WATER SAVINGS PROTOCOL

A protocol for the quantification of water savings from modernising irrigation distribution systems

Version 5.0, October 2018

VICTORIA State Government | Environment, Land, Water and Planning

Acknowledgements

This *Water Savings Protocol* has been developed by the Department of Environment, Land, Water and Planning in collaboration with the Goulburn-Murray Water Connections Project (formerly NVIRP), Goulburn-Murray Water, Grampians Wimmera Mallee Water, Lower Murray Water and Southern Rural Water, and with advice from Hydrology and Risk Consulting (HARC).

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A. Explanatory note from the Minister for Water

As Minister for Water, I am issuing version 5 of the *Water Savings Protocol* – a protocol for the quantification of water savings from modernising irrigation water distribution systems. The *Water Savings Protocol* has been developed over time by the Department of Environment, Land, Water and Planning (DELWP) in collaboration with Goulburn-Murray Water (GMW), the GMW Connections Project team (formerly known as the Northern Victoria Irrigation Renewal Project (NVIRP)), Grampians Wimmera Mallee Water, Lower Murray Water and Southern Rural Water.

The purpose of the *Water Savings Protocol* is to provide guidance for the estimation, allocation and auditing of water savings from irrigation modernisation projects.

The impetus for this update is the continued, significant investment in irrigation modernisation projects in Victoria, and the requirement to demonstrate the resultant water savings are calculated in a consistent and transparent manner using best practice. A summary of the revisions made between the previous and this version of the *Water Savings Protocol* is included in Appendix A.

Context

The *Water Savings Protocol* provides a guide to my expectations for how to demonstrate water savings when:

- Requesting funding for irrigation modernisation projects that deliver water savings.
- Setting aside water savings for future use.
- Making an application to the Minister for Water for a new bulk entitlement, or to amend existing bulk entitlements to reflect long-term water savings achieved through irrigation modernisation projects.
- Auditing the water savings from irrigation modernisation projects.

The nature of the Water Savings Protocol

The *Water Savings Protocol* provides guidance on how to estimate, allocate and audit water savings. It also sets out the associated responsibilities of those involved in irrigation modernisation projects.

The *Water Savings Protocol* is comprised of:

- This explanatory note (chapter A).
- A statement of roles and responsibilities (chapter B).
- A water savings audit process (chapter C).
- A technical manual (chapter D).

The *Water Savings Protocol* reflects current best practice for the calculation of water savings. The *Water Savings Protocol* will be updated periodically to reflect improvements in technology, and developments in the understanding of irrigation system losses. It is predominantly based on the knowledge and experience of irrigation management and modernisation in northern Victoria, but may be applied to the entire State for other modernisation projects.

Lisa Neville MP

Minister for Water

B. Roles and responsibilities

The purpose of this chapter is to set out the high-level roles and responsibilities of those involved in irrigation modernisation projects, and specifically those associated with the quantification of water savings. The roles and responsibilities are consistent with those defined in the *Water Act 1989* and the *Environmental Effects Act 1978*.

The organisations and individuals involved in irrigation modernisation projects include:

- The project proponent
- The system operator
- The resource manager
- The Minister for Water
- The Minister for Energy, Environment and Climate Change
- The Minister for Planning
- The Department of Environment, Land, Water and Planning (DELWP)
- Local environmental managers, particularly the Catchment Management Authorities (CMAs)
- The auditor

Project proponent

The project proponent's role is to plan, design and deliver the irrigation modernisation project. This role includes a responsibility to:

- Identify water saving opportunities.
- Develop the objectives and scope of irrigation modernisation projects in conjunction with the system operator and resource manager.
- Seek all necessary approvals for irrigation modernisation projects.
- Identify potential environmental impacts, and consult with DELWP and the appropriate environmental managers about mitigation measures.
- Consult and communicate the planned works program to the system operator, and any changes as they occur.
- Implement the irrigation modernisation project in accordance with the planned works program.
- Quantify the volume of water savings from irrigation modernisation projects as per the four phases described in the technical manual component (chapter D) of this *Water Savings Protocol.*
- Report the outcomes of these water savings estimates to the system operator, resource manager, the Executive Director of Water Resource Strategy within DELWP, and others as required.
- Arrange in consultation with DELWP for an independent audit of the water savings estimates, in accordance with the audit process in this *Water Savings Protocol*.
- Report the outcomes of the independent audit to the system operator, resource manager, the Executive Director of Water Resource Strategy within DELWP, and others as required.
- If required, propose alternative methods to estimate the water savings from a project or intervention if the water savings cannot be calculated using the methods in this *Water Savings Protocol*.

System operator

The system operator's role is to assist the project proponent with irrigation modernisation projects, and assess whether the remaining loss provisions for the modernised irrigation distribution systems are sufficient to manage deliveries to entitlement holders over the long-term. This role includes a responsibility to:

- Provide quality-assured information to the project proponent that is relevant to the development and implementation of irrigation modernisation projects (including the quantification of water savings).
- In conjunction with the project proponent, consult with water users affected by irrigation modernisation projects.
- Understand the basis and implications of the water saving estimates made by the project proponent, and the independent audits of water savings.
- Where necessary, recommend to the project proponent and DELWP improvements to the estimates of water savings.
- Satisfy themselves that long-term savings, and therefore the remaining loss provisions for modernised irrigation distribution system are sustainable.
- Operate and maintain the irrigation distribution system in accordance with the agreed objectives and scope of the modernisation project.
- Make applications to the Minister for a new bulk entitlement, or to amend existing bulk entitlements to reflect long-term water savings achieved through irrigation modernisation projects.

Resource manager

The resource manager's role is to manage and allocate water resources for irrigation distribution systems in accordance with bulk entitlements. Within the context of irrigation modernisation projects, this role includes a responsibility to:

- Provide quality-assured information to the project proponent that is relevant to the development and implementation of irrigation modernisation projects (including the quantification of water savings).
- Provide the project proponent with actual and projected seasonal determinations and irrigation water deliveries for quantifying phase 2 and 3 water savings.
- Throughout the year, set aside the water savings from irrigation modernisation projects, or allocate them to the relevant bulk entitlements, in line with seasonal determinations and the project proponent's estimates of phase 2 and 3 water savings.
- Understand the basis and implications of the water savings estimates made by the project proponent, and the independent audits of water savings.
- Where necessary, recommend to the project proponent and DELWP improvements to the estimates of water savings.

Minister for Water

In Victoria, the Crown has the right to the use, flow and control of all water in a waterway and all groundwater. This right is managed by the Minister for Water on behalf of all Victorians. With regards to the quantification of water savings from modernising irrigation distribution systems, the Minister with support from DELWP:

- Has approved this *Water Savings Protocol.*
- Will periodically update the *Water Savings Protocol* to reflect best practice.
- Will consider water savings from a project or interventions not covered by this *Water Savings Protocol.*
- Will create new bulk entitlements or amend existing bulk entitlements to reflect long-term water savings realised through irrigation modernisation projects.

Minister for Energy, Environment and Climate Change

The role of the Minister for Energy, Environment and Climate Change is to oversee the management and mitigation of the environmental and cultural heritage impacts of irrigation modernisation projects. The Minister, with support from the relevant Department will:

- Work with the project proponent and the local environmental managers to identify the potential environmental impacts of irrigation modernisation projects, and the measures required to offset them.
- Develop principles for the definition and use of environmental mitigation water, to offset any environmental impacts from water savings achieved through irrigation modernisation projects.
- When necessary, provide advice to the Minister for Planning on the potential impacts of irrigation modernisation projects.

Minister for Planning

The Minister for Planning oversees the adherence of irrigation modernisation projects to all relevant planning legislation. Therefore, the Minister with support from the relevant Department will:

- Provided certain conditions are met, issue planning approvals where required for irrigation modernisation projects.
- Assess any requests from the project proponent to intervene in the planning and heritage processes associated with irrigation modernisation projects.

Department of Environment, Land, Water and Planning

DELWP's role is to support the Ministers. With regards to the quantification of water savings from irrigation modernisation projects, this includes a responsibility to:

- Manage periodic updates of this *Water Savings Protocol* to reflect best practice.
- Establish an agreed method for calculating the long-term cap equivalent (LTCE) conversion factor used to estimate water savings, and provide this LTCE conversion factor to the project proponent and system operator when required.
- Assist with the creation of new bulk entitlements or amendment of existing bulk entitlements to reflect the long-term water savings realised through irrigation modernisation projects.
- Review alternative methods proposed by project proponents for estimating the water savings, in cases where water savings cannot be estimated using the methods in this *Water Savings Protocol*.
- Establish a panel of independent auditors that can be used by project proponents to audit their estimates of water savings.

- Arrange in consultation with the project proponent for an independent audit of the water savings estimates, in accordance with the audit process in this *Water Savings Protocol*.
- Review audited water savings estimates.

Local environmental managers

The local environmental manager, which is typically a CMA, represents the interests of the environment during the development and implementation of irrigation modernisation projects. This includes a responsibility to:

- Work with the project proponent to identify the potential environmental and cultural heritage impacts of irrigation modernisation projects, and the measures required to offset them.
- Work with the project proponent to develop and implement irrigation modernisation projects in a manner that maximises the environmental benefits.
- Work with the project proponent and system operator to define the volume and use of environmental mitigation water required to offset any environmental impacts of water savings.

The auditor

The auditor's role is to verify that estimates of water savings are made in accordance with this *Water Savings Protocol*. This includes a responsibility to:

- Ensure that the data collection and inputs are as accurate as could reasonably be expected for estimating water savings.
- Confirm that water savings have been estimated based on the nature and the extent of all irrigation modernisation works.
- Provide a corrected estimate of the water savings for any component where the project proponent calculations are found to be non-compliant with the *Water Savings Protocol*.
- Recommend to DELWP changes to the *Water Savings Protocol* that will improve the useability and accuracy of water savings estimates.

Summary

Of these roles, most responsibility for the estimation, allocation and auditing of water savings from irrigation modernisation projects is with the Minister for Water supported by DELWP, the project proponent, the system operator and the resource manager. Figure 1 shows the interactions between these different groups, according to the phases of water savings estimates described in chapter D of this *Water Savings Protocol* (the technical manual).

