigation system.
- Irrigation and Drainage Practice (Rural Water Commission of Victoria 1988). Provides design principles for designing new and remodelled channels, pipelines, and pump stations.

5.7 Waterway Enlargement

5.7.1 Description

Increased supply may require the enlargement of the channel waterway. This will also require the enlargement of the associated channel structures such as regulators and siphons. It may also require the replacement of road and farm crossings. Minor increases in capacity may be achieved by reshaping the waterway within the existing channel banks. Major increases in capacity will require the relocation of one of the channel banks and the widening of the waterway. This will require the replacement of outlets in that bank and the extension or replacement of drainage subways.

5.7.2 Advantages and Disadvantages

The advantage of enlarging the existing waterway is that it does not result in additional assets, although it will result in more expensive infrastructure. However there are economies of scale in the construction of larger works. The disadvantages are that it will require the construction to be undertaken in period between the irrigation seasons when the channel system is shut down for maintenance. It will also require the acquisition of additional land and impact on farm works and may require the early replacement of assets.

5.7.3 Past Experience

Most of the main carrier channels of the GMID were enlarged in the 1950s and 1960s following an increase in water entitlements with the construction of Lake Eildon. Major channels enlarged included the East Goulburn Main Channel and the WWC. In recent years the WWC west of the Loddon River has been enlarged to increase water supply for new irrigation development south west of Boort.

5.7.4 Use of the Technology

Channel enlargement would be used to increase supply where it is not practical to meet the supply increase using supplementary works, in or off channel storages or improve the hydraulic efficiency of the channel with lining. Waterway enlargement is an alternative method of increasing the capacity of a supply system to improved hydraulic efficiency and supplementary supply. It is therefore likely to be used for carrier and trunk channels.

5.7.5 Costs and Economics

The evaluation of the use of this approach will also need to be considered on a case by case basis.

5.7.6 References

- Irrigation and Drainage Practice (Rural Water Commission of Victoria 1988). Provides design principles for channel waterway design.

5.8 Higher Operating Levels with Improved Channel Control

5.8.1 Description

Channel systems are designed with bank freeboard ranging from 0.3 metre to 0.9 metre and structure freeboard ranging from 0.25 metre to 0.4 metre depending on the capacity of the channel. The freeboard is provided to give protection against channel bank damage or failure from high water levels that may result in flooding of private land. High water levels may occur from:

- operational fluctuations;
- wind and wave action;
- temporary mis-operation of channel regulators;
- unauthorised interference of control structures;
- obstruction of flows;
- errors in regulation and flow measurement;
- excess inflows after heavy rainfall;
- shutdowns due to rainfall;
- temporary passing of high flows than normal;
- surges which accompany rapid changes in flow; and
- variations to planned farm deliveries.

Channel freeboard also allows for settlement and erosion of the bank over time.

The use of improved channel control and SCADA, which provides greater supervision of the channel operation, may allow the channel to be operated at higher levels, thereby increasing the capacity of the channel.

5.8.2 Advantages and Disadvantages

The advantage of higher operating levels is that it provides significant additional capacity. For example a 0.15 metre rise in the operating level channel increases the capacity of a 200 ML/d channel by approximately 30 percent and a 500 ML/d channel by 20 percent. This is on the proviso that there are no culvert type structures on the channel. The major disadvantage of higher operating levels is that there is a greater risk of the channel overtopping in the event of an operational malfunction. While the channel may appear to have adequate freeboard part of the freeboard may not be suitable for retaining water over extended periods of time. A channel bank consists of clay core and a protective cover. The clay core is constructed using selected low permeability clay material. The top of the clay core has a freeboard of 0.15 metre on the design maximum operating level. The protective cover provides additional emergency freeboard, which is not compacted, is constructed using more permeable low shrinkage material and top soil to maintain the moisture in the clay core and encourage vegetation cover. Hence the risk in raising channel operating levels. The bank freeboard may also comprise silt and vegetation removed from the waterway that has been placed on the bank to improve access.

5.8.3 Past Experience

The use of high operating levels has usually been associated with eliminating channel regulators or overcoming property supply issues. Also changes in irrigation practices has also resulted in main channels operating at high than design capacities, although some of this capacity increase would result from the channels operating at better than design hydraulic efficiencies.