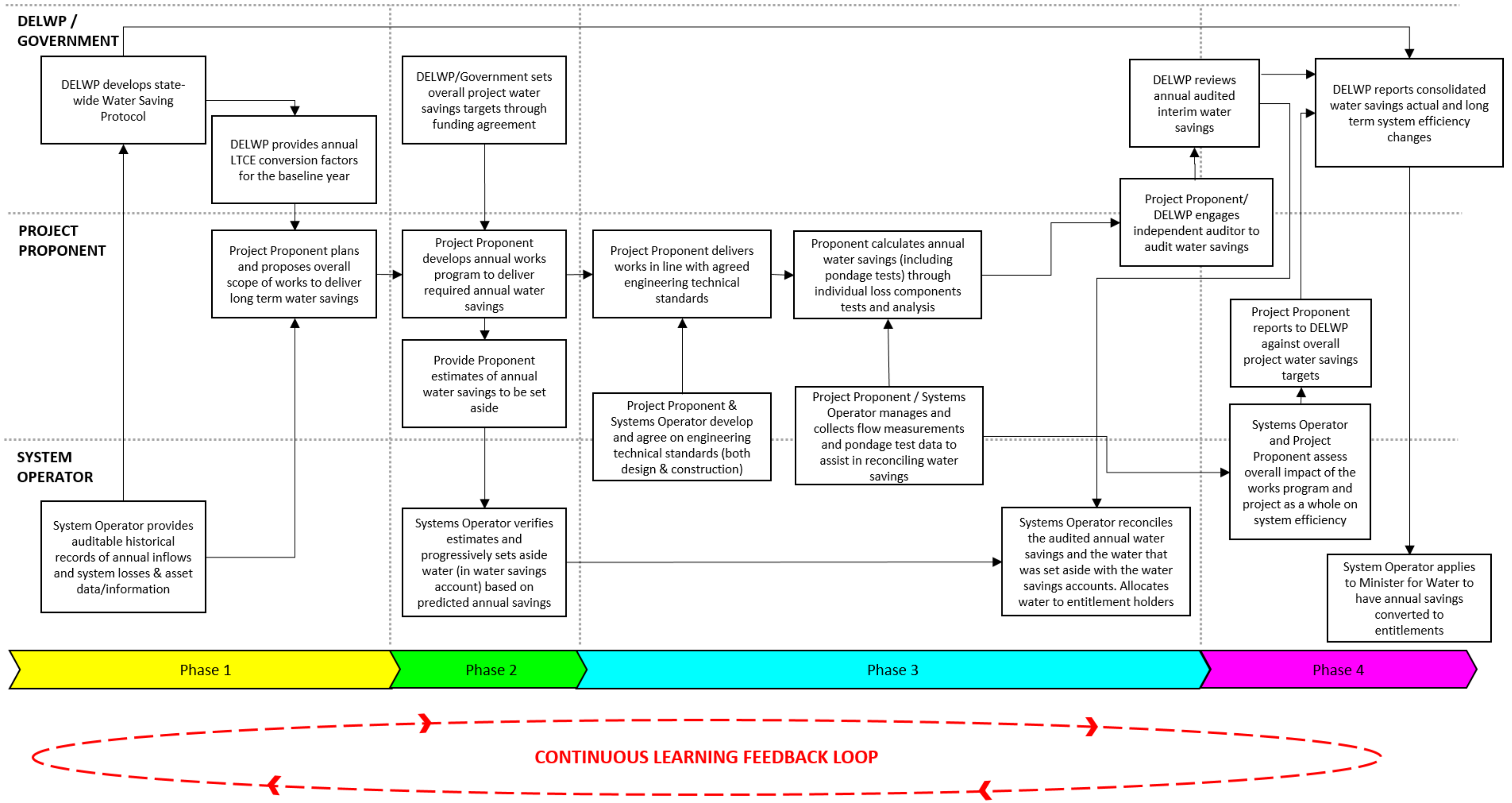

Figure 1: High level process flow for defining, capturing and reporting water savings in irrigation modernisation projects

C. Water savings audit process

The purpose of this chapter is to describe the process for independent audits of water savings estimates. This includes guidelines for appointing an auditor, and defining the scope of work. This audit process can be applied to estimates from any phase of a water savings project. However, for the year-to-year or long-term allocation of water savings, phase 3 and phase 4 estimates (respectively) require an independent audit in accordance with this guideline.

Appointment of an auditor

DELWP has a panel of independent auditors for water savings estimates. For selection to this panel, members needed to demonstrate they had no prior engagements related to Victorian irrigation modernisation projects. Project proponents may engage any panel member to audit their water savings estimates. DELWP may also engage an auditor on behalf of a project proponent.

Scope of independent audit

The scope of the independent audit is:

- Verifying that the water savings estimates have been done in accordance this *Water Savings Protocol*.
- Ensuring that the data collection and inputs are as accurate as could reasonably be expected for estimating water savings.
- Random and targeted checking that the program of works for irrigation modernisation projects have been implemented as documented in the water savings estimates.
- Confirming that water savings have been estimated based on the nature and the extent of all irrigation modernisation works.
- Providing a corrected estimate of the water savings for any component where the project proponent calculations are found to be non-compliant with the *Water Savings Protocol*.
- Identifying potential improvements to the data collection, data analysis, assumptions and methods used to estimate the water savings.
- Recommending to DELWP changes to the *Water Savings Protocol* that will improve the useability and accuracy of water savings estimates.
- Reporting on the status of the suggested improvements made in previous audits.

The audit will evaluate the project proponent's water savings estimates based on:

- Evidence relating to the irrigation modernisation works constructed, and other measures adopted to save water.
- Internal audit and performance reports prepared by the project proponent.
- Direct inspection of water savings estimation spreadsheets and models established by the project proponent.
- Any other relevant information available to, or obtained, by the auditor.

The outcome of the audit will be a detailed report that includes:

- A summary of findings.
- Background information on the irrigation modernisation projects for which the water savings estimates are being audited, including the water savings targets.
- A description of the method(s) used for the independent audit.
- The details and results of any site inspections undertaken.
- An assessment of how well the project proponent's business and information systems and processes support the calculation of water savings.
- The results of random and target sampling of the data trails used in the estimates of water savings.
- An evaluation of all water savings estimates against the *Water Savings Protocol*.
- Documentation of any instances of non-compliance with the *Water Savings Protocol*, and the changes required to the project proponent's estimates of water savings.
- Any recommended improvements to the data and methods used to estimate and report the water savings estimates, including revisions to the *Water Savings Protocol*.

Copies of the report will be provided to the project proponent, system operator, DELWP and the Minister for Water. The report will be made publicly available after being considered by DELWP and the Minister for Water.

Audit timelines

Independent audits are to be undertaken on an annual basis, prior to the allocation of water savings to entitlement holders by the system operator. A recommended timeline for the audit process is included in Figure 2. To meet this timeline, the auditor will require timely access to the relevant information held by both the project proponent and system operator.

The project proponent, or DELWP may also direct additional audits to be conducted at any time on matters relating to the estimates of water savings from irrigation modernisation projects. A further, separate independent audit of the phase 4 estimates of water savings will also occur at the end of irrigation modernisation projects to assess the long-term savings.

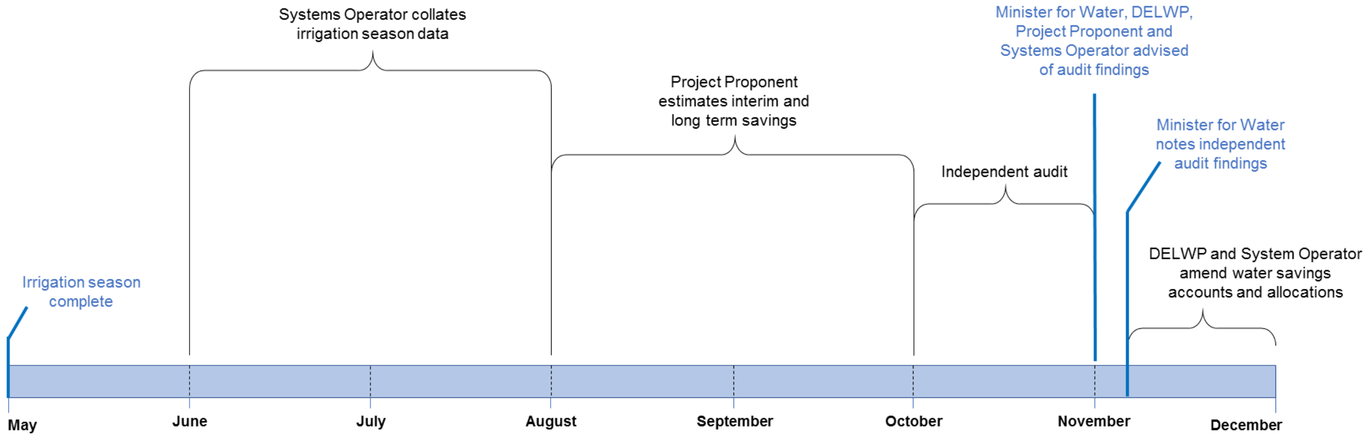

Figure 2: Recommended timeline for audits of phase 3 and phase 4 water savings estimates

D. Technical manual

Objectives

Chapter D of the *Water Savings Protocol* (the technical manual) provides guidelines on how to:

- Estimate the water savings from planned irrigation modernisation projects.
- Estimate water savings that accrue each year from irrigation modernisation works.
- Estimate long-term average water savings from irrigation modernisation projects.

The quantification of water savings is undertaken at four phases of each irrigation modernisation project. These phases are:

- **Phase 1**: The **projected Business Case** long-term average estimate of water savings for the planned program of works.
- **Phase 2**: The **predicted** water savings in a given year due to works completed in that year. These savings may be credited to a water savings account.
- **Phase 3**: The **actual** water savings based on deliveries in a given year and confirmed in a water savings account.
- **Phase 4**: The **long-term** average water savings for the executed program of works.

Phase 1 and phase 2 calculations are used for planning purposes. As these phases are predictive, they are not audited. Phase 3 and phase 4 calculations are used to facilitate the identification, allocation and use of water savings and therefore must be audited. More detail on each phase is provided in Section 5 of this chapter.

Each phase relies on the ability to quantify losses within the irrigation distribution system that is being modernised. This process is described in Part 1 of this chapter of the *Water Savings Protocol*. Part 2 then describes in detail the methods that can be used to estimate the water savings generated from irrigation modernisation.

The *Water Savings Protocol* reflects current best practice for the calculation of water savings. However, continued advancements in the field of water recovery and irrigation modernisation mean the *Water Savings Protocol* needs to be progressively reviewed and updated to ensure the best available knowledge and information is used when estimating water savings. The protocol is predominantly based on the knowledge and experience of irrigation management and modernisation in northern Victoria, but may be applied to the entire State for other modernisation projects.