5.8.4 Use of the Technology

Raising channel operating levels should only be used where there is greater control and supervision of the channel, ie improved channel control and SCADA, and it can be shown that it will not increase seepage and leakage. This technology is more appropriate for carriers and trunks where the main channels operate at the design for longer periods of time and, due to their larger capacity, they have a larger freeboard.

5.8.5 Costs and Economics

Also needs to be considered on a case by case basis. May also be appropriate to assess the use of the technology to provide flexibility in conjunction with achieving water savings.

5.8.6 References

- Rubicon Systems. A description of total channel control: http://www.rubicon.com.au/irrigation/totalChannelControl.asp
- Discussion on the use of total channel control in the Shepparton Irrigation region: http://www.g-mwater.com.au/downloads//pdf version tccs project final report of CG2 pilot December 2 004.pdf
- Water Systems Infrastructure Operational Review (GMW 2002). Provides discussion on the use of total channel control in relation to water savings.
- Irrigation and Drainage Practice (Rural Water Commission of Victoria 1988). Provides design principles for channel waterway design.

5.9 Oversizing Pipeline Systems

5.9.1 Description

An issue with pipeline water supply systems is that their capacity is essentially limited to that of the pipe originally installed. Additional supply capacity can only be provided by relift pumping, pipeline duplication or over sizing of the pipelines to begin with. Gravity irrigation areas are generally extensive and flat, hence the water supply systems comprise channels, which are more cost effective than pipelines, except for small spur systems. Over sizing the pipeline systems will allow the future expansion of the area irrigated. Relift pumping would require the pipes to have an appropriate pressure class while pipeline duplication is less hydraulically efficient than a single pipeline providing the same capacity.

5.9.2 Advantages and Disadvantages

The advantage of over sizing the pipeline system would provide flexibility of supply. The disadvantage is the capital cost involved in over sizing the pipe system.

5.9.3 Past Experience

Early pipeline systems have been associated with irrigations schemes that are supplied by pumping. The design of these schemes was based on the rotation of supply. As an example a flow stream is rotated between four adjacent properties, with each property have the flow stream for two days (the time to irrigate the property) in every eight days, this being the minimum time between irrigations. This design approach does not meet the needs of current irrigation practices. The limitation with the approach have been overcome by supplementing supply with groundwater and duplicating the lower reaches of the pipeline systems to remove capacity constraints.

The current approach taken for the design of irrigation pipeline schemes is to use crop water requirements determined from evaporation data and crop factors for the period of peak demand and an estimate of the total area to be served by the scheme. The required flow is factored up to determine the design flow for the downstream end of spur pipelines to maintain supply flexibility over the whole of the scheme.

An approach taken for the design of gravity pipelines replacing spur channels is to apply the flow formulas used for the design of channels, which use water entitlement and the number of outlets. As pipelines can generally only be justified for small areas, a check is also made of the flow required based on the crop peak water requirement and the total area to be served by the pipeline. To provide some flexibility in the supply system the pipeline would be sized to operate for a part of the time during the peak irrigation cycle. For smaller pod pipelines, the pipelines would be sized to operate at the design flow for 50 to 60 percent of the time during the peak irrigation cycle. This would increase for larger pod pipelines to 60 to 70 percent of the time during the peak irrigation cycle. Where pipelines can be used for trunk pipelines, the pipelines would be designed to operate 65 to 85 percent of the time during the peak irrigation cycle.

5.9.4 Use of the Technology

Pipelines can generally only be justified for the supply of small areas. Given the issues involved with upgrading the capacity of pipelines they should be designed to supply the total area served by the pipeline that is suitable for irrigation, based on crop types appropriate to the area, using modern irrigation practices and taking into account the area occupied by farm development and access tracks.

5.9.5 Costs and Economics

Also needs to be considered on a case by case basis. May also be appropriate to assess the use of the technology to provide flexibility in conjunction with achieving water savings.