PART 1 – CONTEXTUAL INFORMATION ON WATER SAVINGS CALCULATIONS

1. Definition of water savings

For the purposes of this *Water Savings Protocol*, water savings are defined as a permanent reduction of losses within an irrigation distribution system attributable to modernisation of that system. In Victoria, rights to water delivered via major irrigation distribution systems are held by a water corporation under bulk entitlements. Through these bulk entitlements, water corporations have responsibility to deliver water to entitlement holders. Bulk entitlements also provide explicit or implicit rights to a volume of water required to operate the distribution system. This water is termed distribution system operating water or more simply, distribution losses.

Where measures are taken which permanently reduce losses incurred by the water corporation in transporting water from the point of diversion to entitlement holders, the water saved may be transferred or converted into a new entitlement. Hence, the water corporation must be satisfied that the estimated water savings achieved through irrigation modernisation do reduce distribution losses on a permanent basis, without impacting on the corporation's ability to deliver water to entitlement holders.

It is important to understand that the use by others of any water which is part of a water corporation's distribution losses does not constitute a legal entitlement to this water. For example, because they make up part of the distribution losses, the under-recording of water supplied by Dethridge meters or water lost through channel outfalls remains part of the water corporation's bulk entitlement.

2. Defining the baseline for water savings

The volume of water savings is calculated as the difference in distribution losses before and after modernisation of the irrigation distribution system. These savings may then be converted and recognised as new water entitlements in the basin's bulk entitlement(s).

This process requires the establishment of a baseline or benchmark water balance, which is representative of the average asset condition and operation of the system, before it is modernised. A water balance in the context of an irrigation distribution system is an annual account of all the water flowing into and out of the system (the change in volume stored within the system is generally assumed to be negligible). The outflows include all losses from the irrigation distribution system.

For this *Water Savings Protocol*, the following terminology has been adopted:

- **Benchmark Year** – the year against which condition and performance characteristics of the assets is compared at the completion of the irrigation distribution system modernisation.
- **Baseline Year** – the year against which operational change is compared at the completion of irrigation distribution system modernisation.

Improvements in asset condition and operating practices compared to the benchmark / baseline years can generate water savings. The volume of water savings depends on the level of improvement from the benchmark asset condition and the baseline operating year.

The proposed criteria for establishing the benchmark year for asset condition and the baseline year for operating practices is explained in the following sections of this chapter. It is noted that this process may result in two different years being selected for the benchmark and the baseline years. However, where possible, one representative year should be chosen. The water balance for this representative year is then the reference point for assessing the reduction in losses attributable to irrigation modernisation projects, and hence the water savings.

2.1 Defining the benchmark year for asset condition

The selection of the benchmark year for asset condition must reflect:

- The timing of major changes in asset management processes and investment.
- The year in which the bulk entitlement for the area was granted.
- The inclusion of significant assets.
- The availability and quality of asset condition data.

Historical asset conditions and records are required to determine the benchmark year for asset condition. Changes to asset condition are then measured against this benchmark year. Asset condition reflects several factors including wear and tear, quality of maintenance, age and quality of construction. In Victoria water corporations typically given an Asset Condition Rating to their assets on a scale of 1 to 6, with 1 being new and 6 being non-functional.

If there is no significant change in overall system asset condition rating over time, the benchmark year can be based on any one 'representative year'. Otherwise, the nominated benchmark year should be defined by the historical weighted average (by length) of asset condition.

The procedure to select the benchmark year is presented in detail in Appendix B. A case study describing the application of this method for the GMW Connections Project is also provided in Appendix B.

2.2 Defining the baseline year for operational purposes

The selection of the baseline year for operational practices must consider:

- The influences that drive operational change and the timing of these influences, including drought and climate change,
- The operational influences on water allocations, the introduction of efficiency improvements, and economic factors affecting customer requirements.
- The year in which the bulk entitlement for the irrigation distribution system was granted.
- The availability and quality of records on operational practices.

Water savings estimates from interventions will vary depending on the chosen baseline. Ideally, the selection of the baseline year should reflect the original assumptions about the distribution losses adopted when the bulk entitlement was issued, and account for changes in climatic conditions.

A procedure to calculate the baseline year is provided in Appendix B. A case study to illustrate the application of the step by step method is also provided in Appendix B.

3. Long-term cap equivalent conversion factors

Direct comparison of water balances between the baseline and post irrigation modernisation can be problematic because, amongst other things, losses are influenced by irrigation delivery volumes. This variability of losses due to delivery volumes can mask changes in losses attributable to irrigation modernisation. However, this issue can be overcome by converting losses into long-term average volumes using long-term cap equivalent factors.

3.1 Definition

The **long-term cap equivalent (LTCE)** is a common water currency used to compare water savings and water entitlements across different basins or states. Alternative terms, which are similar and interchangeable with LTCE for water savings calculations, are the long-term average (LTA), the long-term average annual yield (LTAAY), or the long-term diversion limit equivalent (LTDLE). LTCE is used throughout this document.

The LTCE is calculated from computer models of a water system run over a long-term climatic sequence. It represents the **average annual volume of water** (e.g. deliveries, water losses and water savings), in either megalitres or gigalitres, that would be expected if the system was operated over the long-term under current operating rules, with the existing cap on diversions, and a repeat of historical climate conditions. Figure 3 illustrates the relationship between the LTCE delivery volume and annual delivery volumes over a nominal period of record.

In addition to comparing water volumes across basins and states, the concept of the LTCE can also be used to compare distribution losses for one year with the distribution losses in another year. This is achieved by using LTCE conversion factors, F(LTCE). To accurately quantify water savings, it is necessary to compare the distribution losses of the baseline year with the distribution losses for the years post irrigation modernisation. This comparison can only be done at a common long-term assessment level, by converting all losses to LTCE volumes. To achieve this, LTCE conversion factors need to be established for both the baseline year and the given year for which water savings are being estimated.

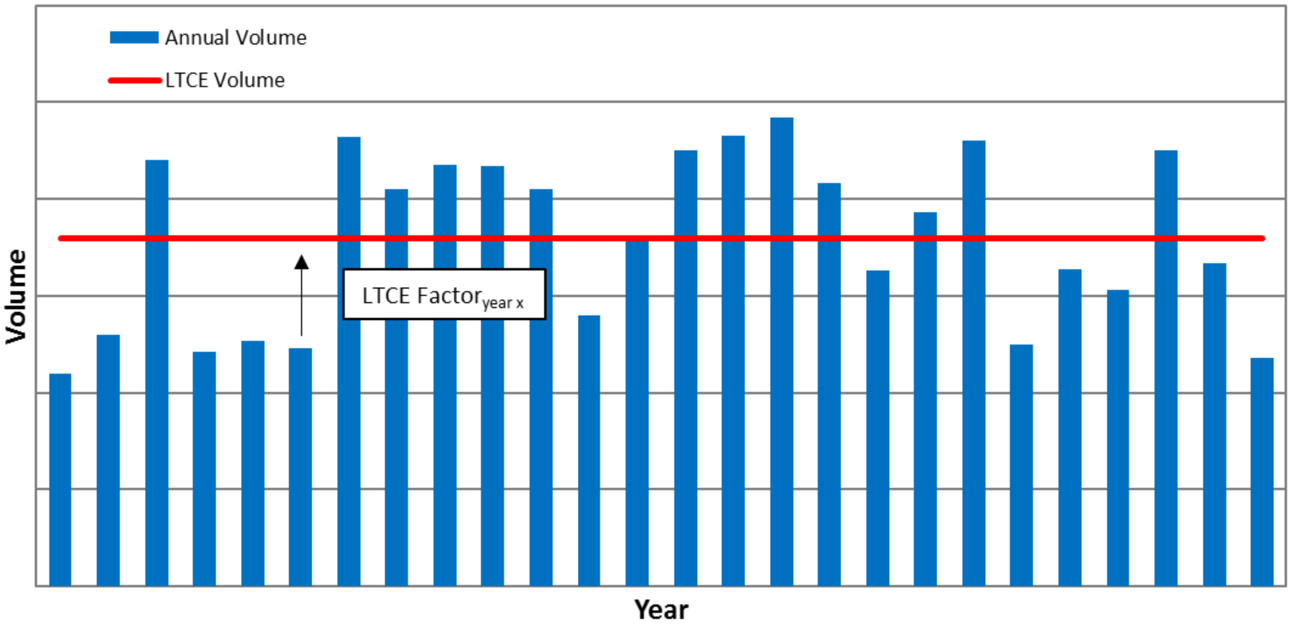

Figure 3: LTCE delivery volume in comparison with annual deliveries

3.2 Calculation

There are two F(LTCE) conversion factors that are applied when calculating phase 1 and phase 4 water savings estimates, namely:

- $F(LTCE_{base})$ – long-term cap equivalent conversion factor for the baseline year
- $F(LTCE_{YearX})$ – long-term cap equivalent conversion factor for a given year

DELWP has developed the method to calculate these conversion factors. This method recognises that losses may be fixed or variable (Figure 4). Variable losses change with delivery volumes, whereas fixed losses do not.

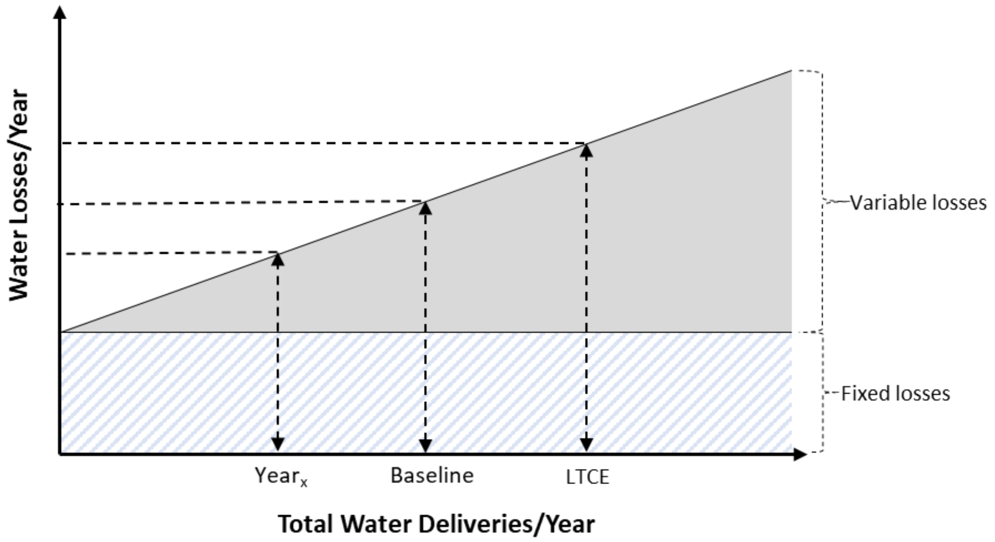

Figure 4: Fixed and variable losses relative to deliveries / diversions (LTCE and Year$_x$)

The LTCE conversion factor for a given year, is the long-term average total loss, minus the fixed loss, divided by the variable loss for that year:

$$\mathbf{F(LTCE_{Year_x})} = \frac{\mathbf{(Total\ Loss_{LTCE} - Fixed\ Loss)}}{\mathbf{Variable\ Loss_{Year_x}}}$$

Applying this equation to the baseline year, the F(LTCE)) is the long-term average total loss, minus the fixed loss, divided by the variable loss in the baseline year:

$$\mathbf{F(LTCE_{Base})} = \frac{\mathbf{(Total\ Loss_{LTCE} - Fixed\ Loss)}}{\mathbf{Variable\ Loss_{Base}}}$$

Where:

- $F(LTCE_{Base\ or\ YearX})$ = Long-term cap equivalent factor for the baseline year or given year
- $Total\ Loss_{LTCE}$ = Long-term cap equivalent (i.e. long-term average) total loss
- Fixed Loss = Fixed losses (i.e. loss volume that is independent of deliveries)
- $Variable\ Loss_{Base\ or\ YearX}$ = Variable loss in the baseline year, or given year

The baseline year variable loss is known from the baseline year water balance. The fixed loss and long-term average variable losses are determined via computer modelling using long-term flows and climatic records.

The above formula can only be used if the system characteristics configured in the water resource models used to estimate long-term average losses are similar to those on the ground. A model that represents the baseline is likely to exist; however, models that represent the yearly progression of irrigation modernisation works are unlikely to be available. Therefore, another approach to estimating the F(LTCE) is often required during the implementation of irrigation modernisation projects.

In this alternative approach, the F(LTCE) for the year in question can be approximated by multiplying the F(LTCE) for the baseline year by the ratio of system deliveries between the two years:

$$\mathbf{F(LTCE_{Year_x})} = \left(\frac{\mathbf{D_{Base}}}{\mathbf{D_{Year_x}}}\right) \times \mathbf{F(LTCE_{Base})}$$

Where:

- D_{Base} = System deliveries in the baseline year
- D_{YearX} = System deliveries in a given year

4. Estimating distribution system losses

The first step to estimate water savings from proposed or completed irrigation modernisation works is to investigate the losses within the irrigation distribution system. The total loss is the difference between bulk inflows and customer deliveries, minus environmental and other passing or returning flows. The total loss is comprised of:

- Outfalls
- Unauthorised use
- Seepage and bank leakage
- Evaporation
- Meter error
- Leakage through and around service points (delivery point to farm)
- Unmetered use

Each loss category is then further separated into fixed and variable components. A **fixed loss** is independent of flow, whereas a **variable loss** is dependent on the volume of irrigation deliveries. The length of the irrigation season and climatic factors are assumed to exert a negligible influence on fixed losses. Table 1 provides an estimate of the fixed or variable nature of each type of water loss.

Categorising losses:

- Enables interventions to be targeted for cost effectiveness.
- Helps identify variable and fixed losses.
- Simplifies the conversion of losses into LTCE volumes, and high or low-reliability water shares.
- Assists proponents and decision-makers to set realistic water savings targets.

Descriptions of each loss category are including in the following sections of this chapter.

Table 1: Fixed and variable system loss categories

System Loss	Nature of Loss
Variable (i.e. delivery-dependent) outfall losses	100% Variable
Fixed (i.e. delivery-independent) outfall losses	100% Fixed
Unauthorised use	100% Variable
Seepage	100% Fixed
Bank leakage	65% Variable, 35% Fixed
Evaporation	100% Fixed
Meter error	100% Variable
Leakage through and around service points	100% Fixed
Unmetered use	100% Variable

4.1 Outfall losses

Flows through outfall structures fall into one of three categories. These are:

- Variable or customer delivery-dependent outfall losses (proportional to customer delivery volume).

- Fixed or customer delivery-independent outfall losses (e.g. draining of channels for maintenance).
- Flows through outfall structures that are outside of system loss provisions in bulk entitlements (e.g. deliveries to downstream customers or return flows).

Where possible, for the purposes of estimating water savings, outfall volumes should be classed into these three categories with each treated differently in calculations as described below.

4.1.1 Variable or customer delivery-dependent outfall losses

The outfall losses that are influenced by factors such as customer deliveries, rainfall, the annual volume of water delivery, and the length of the irrigation season are treated as 100% variable for the purposes of estimating long-term average water savings. Delivery-dependent outfall losses occur for the following reasons:

- Rainfall rejection; and/or
- Operational activities to maintain a flow rate or pool levels at an agreed service standard (e.g. delivery of water within a certain timeframe).

In manually controlled irrigation distribution systems, there may be insufficient time to adjust channel pool levels to keep water within the system when irrigators cancel orders in response to recent or predicted rainfall. This water is then ‘outfalled’ from the channel system. Such losses are called rainfall rejections.

Operational outfall losses in manually controlled systems are caused by the difficulty of maintaining specific water levels in some supply channel pools.

For the Goulburn Murray Irrigation District (GMID) it is assumed that 50% of outfall losses are attributable to rainfall rejections and 50% to operational activities. This is based on studies of outfalls in the GMID, Shepparton Irrigation Area, and outcomes from the Strategic Measurement Program. More information on the variability and composition of outfall losses in the GMID can be found in Appendix C. However, these 50:50 factors may not be applicable to all irrigation distribution systems, because each system has a variety of factors that influence the volume and timing of operational and rainfall rejection losses

4.1.2 Fixed or delivery-independent outfall losses

The outfall losses that occur independent of customer deliveries are fixed losses. Examples of these include when channel sections are lowered or drained to undertake maintenance works, leakage through the outfall structure, or when water is used to dilute groundwater discharge into the channels to improve water quality.

While these are termed fixed losses, some may vary in magnitude from year-to-year, based on the volume of water required to carry out these activities.

4.1.3 Flows through outfall structures that are not system losses

Some flows through outfall structures should be excluded from savings calculations because they are not part of system loss provisions. These include customer deliveries through the outfall structure (e.g. delivery to a downstream irrigation area or environmental water site), or floodwaters that are diverted into the irrigation system.

4.1.4 Categorisation of outfall volumes

The category of outfall volumes should be determined on a case-by-case basis, with justification, using Table 2. Alternative categorisations to those presented in Table 2 may be used, if it is supported by adequate documentation and is approved by DELWP. If the type of outfall volume cannot be identified or justified, it should be treated as a customer delivery-dependent (variable) loss.

Table 2: Outfall volume categories and examples

Category	Examples of outfall volumes in each category
Delivery-dependent (variable) outfall losses	• Rainfall rejection • Operational water delivered to maintain channel water levels and/or provide customer deliveries
Delivery-independent (fixed) outfall losses	• Dewatering for channel maintenance or construction works – this occurs mainly in the winter (non-irrigation season), but could happen at any time • Net outfall losses from water used to dilute groundwater that enters the channel system (sometimes called groundwater dilution flows) • Leakage through the outfall structure
Outfall volumes that are not system losses and therefore should be excluded from savings calculations	• Deliveries through outfall structures, including mitigation water (Section 5.2) and environmental water • Net flood water discharge and metered groundwater pump discharge through outfall structures

4.1.5 Monitoring outfall volumes

Flows through large outfall structures are usually monitored continually throughout each year. This means the losses can be reliably quantified. Spot measurements are often undertaken at outfall structures that are not continually monitored. However, studies have shown that outfall volumes determined from once or twice daily spot measurements are sometimes significantly underestimated. For example, a study[1] of 19 outfall structures in the Katandra irrigation area showed an average underestimate of at least 60% of losses when outfall losses were spot measured. An allowance for this under-estimation should be made for all calculations where spot measurements are used, where this can be technically substantiated.

The volume of water passing through each outfall structure or regulator depends on the storage capacity of the upstream channel system and the number of service points upstream of each outfall structure. Permanent reductions in losses from outfalls can result from:

- Improving channel management/control (e.g. automation);
- Reducing water demand on the section of channel upstream of the outfall; and/or
- Improved regulator seals.

Automation of main channels reduces losses from outfalls located on main channels, and a proportion of the losses from outfalls located on spur channels. The proportion of loss reduction from outfalls located on spur channels attributable to automation depends on system configuration and the extent of relocation of service points to the backbone. If the spur channel is long and isolated (e.g. by undershot doors) from a main channel, the impact of automation may be minimal. Conversely, for short spur channels, the impact of automation on loss reduction is likely to be high.

Outfall loss reduction on spur channels may also be ascribed to the decommissioning of part or the entire spur channel system, and the associated removal or transfer of service points to the backbone. However, an investigation[2] of how to attribute GMID outfall savings demonstrated that outside the two extremes (totally backbone and totally isolated spur), the division of water savings ascribed to channel automation and to channel asset removal is difficult to define and involves relatively small volumes of water savings.

[1] *Quantification of Unmetered Channel Outfall Water*, Hydro Environmental, May 2011.

[2] *Attributing Outfall Losses and Savings*, SKM, Dec 2011.

Hence, because there is no need to tag outfall savings to channel asset removal, except in cases where spur channels can be shown to be operationally isolated from the backbone, it is assumed for simplicity that all outfall savings are attributed to channel automation.

4.2 Unauthorised use

Unauthorised use is defined as water taken from any part of the system without the necessary authorisation. It is a variable loss and is influenced by the volume of deliveries and the length of the irrigation season. Unauthorised water for the baseline year can be estimated as 0.9 ML/ year per service point, or the sum of detected unauthorised use, whichever is greater. A 20% allowance to account for undetected unauthorised use should be added to the sum of 'detected and suspected unauthorised use' where there is a high level of detection, to account for assumed undetected unauthorised use.

There is a greater uncertainty with the overall water balance for irrigation distribution systems in years of high water allocations. There also tends to be less community vigilance of water use in years where water is plentiful. For these reasons, it is assumed that there is a larger volume of water lost to unauthorised use in years of high allocations, and that this loss is therefore variable.

4.3 Seepage and bank leakage

Combined seepage and leakage losses are defined as all water lost through or over water supply channel banks and beds, or through the valves or joints on concrete or pipe structures. Seepage is the water lost via diffusion through the soil that forms the lower channel banks and bed, while leakage refers to the water lost at discrete locations (e.g. through structures, or holes and cracks in channel banks). Leakage through and around service points is covered in Section 4.6 of this chapter. The remaining leakage loss is termed bank leakage, and is discussed here.