5.9.6 References

- Irrigation and Drainage Practice (Rural Water Commission of Victoria 1988). Provides design principles for establishing system capacities.
- Water Systems Infrastructure Operational Review (GMW 2002). Discussion on the pipelining of spur channels.
- Canal Capacities for Demand Under Surface Irrigation (Clemmens A, 1986).
- Design and Congestion Considerations for Flexible Irrigation Supply Systems (Merriam J & Styles S, 1997).
- Operation-Based Design Guidelines for Modern Irrigation Delivery Systems (Rogers D, Mallicoat O and Lindstrom S, 1999).
- Design of Semi-Closed Pipeline Systems (Merriam J, 1987).

5.10 Channel System Reconfiguration

5.10.1 Description

A large part of the irrigation water supply systems managed by G-MW were developed in the early 1900s. The main channels of the systems were remodelled in the mid 1900s following the enlargement of Lake Eildon and Lake Hume and increase in water entitlements.

The development of the irrigation systems was based on channel and farm irrigation layout construction practices, which limited the movement of earth, and farming practices at the time. With water being the limiting resource, water allocations were distributed to allow the total irrigation of small properties and the partial irrigation of larger areas. Larger properties generally comprised a mix of intensely irrigated area, sparsely irrigated area and area not irrigated. Consequently a large part of the area served by irrigation infrastructure is either sparsely irrigated or not irrigated at all.

With changes in construction and irrigation farming practises combined with the separation of water from the land and an emphasis on improving the efficiency of the delivery and use of irrigation water there is the opportunity to reconfigure irrigation systems.

5.10.2 Advantages and Disadvantages

The advantage of system reconfiguration is the delivery of supply with less infrastructure and therefore at a lower cost and a greater distribution efficiency. The disadvantage is that generally it will involve community cooperation.

5.10.3 Past Experience

Generally past experience of system reconfiguration has involved the replacement of poor condition concrete lined irrigation channels with pipelines. A recent example of this is in Woorinen area near Swan Hill in Northern Victoria where the supply was also relocated from the Kerang Lakes channel system to direct from the River Murray.

G-MW has also undertaken a minor form of system reconfiguration with the asset rationalisation program. This program involves payment to landowners to enable the reorganisation of their supply from the present value of the saving from the abandoned assets.

5.10.4 Use of the Technology

The use of this technology will be applied to pods where there is the potential for large changes in the water entitlement.

5.10.5 Costs and Economics

The development and assessment of system reconfiguration requires considerable attention to developing the re-configuration options, the costs of those options, and assessing their economic environmental and social merits. A key factor in achieving successful reconfiguration is acquiring community acceptance of the proposal. Such a process is well advanced for the reconfiguration of the Pyramid-Boort Irrigation Area managed by Goulburn-Murray Water (reference listed), and is also underway for the Authority’s Torrumbarry Irrigation Area.

5.10.6 References

- Future Management Strategy – Facilitating the Restructure of the Pyramid-Boort Irrigation Area (RMCG 2006).

- Water Systems Infrastructure Operational Review (GMW 2002). Discussion on the consolidation and rationalisation of the supply system.

5.11 Short Life Infrastructure

5.11.1 Description

Traditionally irrigation infrastructure has been designed as long life infrastructure. Typical average lives are 70 to 80 years for earthen channel banks, 80 years for concrete regulating and culvert structures, 100 years for concrete bridges, 60 years for Dethridge outlets and 70 years for pipelines although the life of structure can vary depending on site and operating conditions. Circumstances outside the control of the water authority may require significant change to the infrastructure before the end of its useful life resulting in the original investment not being fully used. With the introduction of transferable water entitlements, the movement of water is constrained by the capacity of supply systems. Short life infrastructure would reduce costs associated with change in supply capacity requirements.

5.11.2 Advantages and Disadvantages

The advantages of short life infrastructure are lower capital cost and less likelihood of the investment not being fully utilised. The disadvantages are that generally the infrastructure is less robust and there is a greater risk of the infrastructure not achieving the desired outcomes.

5.11.3 Past Experience

Past experience of short life infrastructure is limited as up until recently water entitlement has been attached to the land as there was certainty over the long term viability of supply. Also water supply systems are operated in a severe environment for most of the year with turbulent flow and heading across structures. The nature of irrigation infrastructure is that where there is a known requirement the condition can be managed to meet this requirement.

More development with irrigation infrastructure has occurred in reducing construction costs through the use of precast concrete. As consequence there has been little development of short life infrastructure. Some examples of short life infrastructure are lay flat pipes, culverts without headwalls and steel sheet piling weirs.

5.11.4 Use of the Technology

Short life infrastructure would be used for pods where there is there is likely to be more uncertainty in the continuation of supply.

5.11.5 Costs and Economics

Needs to be assessed on a case by case basis. Is expected to involve an assessment of the whole of life cost of the short life infrastructure in comparison to conventional methods of infrastructure development or replacement. An assessment of the risks and consequences of failure would also need to be undertaken and included in the selection of this approach.

5.11.6 References

- Website of CE Bartlett of Ballarat. Information on lay flat pipe.

  http://www.bartlett.net.au/fluming.php

5.12 Groundwater Injection/Aquifer Recharge

5.12.1 Description

This technology involves the injection of channel flow, during periods of low demand, into suitable aquifers where it would be stored for recovery during periods of high demand by discharging the stored water to the channel system. It is a similar operation to using in- and off-channel storages. Deep leads are considered to be the most appropriate type of aquifer for this purpose. Shallow aquifers may create a groundwater mound close to the surface and are therefore not considered to be appropriate for aquifer storage.

5.12.2 Advantages and Disadvantages

The technology will provide the flexibility to meet varying demands without the need for extensive infrastructure. The disadvantages include:

- the potential to adversely affect local and regional watertables;
- that it is contrary to the focus of regional salinity management plans, which has been on lowering watertables in the irrigation areas;
- the availability of suitably located aquifers of appropriate capacity;
- the feasibility of the technology;
- the potential to contaminate aquifers from the injection source;
- the potential for the aquifer to contaminate the injected water;
- the uncertainty of the ownership of the injected water;
- the potential to create groundwater mounds adjacent to the point of injection;
- increase operational complexity; and
- it may be technically difficult to inject and extract water at useful flow rates.

5.12.3 Past Experience

In recent years considerable experience has been gained in groundwater extraction as watertable control has been a major focus in the management of salinity irrigation areas to reduce the impact of perched watertables on crop production. In addition a large number of landowners have installed groundwater extraction pumps to supplement irrigation supplies. Experience with aquifer injection and recovery in Australia is limited. It consists of schemes for using stormwater to water the racecourse at Whyalla, supplement the town water supply for Mt Gambier and irrigate vegetables on the North Adelaide plains. The technology has been widely used for irrigation in Arizona, USA.

5.12.4 Use of the Technology

The technology would only be used where it was determined to be more cost effective than other storage techniques and the associated operation and management risks could be mitigated.

5.12.5 Costs and Economics

Needs to be assessed on a case by case basis. The impacts a proposed system may have on the environment will also need to be taken into account.

5.12.6 References

- Water Systems Infrastructure Operational Review (GMW 2002). Discussion on GMW considerations of the use of the technology for the Shepparton Irrigation Region.
- Proceedings of the second international Symposium on Artificial Recharge of Ground Water published by the American Society of Civil Engineers 1996
- Technical pamphlet on aquifer storage and recovery – Australian Water environments
- Experiences in injecting storm water into aquifers to enhance irrigation water supplies in South Australia. N.Z. Gerges, X.P. Sibenaler & D. Armstrong. Artificial Recharge of Groundwater II, ASCE Conference 1994.

5.13 Mothballing Channels

5.13.1 Description

Where a channel is no longer required for water supply the practice has been to abandon it and return the land to the parent property. More often channel abandonment has been due to the poor condition of the channel and alternative arrangements have been made to maintain supply.

The movement of water as a result of transferable water entitlement may result in the abandonment of channel that has not reached the end of its useful life and has a significant value. An option to disposing of the channel is to retain the asset for future use.

The major high wear component of a channel is the banks. Experience has shown that bank deterioration is function of the channel use. Isolating the channel from the adjacent property will allow the channel to be mothballed for future use.

5.13.2 Advantages and Disadvantages

Ceasing irrigation will return the property to dryland farming. Disposing of the channel to the adjacent landowners and returning the land to farming will have only a small benefit. However retaining the channel would allow the properties served be the channel to be returned to irrigation in the future. The disadvantage is that the water authority would have to retain an unused asset on its books. Channels would require regular inspection to ensure future functionality.