The most accurate means of estimating seepage and bank leakage losses is via a pondage test. A pondage test uses a water balance to estimate seepage and bank leakage in an isolated channel or channels. The pondage test results should show supply level, adjacent ground level, and include a starting water level at or preferably 0.1 m above the normal supply level in the upper part of the pool.

The losses occurring at the operating level in a pondage test can include both seepage and bank leakage. In pools with both seepage and bank leakage, as the water level decreases the proportion of the loss attributed to seepage increases. At the point where the water loss curve flattens, or changes in the gradient of the curve become indiscernible, all the loss is associated with seepage (Figure 5(a)). Bank leakage is then calculated as the difference between the total loss rate and the seepage rate. In many pools, only seepage is observed during a pondage test. In these pools the rate of loss remains relatively constant as the water level decreases (Figure 5(b)), and all the loss is assumed to be seepage.

Although the level at which the water loss curve will plateau varies between pools that exhibit both seepage and bank leakage, a single water level is sometimes selected across an irrigation area to provide consistency between pools. For example, GMW often calculate seepage as the loss rate 0.2 m below the operating level.

Pondage tests only account for the static channel losses. Appendix G outlines a process for estimating the additional dynamic losses when the channels are flowing, using an adjustment factor (F(PA)). Further detail on the estimation of seepage and bank leakage rates is also provided in Appendix D.

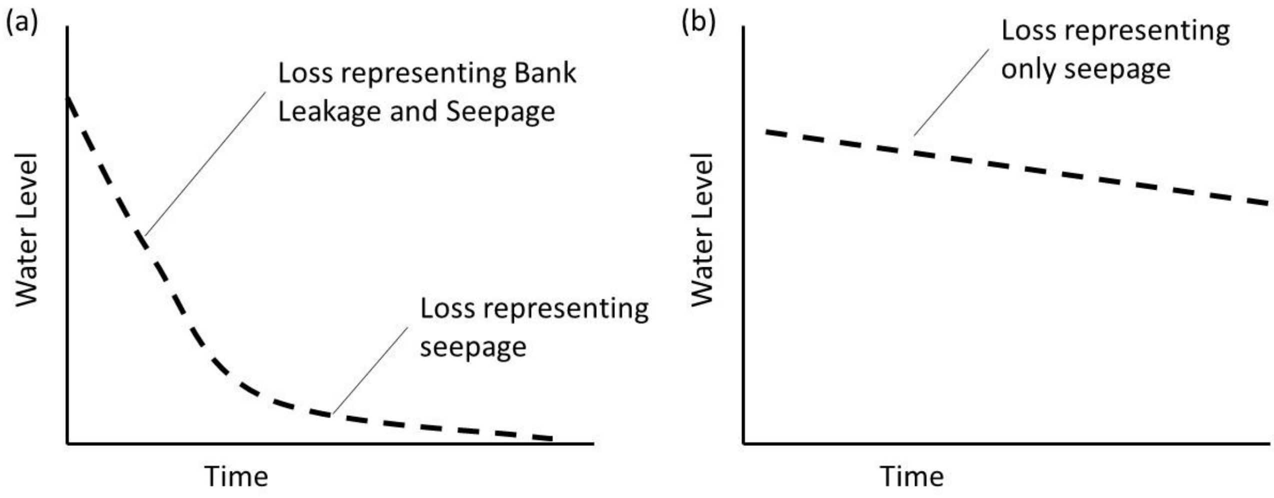

Figure 5: Pondage test representation of losses where (a) represents a pool with both seepage and bank leakage losses, and (b) represents a pool with only seepage

Apart from pondage tests, there are other methods available for estimating seepage and/or bank leakage losses[3]. These include:

- **Inflow – outflow:** This method is based on the same water balance approach used for pondage tests, but with inflow into and outflow from the isolated channel section included in the water balance. To increase the accuracy of this test, the outflow is set to zero, in which case the inflow needed to maintain a constant water level is equal to the pool losses (plus within pool delivery). Accuracy is further increased by use of a MagFlow or similar pipe meter to more accurately record low inflows.
- **Point measurement:** A point test refers to any technique which directly measures losses (typically seepage only) at a given point. It usually involves the application of water to the soil surface, or a hole, within the channel and the measurement of the rate of water loss.
- **Subsurface characterisation:** Soil type is one of the most influential variables effecting seepage rates. Using soil structure/type and geological information to assess actual or potential seepage assumes that seepage is primarily a function of hydraulic conductivity, which is in turn a function of the soil texture. This technique is used to theoretically calculate losses where other better information is not available.
- **Groundwater assessment:** The use of groundwater surface grade and groundwater quality assessments to identify and estimate seepage is based on the principle that if water is introduced to a soil profile and reaches the water table, there will be changes in the hydraulic and chemical conditions within the aquifer. When compared with channel running levels, the trends in the groundwater levels can provide an indication of losses, and from these it may be possible to indirectly estimate seepage rates.
- **Geophysical assessment:** The use of geophysics can identify channel sections where there are existing high seepage rates. The results from these tests may be related to soil types.
- **Remote sensing:** Remote sensing can be used to identify areas of land adjacent to channels that are affected by seepage from the channels. These areas either have moist soil that alters the thermal characteristics of the soil, or the areas have different vegetation health and density.

[3] *Best Practice Guidelines for Channel Seepage Identification and Measurement*, ANCID, 2003;
Review of Bank Leakage and Seepage Estimates, Jacobs, 2015.

4.3.1 Seepage

Seepage is a fixed loss which is independent of system deliveries. Evidence of this is provided in Appendix D. Seepage can vary however, if channel systems are operated for different lengths of time, and/or the depth of water in the channel varies significantly between seasons. Therefore, if the extent of the irrigation season and/or proportion of time channels are dry changes significantly from year-to-year, this will need to be reflected in estimates of seepage.

A direct measurement of seepage losses is preferred prior to any seepage mitigation intervention. However, on time constrained projects, estimates of seepage using best available theoretical technologies is acceptable. The sub-surface characterisation method is normally appropriate for phase 1 estimates of seepage losses and potential savings. This method includes estimating asset-based channel widths and lengths via aerial photography or asset-based information. However, where there has been significant batter erosion, the channel widths are often greater than those recorded in asset databases. In addition, where a channel overlies an old waterway, the seepage rates can be higher than average. In both these cases, seepage rates should be adjusted to reflect the local conditions.

4.3.2 Bank leakage

Bank leakage has a fixed component (dependent only on the length of the season) and a variable component dependent on deliveries and length of season). Anecdotally, there are also usually more channel bank leakage losses when the water levels in the channel systems exceed the design or nominal operated water level. The reasons for this are:

- The upper part of the banks are dryer and the soil is more cracked;
- There is a higher hydraulic head on the banks than usual; and/or
- The upper part of the banks is not as compacted and hence not as well waterproofed.

From analysis of data from the Central Goulburn and other GMID irrigation areas, and GMW pondage tests, it has been estimated that 65% of leakage losses are variable, and 35% fixed within earthen channels. Further information on this is provided within Appendix D.

Concrete and lined channels perform differently to earthen channels, so adopting these ratios may not always be appropriate. Instead, site-specific analysis will be required to determine the most appropriate proportion of variable and fixed leakage loss for the infrastructure planned for modernisation.

There is a large level of uncertainty surrounding bank leakage. There is also significant difficultly in capturing real time measurement for bank leakage, because it can vary significantly spatially and over time. In the absence of pondage tests on all channel sections, bank leakage is therefore often estimated as the balancing component in water balances for irrigation distribution systems. This means the uncertainty associated with all other parts of the water balance (i.e. inflows, deliveries, passing flows, and other loss components) is included in the bank leakage estimates.

If total bank leakage losses need to be disaggregated further, they can be attributed to three causes:

- **Bank point source leaks:** Bank point source leakage is estimated by summing the number of leaks detected, and multiplying this by an approximate average of 4 ML/year (or the amount determined through measurement) per leak.
- **Overtopping losses:** Overtopping losses can be assessed on a case-by-case basis where there is available data.
- **Remaining bank leakage (i.e. diffuse bank leakage):** These are the remaining bank leakage losses after subtracting the best estimate of bank point source leaks and overtopping losses.

4.4 Evaporation

Evaporation is the water lost from the surface of the irrigation distribution system. Evaporation losses are calculated by multiplying evaporation rates by surface areas estimated from asset-based channel widths and lengths. Evaporation should not vary significantly from year to year, because provided the channels have water in them, the evaporative loss is not dependent on deliveries. Therefore, evaporation is a fixed loss.

The net evaporation within a channel section is calculated by the following formula:

$$\textbf{Annual Net Evaporation (ML)} = \left(\frac{(\mathbf{E} \times \mathbf{PEF}) - \mathbf{R}}{\mathbf{1,000,000}}\right) \times \textbf{ Area } \times \textbf{CWF } \times \textbf{time}$$

Where:

- E = Evaporation (mm/day)
- PEF = Pan evaporation factor
- R = Rainfall (mm/day)
- Area = Surface area (m^2)
- CWF = Channel width factor
- time = Number of days

Rainfall and evaporation can vary significantly between locations. Therefore, it is important that the closest gauge is used to estimate evaporation and rainfall.

Evaporation is commonly measured in Australia using Class A pans. An adjustment to evaporation measured from a pan is required before being used to estimate actual evaporation from a larger water body (e.g. irrigation channel). This adjustment is termed the pan factor.

The pan factor appropriate to each irrigation distribution system will depend upon the environment in which the pan sits. In the absence of better information, a pan evaporation factor of 0.83 has been adopted for the GMID.

Water supply system channel banks often deteriorate over time, resulting in increased width and a proportionally larger surface area. Therefore, a channel width factor (CWF) can be applied to account for this increase in channel surface area. The best available information should be used to determine the CWF.

An alternative and more accurate method to determine net evaporation is to use weather station data to calculate the theoretical evaporation (if the required data is available). A comprehensive collation of the theoretical methods available for calculating evaporation losses is available in a 2013 paper[4], including a summary of their respective suitability for estimating evaporation from different types of water bodies.

[4] *Estimating actual, potential, reference crop and pan evaporation using standard meteorological data: a pragmatic synthesis*, T. A. McMahon et al., 2013

4.5 Meter error

Meter error is the additional volume of water that passes through a meter that is not accounted for due to the under recording of the meter itself. Meter error loss is variable, because it depends on the volume of water that passes through the meter.