A key to maintaining the asset will be the fencing off of the channel from the adjoining properties. This will require the water authority acquiring freehold of the land occupied by the channel where the channel is on easement.

Channel banks dry out and shrink during the winter shut down period that can result in significant water loss during the channel fill process. There is the risk that not filling the channel for an extended period may result in extensive cracking of the banks requiring extensive refurbishment before they can be used. This would be dependent on the condition of the bank at the time it is mothballed.

5.13.3 Past Experience

Whilst mothballing of equipment is common in the manufacturing industry and defence there is no previous experience of mothballing channels.

5.13.4 Use of the Technology

Mothballing of channels would only be used where they have significant remaining life and the soil types are suitable for irrigation.

5.13.5 Costs and Economics

Mothballing a channel or channel system will essentially be a cost saving measure. A mothballed channel would remain an asset of the authority but would only bee maintained to the extent necessary to facilitate its re-commissioning when decided to be necessary. It is considered likely that the decision to mothball would be made in consultation with nearby landowners.

5.13.6 References

None identified.

Section 6 General References

JL Merriam, SW Styles, BJ Freeman (2007) Flexible irrigation systems: Concept, design, and application. Journal of Irrigation and Drainage Engineering, DOI: 10.1061/(ASCE)0733-9437(2007)133:1(2).

JL Merriam, BJ Freeman (2007) Operational cost benefits study of flexible on-farm irrigation supply systems. Journal of Irrigation and Drainage Engineering, DOI: 10.1061/(ASCE)0733-9437(2007)133:1(12).

Section 7 Limitations

URS Australia Pty Ltd (URS) has prepared this report in accordance with the usual care and thoroughness of the consulting profession for the use of The Department of Primary Industries and only those third parties who have been authorised in writing by URS to rely on the report. It is based on generally accepted practices and standards at the time it was prepared. No other warranty, expressed or implied, is made as to the professional advice included in this report. It is prepared in accordance with the scope of work and for the purpose outlined in the Proposal dated 23 June 2006.

The methodology adopted and sources of information used by URS are outlined in this report. URS has made no independent verification of this information beyond the agreed scope of works and URS assumes no responsibility for any inaccuracies or omissions. No indications were found during our investigations that information contained in this report as provided to URS was false.

This report was prepared between 23 August 2006 and 6 April 2007 and is based on the conditions encountered and information reviewed at the time of preparation. URS disclaims responsibility for any changes that may have occurred after this time.

This report should be read in full. No responsibility is accepted for use of any part of this report in any other context or for any other purpose or by third parties. This report does not purport to give legal advice. Legal advice can only be given by qualified legal practitioners.

APPENDIX

Experience of other agencies

Prepared for

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Contents

Executive Summary

Introduction

URS Australia was commissioned by the Department of Primary Industries (DPI) to prepare a handbook of technologies that are available to provide flexibility in irrigation delivery systems to deal with the varying irrigation demands which may occur in the future.

An early step in developing the handbook was to explore what consideration the designers and managers of other irrigation distribution systems in Australia and overseas have given to the subject, and what experience they have gained. This document reports on the process and findings of that activity which included:

- a literature search;
- discussions with irrigation system designers and operators locally and in other regions of Australia; and
- contact with irrigation system designers and operators in north America.

Noting that the aim of the flexible irrigation technologies project has been to prepare a handbook of technologies that are available for consideration in providing flexibility in irrigation delivery systems, the results of this information gathering activity have followed through to the handbook which is presented separately: "Handbook of Flexible Irrigation Technologies".

Literature Search

The literature search was undertaken of some 33 international agricultural and water databases. The search was undertaken using key words including irrigation, innovation, delivery, flexibility, and technology with variations of these. Although not specially included in this search, it is believed that articles published by agencies such as the International Commission on Irrigation & Drainage and the U.S. Committee on Irrigation & Drainage would have been identified.

This database search produced some 1,000 results, from which 47 abstracts of articles were obtained and reviewed for possibly providing useful information. From these abstracts, 18 articles were obtained for further consideration.

The search did not reveal any consideration by overseas agencies, or any local agencies that were covered in the database search, of providing strategic flexibility in irrigation distribution systems. There appears to have been a significant amount of consideration given to providing operational flexibility to both distribution systems and on-farm systems.