The Australian Standard for non-urban water supply meters (AS 4747.3-2013) says that meter error can be expressed as a percentage, equal to:

$$\textbf{Meter Error}\ (\%) = \frac{(\mathbf{V_i} - \mathbf{V_a})}{\mathbf{V_a}} \times \mathbf{100}$$

Where:

- V_a = Actual volume (i.e. as determined by an accurate reference device)
- V_i = Indicated volume (i.e. as measured by the meter being tested)

The meter correction factor (MCF) is the ratio of the actual volume to the indicated volume (V_a to V_i), and is related to the meter error as per the equation:

$$\mathbf{MCF} = \frac{\mathbf{V_a}}{\mathbf{V_i}} = \frac{\mathbf{1}}{\left[\frac{\mathbf{MeterError}}{\mathbf{100}}\right] + \mathbf{1}}$$

Potential water savings from removing meter error are calculated as the difference between the indicated volume (V_i), and the indicated volume (V_i) multiplied by the MCF.

V_a can be tested directly with flow measurement equipment that is known to be accurate. For example, the large Dethridge meter has a standard rating of 822 litres per rotation of the wheel. If an in-situ field test with a more accurate meter shows the actual volume delivered per revolution of the wheel is 893, the meter error is:

$$\textbf{Meter error} = \frac{(\mathbf{822} - \mathbf{893})}{\mathbf{893}} \times \mathbf{100} = -\mathbf{8.0}\%$$

The MCF is then:

$$\mathbf{MCF} = \left(\frac{\mathbf{893}}{\mathbf{822}}\right) = \frac{\mathbf{1}}{\left[\left(-\frac{\mathbf{8.0}}{\mathbf{100}}\right) + \mathbf{1}\right]} = \mathbf{1.086}$$

This means the potential water savings from removing the meter error is (1.086 x 822) – 822, which equals 71 litres per wheel rotation or 8.6% indicated volume (i.e. the volume recorded by the Dethridge meter).

Measurement accuracy varies between types of meters, and also between individual meters within a given type. Therefore, to claim water savings from removing or reducing meter error, the project proponent must be able to show that there is existing bias in meter error, and that this bias will be removed or reduced by the irrigation modernisation project.

4.5.1 Dethridge meter error

There are three methods to estimate Dethridge meter error. These are:

- To adopt the estimated State-wide average Dethridge meter error for all Dethridge meters within the area of meter modernisation.
- To undertake indirect measurement using Dethridge meter wheel clearances and simulation models.
- To undertake direct in-situ measurements.

4.5.1.1 State-wide average

The State-wide average Dethridge meter error has been derived from previous studies into Dethridge meter accuracy, and verified using field measurements of both large and small Dethridge meters in the GMID. Specifically, in 2010 a review[5] was under taken for GMW of all the tests undertaken on Dethridge meter error in the GMID. This review concluded:

- From 2007-2010, over 300 tests were undertaken with meter error found to range from -32.6% to + 5.77%.
- The average meter error after taking into account the influence of flow rate, bottom clearance, supply depth, tail water depth, the region and maintenance level was -8.42%, with a 95% confidence interval of between -10.65% to -6.20%. This means that these meters deliver, on average, 8.42% more water than is recorded.
- Meters selected for testing and the conditions for testing were generally representative of the GMID prior to irrigation modernisation. However, it was noted that some of the later testing had a bias towards high flow rates through meters located on well operated channels.

For Version 5 of the *Water Savings Protocol* it has been decided to retain an average meter error of -8.0% for Dethridge meters. This value is generally reflective of, and conservatively within, the range of the average bias for this type of meter. Project proponents and system operators should therefore adopt an average MCF of 1.086 for Dethridge meters.

4.5.1.2 Indirect measurement (using mathematical model)

The theoretical meter error for Dethridge meters can be estimated indirectly by applying an experimentally derived mathematical model, using information obtained from service points such as drum fin clearance level, normal supply depth and normal flow rate (delivery). This method is only appropriate if the meters in the area to be modernised are not significantly different in size, condition and model, to those in the GMID (prior to GMID modernisation). Justification of why this method is appropriate should be provided to DELWP for approval prior to its use to estimate water savings. If accepted, the adjusted average can then be applied to all meters within the area being modernised.

The project proponent and system operator will need to jointly prove that the nominated meter error should be adopted by:

- Selecting a representative sample of service points within the area to be modernised;
- Collecting the information required to perform an indirect measurement at each service point; and
- Calculating the theoretical meter error using a mathematical model[6].

4.5.1.3 Direct measurement

Direct measurement provides the most accurate measure of Dethridge meter error. With direct measurement, the flow through a Dethridge meter in the field is compared with a laboratory verified meter. For example, this has previously been done using a Remote Electronic Verification System (REVS) owned by Thiess. REVS is a large portable meter certification rig that collects data that can be used to determine the accuracy of the meter.

The project proponent and system operator can choose to undertake direct accuracy testing on each Dethridge meter that is planned to be replaced or removed. Alternatively, the REVS can be used to test a statistically valid set of meters to determine the average reduction in water loss resulting from the installation of more accurate meters.

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[5] *Review of FlumeGateM^{TM} and Dethridge Meter Studies*, SKM, May 2010

[6] *In-situ REVS Testing of Large Dethridge and other Meters in the GMID*, Hydro Environmental, 2008

4.5.2 Other meter error

Generally, the measurement error associated with meters other than Dethridge meters can be ignored when undertaking a system water balance and calculating the potential water savings. This is on the basis that:

- There is no known bias in the average meter error; and
- There have been no significant changes to average meter accuracy since the baseline year.

If water savings are to be claimed for replacing or removing meters other than Dethridge meters, the project proponent must undertake appropriate testing to justify the claim, and obtain approval from DELWP for the adopted meter error.

4.6 Leakage through and around service points

Some distribution losses can be attributed to water leaking through and around Dethridge meter and open outlet service points, even when deliveries are not occurring. Both these losses are of a fixed nature and occur whenever the irrigation distribution system is operating. These losses are different and additional to losses due to unauthorised use.

Leakage through service points is defined as the unmetered water that moves through a service point due to poorly maintained seals, or the improper closing of the door by customers. Research undertaken by GMW in the Central Goulburn 1-4 (CG1-4) system (Appendix E), established that 20-30% of the previously existing Dethridge meter service points had leaks through the door seals. Based on this research, the adopted average loss rate through Dethridge meter and open outlet service points is 1.9 ML per service point per year.

Water that is lost due to inadequate design of concrete cut-off walls, poor bank compaction around the service point and/or eroded banks at the service point are all considered leakage around service points. The concrete cut off walls, and the compacted banks around the Dethridge style and open outlet service points deteriorate over time. If these are left unmaintained, leakage and seepage paths can develop. Yabbies can also cause damage around service points, thus creating seepage paths and eroding the water tightness of the infrastructure.

A loss of 0.4 ML per service point per year can be adopted to estimate the leakage lost around service points on channels prior to irrigation modernisation. This average loss rate is based on studies of service point leakage rates across the GMID, particularly the CG1-4 system (Appendix E).

Where the typical service point design and condition is significantly different to those in the GMID, an alternative loss rate can be used, provided the technical basis for the loss rate has been approved by DELWP.

4.7 Unmetered use

Unmetered use is defined as the volume of water taken in excess of allocations at unmetered service points. Often domestic and stock (D&S) and some small irrigation service points are not metered, particularly when supplied through small pipe service points (outlets) measuring between 50 mm and 200 mm in diameter. However, these unmetered service points are usually allocated a deemed volume of use.

Under deeming, the service point is assigned a volume of water that can be taken each year. Nonetheless, customers may use more water than their deemed volume depending on their usage practice and climatic conditions. Where a customer uses more water than their annual deemed volume, this becomes a loss from the irrigation distribution system.

The nature of unmetered use means it is difficult to estimate the associated losses. In the absence of better information, the long-term loss associated with each unmetered service point can be estimated from the deemed volumes and the same MCF applied for Dethridge meters.

The losses from unmetered use are considered variable. This is because deemed volumes are adjusted down on the same basis as other water shares in years of low allocation.

The relevant equations for estimating the savings associated with metering or removing unmetered services points are provided in Part 2 of chapter D. It is recognised, that generally there are only small savings to be gained through metering of deemed service points.

4.8 Other distribution losses

4.8.1 Bulk inflow/outflow measurement error

Bulk inflow/outflow measurement error is the average bias associated with measurements of bulk diversions into and out of an irrigation distribution system. Due to the large volumes associated with bulk diversions, even a small measurement error (i.e. within the expected ±5% uncertainties cited in the Australian Standard AS 4747.3-2013 for non-urban water supply meters), can result in large volumes of unaccounted water.

However, the measurement error associated with bulk diversion can generally be ignored when undertaking a water balance for an irrigation distribution system and calculating the potential water savings from modernisation provided that:

- The average bias in the bulk diversion measurement is 0%;
- The water balance and savings are calculated using flow data from a period longer than a week; and
- There are no significant changes to the bulk diversion measurement accuracy since the baseline year.

The assumption of an average 0% bias is based on the expectation that measurement error at bulk diversions is often flow dependent, and therefore over measurement at some flow rates and under measurement at others will cancel each other out. However, where possible, to improve the water balance calculations for the years of and beyond the modernisation program, bulk inflow and outflow measurements should be understood and improved before modernisation within the system begins.

4.8.2 System filling

The system filling loss is defined as the volume of water delivered to the irrigation distribution system at the beginning of the irrigation season to bring the channels back to their required operating levels. This volume accounts for the losses from the irrigation distribution system during the period between irrigation seasons (generally 15 May to 15 August).

In general, the losses in irrigation distribution systems are estimated from water balances that span a whole year (i.e. not just the irrigation season). In these cases, the system filling loss does not need to be estimated, because it will be accounted for within the outfall, seepage, leakage and net evaporation estimates.

4.8.3 Unallocated losses

Unallocated losses are the remaining losses in the water balance for the irrigation distribution system after all other loss components have been calculated. However, to close the water balance it is usual to re-categorise unallocated losses as bank leakage, and set unallocated losses to zero.

A negative unallocated loss is indicative of an inflow or outflow measurement error. If this occurs, a thorough review of the inflow and outflow measurements should be undertaken to check for errors. If appropriate, the inflow or outflows may be adjusted to reflect known biases.

PART 2 – WATER SAVINGS CALCULATION METHOD

Part 2 of chapter D, provides:

- A description of the overall process for calculating water savings from irrigation modernisation projects.
- Guidance as to which calculations apply to each phase of each project.
- A description of each water savings intervention and the components of loss targeted by each intervention.
- The effectiveness and durability of the water savings from each intervention.
- The equations for calculating water savings for the various interventions.