Experience Elsewhere

Another activity of the project was to contact the designers, managers and operators of irrigation distribution systems overseas and elsewhere in Australia.

For overseas experience, an emphasis was placed on Canada and the USA because of the similarity to Australia of the systems they operate and the institutional arrangements in place for their management, and because of some existing relationships with members of the north American irrigation community.

In canvassing the experience of designers and managers elsewhere in Australia, the objectives have been to include :

- the operators of the major systems in south eastern Australia;
- experience representing every region of significant irrigation activity; and
- private as well as public irrigation systems.

North America

Contact was made by e-mail with several north American agencies:

- the United States Department of Agriculture;
- the United States Bureau of Reclamation;
- the United States Committee on Irrigation and Drainage;
- the Irrigation Training and Research Centre (California);
- three private irrigation consulting firms;
- the Imperial Valley Irrigation District (California);
- several of the irrigation districts of the province of Alberta in Canada.

Although covering a reasonable range of relevant expertise, the results to-date have been disappointing in that a low level of response has been achieved. From the limited number of responses that were received, however, the indications were:

- that similar technologies are being used in the USA to those used in Australia to operate systems more efficiently and save water savings;
- there does not appear to be a clear trend towards providing strategic flexibility in irrigation distribution systems.

Elsewhere in Australia

The experience of other irrigation designers and system managers in the various regions of Australia was undertaken by means of:

- personal interview:
    - Southern Rural Water (Vic);
    - Murray Irrigation (NSW);
    - SunWater (Qld);
    - Coleambally Irrigation (NSW); and
    - Goulburn-Murray Water (Vic);
- telephone interview:
    - Harvey Water (WA);
    - Aquatech Consulting (NSW);
    - Auscott Pty Ltd (NSW);
    - Department of Water, Land and Biodiversity Conservation (SA);
    - Water Reticulation Services Virginia (SA); and
    - Ord Irrigation Co-operative (WA).

In general, it was found that:

- Several agencies have identified the possible need for providing flexibility. One in particular, Harvey Water, has taken specific action by planning for a certain level and location of future development and sizing new works accordingly.
- Agencies planning pipeline replacement of existing assets are taking into account future demand needs in terms of likely service level requirements or possible areal expansion.
- Some agencies already have a degree of flexibility through:

  - infrastructure being in place but water availability reducing;
  - infrastructure having been established in anticipation of an extent of farm development that has not eventuated;
- All the agencies, public and private, generally install conventional long-life infrastructure.

Section 1 Introduction

URS Australia was commissioned by the Department of Primary Industries (DPI) to prepare a handbook of technologies that are available to provide flexibility in irrigation delivery systems to deal with the varying irrigation demands which may occur in the future. The project follows on from a process of scenario planning which was used by the Department to develop a vision for the future of irrigated agriculture in the Goulburn-Broken Catchment of Northern Victoria.

The scenario planning process highlighted the need for flexibility in irrigation systems in order to meet the potentially profound and rapid changes in operating environment that are anticipated. In order to prepare for this occurrence, it was proposed that a handbook of flexible irrigation infrastructure be developed which could be used by irrigation system designers and provide guidance to them in understanding of the implications of how future changes might impact on their systems and the technological options available to them.

An early step in developing the handbook was to explore what consideration the designers and managers of other irrigation distribution systems in Australia and overseas have given to the subject, and what experience they have gained. This document reports on the process and findings of that activity which included:

- a literature search;
- discussions with irrigation system designers and operators locally and in other regions of Australia; and
- contact with irrigation system designers and operators in north America.

Noting that the aim of the flexible irrigation technologies project has been to prepare a handbook of technologies that are available for consideration in providing flexibility in irrigation delivery systems, the results of this information gathering activity have followed through to the handbook which is presented separately: “Handbook of Flexible Irrigation Technologies”.