5. Steps to calculate water savings

Water savings calculations are based on the ability of each intervention to reduce the various components of losses in irrigation distribution systems. The general concept is described in the following equation:

$$\textbf{Water Savings} = \textbf{Losses}_{\textbf{pre intervention}} - \textbf{Losses}_{\textbf{post intervention}}$$

In order to estimate long-term water savings from irrigation modernisation projects, the following is adopted:

$$\textbf{Water Savings} = \textbf{Baseline Year Losses}_{\textbf{pre intervention}}\ (\textbf{LTCE}) - \textbf{Losses}_{\textbf{post interventions}}(\textbf{LTCE})$$

5.1 Phases for calculating water savings

Water savings are calculated for four project phases. The first phase is for Business Case estimates (to seek funding and project approval). The second and third phases are used to assist in the allocation of water savings during the implementation phase, and the fourth is for evaluating the achieved long-term water savings.

- **Phase 1**: The **projected** long-term average estimates of water savings for the planned program of works.
- **Phase 2**: The **predicted** water savings in a given year due to works completed in that year. These savings may be credited to a water savings account.
- **Phase 3**: The **actual** water savings based on deliveries in a given year and confirmed in a water savings account.
- **Phase 4**: The **long-term** average water savings from the executed program of works.

Water savings can only accrue from the date that each intervention is effectively installed, commissioned and becomes operational. In some cases, changes in regulations or contractual arrangements between the operator and the proponent of the water savings intervention may mean that the date of savings accrual is some time after commissioning.

The general steps associated with the water savings calculations are as follows:

- **Step 1**: Determine the baseline year and the associated baseline distribution losses (as per Part 1).
- **Step 2**: Convert baseline distribution losses into LTCE losses.
- **Step 3**: Calculate water savings using appropriate water savings formulae.

The application of the phases for each type of project are shown in Table 3. For major irrigation modernisation projects, especially those that are implemented over several years, or where there is a need to assess actual annual water savings as well as long-term water savings, all four phases will apply.

If works are installed partway through an irrigation season, the estimates of phase 2 and phase 3 water savings are calculated pro-rata to account for the proportion of the irrigation season that the works were operating. Phase 4 estimates of water savings should also be updated once data from a complete season of operation becomes available. Where phase 3 estimates have been determined and audited using measured deliveries, these values should be used in preference to phase 2 estimates.

Table 3: Guidelines for the application of the phased methods

Type of Project	Phase 1 (LTCE)	Phase 2 (Interim)	Phase 3 (Interim)	Phase 4 (LTCE)
Project completed within one year	✓			✓
Project completed over several years, but no need to allocate or report savings until project is finished.	✓			✓
Project completed over several years, and need to allocate savings as they occur	✓	✓	✓	✓

Figure 6 outlines the purpose, responsibilities, inputs, outputs and reporting requirements for each phase of the water savings calculations. These roles and responsibilities for the entities involved in irrigation modernisation projects are detailed in chapter B of this *Water Savings Protocol*.

The project proponent and system operator must provide evidence of the source and accuracies of data used to calculate water savings. Data sets should include both raw data and adjusted data with appropriate notation of any changes between the two data sets. The process and procedures used for data collation, manipulation and analysis must also be appropriately described.

The extent and definition of the channels and works that define the water supply system for each water savings calculation should also be agreed between the proponent and the system operator. The system may be defined as a channel, a channel and its spurs or a collection of channels and spurs.

A water balance of the modernised irrigation distribution system will be required at the end of the project, and may be required at interim stages during its implementation. This process assists with continual improvement of water savings estimation techniques, as well as confirmation of water savings effectiveness and durability. Further details of the procedure to verify long-term water savings is provided in Section 0 of this chapter.

Phases for Estimating/Verifying Water Savings as described in the Water Savings Protocol					
	PURPOSE	RESPONSIBILITY	INPUT	OUTPUT	REPORTING TO
PHASE 1	For business case target setting	Project Proponent	• Historical records of annual inflows and system losses • System characteristics and asset information • Planned works programs • Effectiveness and durability factors • Phase 1 Methodology	LTCE estimate of water savings upon complete works program	• DELWP • System Operator
PHASE 2	For setting aside predicted year to year water savings within the System Operator's water saving account	Project Proponent (for formal planning purposes) Systems Operator (for water allocation and risk management purposes)	• Expected system deliveries for year in question • Systems characteristics and asset information for works during year in question • Works program planned for year in question • Effectiveness and durability factors • Phase 2 Methodology	Predicted actual water savings to be realised in the year in question	• DELWP (for information purposes only) • System Operator
PHASE 3	For setting aside actual year to year water savings within the System Operator's water saving account	Project Proponent (for formal planning purposes) Systems Operator (for water allocation and risk management purposes)	• System deliveries and loss records for the year in question • System characteristics and asset information for the works completed during the year in question • Records of works program implemented • Effectiveness and durability factors • Phase 3 Methodology	Actual water savings realised in the year in question	• DELWP • System Operator TO BE AUDITED
PHASE 4	For assessing changes in overall system efficiency and converting water savings to entitlements	Project Proponent (for formal planning purposes) Systems Operator (for water allocation and risk management purposes)	• Historical records of annual deliveries and system losses • System characteristics and asset information • Implemented works program • Effectiveness and durability factors • Phase 4 Methodology	LTCE program water savings and system efficiency changes	• DELWP • System Operator TO BE AUDITED

Figure 6: Summary of requirements for the separate phases of assessing water savings in irrigation modernisation projects

5.2 Mitigation water

Irrigation modernisation projects generally result in less unplanned water discharges from the irrigation distribution system (though outfall structures or escapes). Some of these discharges may have entered wetlands or waterways and supported high environmental values protected under legislation. To meet environmental planning approval requirements for irrigation modernisation projects, it may therefore be necessary to set aside a portion of the gross water savings to support these key values (i.e. mitigate the impacts of the project on these values). The water that is set aside for this purpose is termed mitigation water.

In certain cases, mitigation water may be supplied from other sources such as a third-party, the employment of consumptive water en-route, or from drainage system flows, if they are of suitable quality.

The source and volume of mitigation water is determined on a project by project basis and is not included in this *Water Savings Protocol*. However, when some of the gross water savings from a modernisation project are identified as part of the mitigation water obligations for that project, the project proponent must:

- Deduct the volume of any water savings required for mitigation purposes from gross water savings identified at individual outfalls prior to water savings being transferred to project beneficiaries.
- Ensure that the volume of mitigation water at any outfall is not greater than that which can be saved at this point.
- Ensure that the volume of any water that is released at outfall structures for the purposes defined in the bulk entitlements or environmental entitlements (i.e. scheduled deliveries of environmental water) is not categorised as an outfall loss. These volumes should be deducted from the measured flow through the outfall structure before calculating the outfall losses and savings.

6. Water savings interventions

Water savings interventions are actions taken to generate water savings. These interventions target specific distribution losses and are designed to improve system delivery efficiency.

The water savings interventions associated with irrigation modernisation projects throughout Victoria are:

- Channel asset removal (rationalisation/decommissioning), which can reduce leakage, seepage, net evaporation, unauthorised use and outfalls losses.
- Automation of channels, which can reduce outfalls losses.
- Channel remediation through re-lining (plastic, clay or concrete) or replacement with pipelines, which can reduce leakage and seepage.
- Service point and/or meter replacement, which can reduce meter error, unauthorised use and leakage.
- Service point removal (rationalisation), which can reduce meter error, leakage and outfalls on spur channels.

Purchase of water entitlements may also be associated with channel asset removal. The volume purchased may be included in project targets, but is regarded as a water recovery and not a water saving.

A summary of the water savings interventions and the losses they target is presented in Table 4. As shown, many of the loss categories appear in more than one intervention. Hence, it is critical that sound procedural practices are adopted to ensure that savings from these losses are not double counted. Specifically, outfall losses (refer to Section 4.1) are aggregated into the single intervention (channel automation) to avoid double counting.

Furthermore, users of the water savings equations need to be mindful of maintaining a credible water balance. This can be done by continually checking that the sum of loss components equals estimates of total losses in the baseline and assessment years, and the sum of savings by works type equals estimates of total savings.

Methods to calculate water savings resulting from interventions are presented in the following sections. In some cases, measured data before or after irrigation modernisation interventions may not be available. In these cases, a theoretical calculation based on best practice and consistent with this Protocol should be used.

Table 4: Distribution losses targeted in irrigation modernisation projects

Intervention	Target losses[1]
Channel asset removal	Seepage, bank leakage, evaporation
Channel automation	Outfalls
Service point replacement	Meter error, leakage through and around the service points, unmetered use, unauthorised use
Service point removal	Meter error, leakage through and around the service points, unmetered use, unauthorised use
Channel remediation: Lining with plastic or concrete	Seepage, bank leakage
Channel remediation: Lining with clay	Seepage, bank leakage
Channel remediation: Channel bank remodelling with clay	Bank leakage

Note 1 Some interventions may result in savings of other types of losses (for example, channel automation may reduce bank leakage). However, for ease of calculating water savings these are the loss categories assigned to each intervention.

7. Effectiveness and durability of water savings

The ***effectiveness*** of each water savings intervention is its immediate ability to reduce distribution losses. It is the ratio of water saved to the volume of loss prior to intervention (i.e. baseline loss), i.e.:

$$\textbf{Effectiveness} = \frac{\textbf{Loss}_{\textbf{pre intervention}} - \textbf{Loss}_{\textbf{immediately post intervention}}}{\textbf{Loss}_{\textbf{pre intervention}}}$$

The ***durability*** of each of the water savings intervention is a measure of longevity of the water savings. It is calculated such that:

$$\textbf{Durability} \times \textbf{Effectiveness} = \frac{\textbf{Loss}_{\textbf{pre intervention}} - \textbf{Loss}_{\textbf{immediately prior to renewal of the intervetion}}}{\textbf{Loss}_{\textbf{pre intervention}}}$$

Figure 7 illustrates the application of water savings durability factors. These factors assume there is periodic renewal of all interventions. Figure 7 also shows that average water savings over the long-term may be greater than the volumes that can be converted to entitlement when the recommended durability factors are applied. However, water savings must be adjusted for durability before conversion into entitlement, and generally these water savings volumes are also used for reporting purposes.