Section 2 Literature Search

2.1 Database Search

The literature search was undertaken of a number of international agricultural and water databases (list available from URS). The search was undertaken using key words structured as follows:

Table 0-1 Search Key Words

Set	Description
S1	IRRIGATION
S2	INNOVAT?
S3	DELIVERY
S4	INNOVAT? OR DELIVERY
S5	FLEXIBLE
S6	FLEXIBILITY
S7	FLEXIBLE OR FLEXIBILITY
S8	PORTABLE
S9	NEW
S10	TECHNOLOGY
S11	NEW(W)TECHNOLOGY
S12	PORTABLE OR NEW()TECHNOLOGY
S13	S1 AND (S4 OR S7 OR S12)
S14	PY=2000 : PY=2006
S15	S13 AND PY=2000:2006
S16	IRRIGATION/TI
S18	S16 AND PY=2000:2006 AND (S4 OR S7 OR S12)

Although not specially included in this search, it is believed that articles published by agencies such as the International Commission on Irrigation & Drainage and the U.S. Committee on Irrigation & Drainage would have been identified.

This database search described above produced some 1,000 results, from which 47 abstracts of articles were obtained and reviewed for possibly providing useful information. A listing of these is available from URS. From these abstracts, 18 articles were obtained for further consideration.

2.2 Literature Reviewed

A summary of the content of the 18 articles reviewed is as follows:

1. Irrigation District Services in the Western United States (USBR):
   - operational flexibility rather than distribution flexibility;
   - frequency of watering, flow rate, duration;
   - technologies – on-and off-farm storages, automation of regulation (use of flap gates), SCADA.

2. Volume Compensation Method for Routing Irrigation Canal Demand Changes – (Journal of Irrigation & Drainage Engineering - ASCE):
   - operational – managing demand changes;

- routing demand changes in open channel delivery systems;
- proposed a volume compensation method.

3. Irrigation Technology Adoption and Gains from Water trading under Asymmetric Information (American Journal of Agricultural Economics):
   - on-farm technologies.
4. Benefits of Flexible Irrigation Water Supply (JI & DE):
   - operational flexibility – allows farms to choose to use efficient on-farm systems.
5. Assessing Sensitivity Factors of Irrigation Delivery Structures (JI & DE):
   - operational use of gated regulating structures.
6. Performance Assessment of Irrigation Water Management (Irrigation and Drainage Systems 2005 – Loughborough University):
   - irrigation water management.
7. Adapting 100-year Old Infrastructure to Meet the Needs of Today's Irrigators and Regulators (Luscombe and Court – GMW):
   - total channel control in GMW irrigation systems.
8. A Model for Investment Under Uncertainty: Modern Irrigation technology and Emerging Markets in Water:
   - investment in new on-farm technologies.
9. Design and Performance Analysis of Low Pressure Irrigation Distribution Systems:
   - methodology for design and analysis of flow regimes in a piped system for optimisation during design.
10. Technology Adoption under Production Uncertainty: Theory and Application of Irrigation Technology:
    - on-farm technology adoption.
11. A Case Study for Irrigation modernisation – Parts 1 and 2:
    - development and use of surface water simulation models to assess system performance;
    - applied to seven modernisation scenarios in on-farm border irrigation systems.
12. Irrigation Management Under Water Scarcity:
    - on-farm irrigation management.
13. Spatial and Temporal Variability Performance of Water Delivery in Irrigation Schemes:
    - quantification of water actually delivered at a specific time and location. Deviation from the intended amount determines performance level;
    - adequacy, reliability and equality of delivery systems.
14. Basin Wide Water Management Initiatives Stimulate Century-old Irrigation Industry in Semi-arid Southern Alberta, Canada
    - discusses a major rehabilitation of the irrigation infrastructure of Southern Alberta.

Note – a request has been sent to Eastern Irrigation District about what consideration might have been made to providing flexibility.

15. Multiple-use Management in Larger Irrigation Systems: Benefits of Distributed Secondary Storages:
    - discusses the use of storages to provide operational flexibility – responsive supply capability.
16. Volume Compensation Method of Routing Irrigation Canal Demand Changes;
    - part of a study to develop a comprehensive automated control system for channel delivery systems.
17. Operation of Irrigation Water Delivery Systems: Progress, Limitations and Future Directions:
    - channel automation.
18. Canal Automation for Water Conservation and Improved Flexibility:
    - operational flexibility.

2.3 Conclusion

The search did not reveal any consideration by overseas agencies, or any local agencies that were covered in the database search, of providing strategic flexibility in irrigation distribution systems. There appears to have been a significant amount of consideration given to providing operational flexibility to both distribution systems and on-farm systems.

Details of the search results, abstracts, and articles obtained are available from URS.

Section 3

System Designers and Managers

3.1 Experience Elsewhere

Another activity of the project was to contact the designers, managers and operators of irrigation distribution systems overseas and elsewhere in Australia. In preparation for this, a list of appropriate contacts or agencies was established in discussion with members of the Reference Group for the project.

For overseas experience, an emphasis was placed on Canada and the USA because of the similarity to Australia of the systems they operate and the institutional arrangements in place for their management, and because of some existing relationships with members of the North American irrigation community.

In canvassing the experience of designers and managers elsewhere in Australia, the objectives have been to include:

- the operators of the major systems in south eastern Australia;
- experience representing every region of significant irrigation activity; and
- private as well as public irrigation systems.

The results of this consultation is reported in the following.

3.2 North America

3.2.1 Agencies Contacted

Contact was made by e-mail with several north American agencies. In general the contact network was developed starting with potential candidates nominated by Reference Group members or from within URS, and building on the initial list. The eventual list is available from URS and included representatives of:

- the United States Department of Agriculture;
- the United States Bureau of Reclamation;
- the United States Committee on Irrigation and Drainage;
- the Irrigation Training and Research Centre (California);
- three private irrigation consulting firms;
- the Imperial Valley Irrigation District (California);
- several of the irrigation districts of the province of Alberta in Canada.

3.2.2 Results

Although covering a reasonable range of relevant expertise, the results to-date have been disappointing in that a low level of response has been achieved. From the limited number of responses that were received (available from URS), however, the indications were:

- that similar technologies are being used in the USA to those used in Australia to operate systems more efficiently and save water savings;
- there does not appear to be a clear trend towards providing strategic flexibility in irrigation distribution systems.

Further contact is being pursued.

3.3 Elsewhere in Australia

3.3.1 Agencies Contacted

The process of canvassing the experience of other irrigation designers and system managers in the various regions of Australia was undertaken by means of:

- personal interview. These included:
    - Southern Rural Water (Vic);
    - Murray Irrigation (NSW);
    - SunWater (Qld);
    - Coleambally Irrigation (NSW); and
    - Goulburn-Murray Water (Vic);
- telephone interview:
    - Harvey Water (WA);
    - Aquatech Consulting (NSW);
    - Auscott Pty Ltd (NSW);
    - Department of Water, Land and Biodiversity Conservation (SA);
    - Water Reticulation Services Virginia (SA); and
    - Ord Irrigation Co-operative (WA).

Details of the contact person and the position they hold within these agencies are available from URS.

3.3.2 Results

In general, it was found that:

- Several agencies have identified the possible need for providing flexibility. One in particular, Harvey Water, has taken specific action by planning for a certain level and location of future development and sizing new works accordingly.
- The agencies planning pipeline replacement of existing assets are taking into account future demand needs in terms of likely service level requirements or possible areal expansion. These agencies include G-MW, Harvey Water, the pumped districts in the Riverland of South Australia, and Lower Murray Water.
- Some agencies already have a degree of flexibility through:
    - infrastructure being in place but water availability reducing (Auscott cotton farms);
    - infrastructure having been established in anticipation of an extent of farm development that has not eventuated (Coleambally Irrigation).
- All the agencies, public and private, generally install conventional long-life infrastructure.

The results of the interviews are available from URS.

Section 4

Limitations

URS Australia Pty Ltd (URS) has prepared this report in accordance with the usual care and thoroughness of the consulting profession for the use of the Department of Primary Industries and only those third parties who have been authorised in writing by URS to rely on the report. It is based on generally accepted practices and standards at the time it was prepared. No other warranty, expressed or implied, is made as to the professional advice included in this report. It is prepared in accordance with the scope of work and for the purpose outlined in the Proposal dated 23 June 2006.

The methodology adopted and sources of information used by URS are outlined in this report. URS has made no independent verification of this information beyond the agreed scope of works and URS assumes no responsibility for any inaccuracies or omissions. No indications were found during our investigations that information contained in this report as provided to URS was false.

This report was prepared between 23 August 2006 and 17 April 2007 and is based on the conditions encountered and information reviewed at the time of preparation. URS disclaims responsibility for any changes that may have occurred after this time.

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