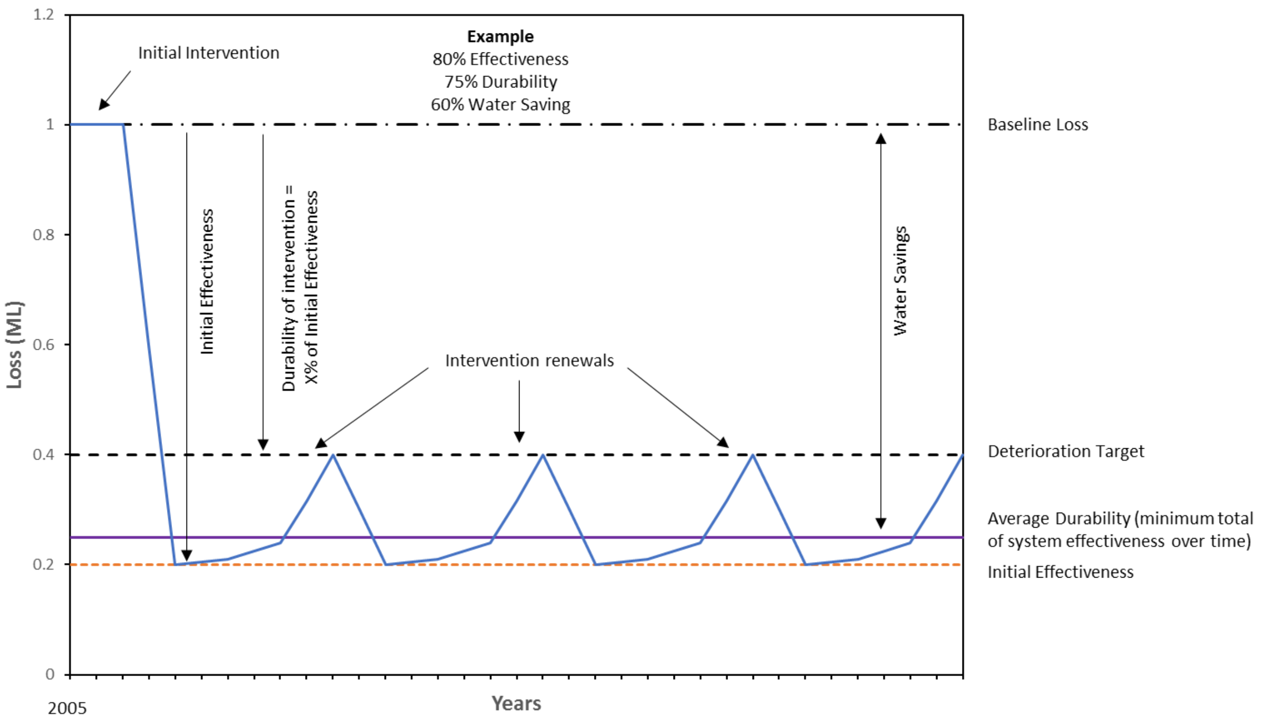

Figure 7: Application of effectiveness and durability factors in water savings calculations

The nominated durability of any intervention is based on the expected renewal periods, which depend on:

- The rate at which water tightness deteriorates over time.
- The likely cost of replacing or refurbishing the intervention so it continues to generate water savings.
- The balance between length of time between replacing or refurbishing the intervention relative to the expected loss–age relationship, and the cost effectiveness of the intervention.

Table 5 provides a summary of the effectiveness and durability factors applicable to each water savings intervention. Justification for each factor is provided in the chapter sections that follow.

Table 5: Effectiveness and durability of water savings techniques

Intervention	Effectiveness factor[1]	Durability factor[1,2]
Channel asset removal	100%[3]	100%[3]
Channel automation – Variable outfall losses	85%	95%
Channel automation – Fixed outfall losses	0%	N/A
Service point (i.e. meter) replacement – Meter error	100%	100%
Service point (i.e. meter) replacement – Unauthorised water use	80%	100%
Service point replacement – Leakage through the service point	100% with automatic control 90% with manual control	80%
Service point replacement – Leakage around the service point	100%	85% - 95% dependent on engineering standards
Service point removal – Meter error	100% when deliveries are transferred to an accurately metered service point	100%
Service point removal – Leakage through the service point – Leakage around the service point – Unauthorised use	100%	100%
Channel remediation: Channel lining with plastic or concrete – Seepage and bank leakage	95%	85% (lining exposed) 95% (lining covered with soil)
Channel remediation: Channel lining with clay – Seepage and bank leakage	85%	80%
Channel remediation: Channel bank remodelling with clay – Bank leakage	85%	80%

Note 1 Assumes assets are replaced before they deteriorate beyond condition rating 3 or pre-intervention condition, whichever is higher.

Note 2 Factors to be applied as ratios in the water savings formulae presented in the chapter sections that follow.

Note 3 Subtract residual losses if the removed channels are replaced by pipelines

7.1 Application of durability and effectiveness

Effectiveness is applied to phase 1, 2, 3 and 4 estimates in situations where there is no direct measurement data on pre and post intervention distribution losses or water savings. Durability factors are only applied for phase 1 and 4 water savings estimates.

There is no durability related reduction for phase 2 and 3 water savings estimates. However, if interventions are greater than five years old, durability factors should be used in phase 2 and phase 3. In these circumstances, the factors in Table 5 may be used on a pro-rata basis relative to the design life of the intervention.

Alternative effectiveness and durability factors to those presented in Table 5 may also be used, if supported by adequate documentation which justifies the changes, and approved by DELWP.

7.2 Glossary of symbols and terms

All the calculation methods and equations explained in the following sections use a series of common equation symbols, which are listed in Section 14. The terms used also follow a common vocabulary, as summarised in Section 15.

8. Channel asset removal

8.1 Distribution losses

In this Protocol, the term 'channel asset removal' refers to channels, pipelines or storages that are rationalised, decommissioned or removed from the publicly owned irrigation distribution system.

Removing these assets from the system as part of an irrigation modernisation project will reduce losses to:

- Seepage
- Bank leakage
- Net evaporation

Outfall savings which may be attributable to asset removal are included under channel automation. The associated savings of unauthorised use, and leakage through and around meters when channels are removed are included under service point replacement or removal.

For the GMW Connections Project, the baseline year water balance has losses separately itemised for backbone and spur channels. The equations for estimating water savings therefore only apply to removal of a proportion of the spur channels.

An alternative approach to using irrigation distribution system averages to estimate baseline year seepage, bank leakage and evaporation losses from channels is to develop a channel loss model (e.g. which relates soil and other channel characteristics to pondage test results for a sample of channels). If baseline year losses are to be estimated using a channel loss model, then the project proponent must submit the model to DELWP for review and approval. Once approved the model may be used to calculate the water savings from channel asset removal. The channel loss model and estimated water savings will be subject to the annual audit process.

8.2 Effectiveness

Channel asset removal is **100% effective** in achieving water savings.

That is, evaporation, seepage and bank leakage losses are reduced by 100% where channels, pipelines or storages are completely removed from the irrigation distribution system.

If removed channels are replaced with pipelines, losses from the pipelines need to be accounted for when estimating water savings. For low pressure pipelines (<15 m head) of 1200 mm diameter or less, a loss rate of 0.4 ML/km/year is recommended for phase 2 and phase 3 calculations. A report by GHD (2017)[7] contains further details on the technical justification for estimating savings in this manner. This approach is also based on the assumption that the pipelines are well constructed, and pressure tested prior to commissioning. For pipelines that do not fit the pressure and size criteria described above, the loss rate adopted in the water savings calculations should be discussed and agreed with DELWP.

8.3 Durability

Where assets are completely removed from the irrigation distribution system, the savings of evaporation, seepage and bank leakage will be **100% durable**.

If removed channels are replaced with pipelines, losses of 0.6 ML/km/year (i.e. 0.2 ML/km/year higher than cited in Section 8.2) need to be subtracted from the Phase 1 and Phase 4 estimates of long-term savings. This again only applies to low pressure pipelines (<15 m head) of 1200 mm diameter or less. The durability assumptions for other types of pipelines should be discussed and agreed with DELWP.

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[7] *GMW Water Savings – Review of Pipeline Losses in the Technical Manual*, GHD, 2017

8.4 Water saving equations for channel asset removal

8.4.1 Channel asset removal – PHASE 1 – business case

$$\mathbf{WS_{LTCE} = WS_{seepage(LTCE)} + WS_{bank\ leakage(LTCE)} + WS_{evaporation(LTCE)} - R}$$

Where:

$$\mathbf{WS_{seepage(LTCE)} = S_{Base} \times EF \times DF \times CL}$$

$$\mathbf{WS_{bank\ leakage(LTCE)} = [(L_{Base} \times FL) + (L_{Base} \times VL \times F(LTCE_{Base}))] \times EF \times DF \times CL}$$

$$\mathbf{WS_{evaporation(LTCE)} = E_{Base} \times EF \times DF \times CL}$$

- $\mathrm{WS_{LTCE}}$ = Estimate of long-term water savings (ML LTCE)
- $\mathrm{S_{Base}}$ = Seepage in the baseline year (ML)[1]
- $\mathrm{L_{Base}}$ = Bank leakage in the baseline year (ML)[1]
- $\mathrm{E_{Base}}$ = Net evaporation in the baseline year (ML)[1]
- FL = Proportion of bank leakage loss that is fixed – (refer Table 1)
- VL = Proportion of bank leakage loss that is variable – (refer Table 1)
- EF = Effectiveness factor (refer Table 5)
- DF = Durability factor (refer Table 5)
- CL = Ratio of length of channels to be removed to the total length of channel[1]
- $\mathrm{F(LTCE_{Base})}$ = Conversion factor for long-term cap equivalent
- R = Residual losses if channel is replaced by pipeline (0.6 ML/km/year)[2]

Note 1 For the GMW Connections Project, S_{Base}, L_{Base} and E_{Base} are the losses on all spur channels, and CL only applies to spur channels.

Note 2 This applies to low pressure pipelines (<15 m head) with diameter ≤1200 mm

8.4.2 Channel asset removal – PHASE 2 – setting aside

$$\mathbf{WS_{Year_x} = WS_{seepage} + WS_{bank\ leakage} + WS_{evaporation} - R}$$

Where:

$\mathbf{WS_{seepage} = S_{Base} \times EF \times t_r \times CL}$

$\mathbf{WS_{bank\ leakage} = \left[(L_{Base} \times FL) + \left(L_{Base} \times VL \times \left(D_{Year_x}/D_{Base}\right)\right)\right] \times EF \times t_r \times CL}$

$\mathbf{WS_{evaporation} = E_{Base} \times EF \times t_r \times CL}$

• WS_{Year_x}	=	Water savings estimate for the year in question (ML)
• S_{Base}	=	Seepage in the baseline year (ML)[1]
• L_{Base}	=	Bank leakage in the baseline year (ML)[1]
• E_{Base}	=	Net evaporation in the baseline year (ML)[1]
• FL	=	Proportion of bank leakage loss that is fixed – (refer Table 1)
• VL	=	Proportion of bank leakage loss that is variable – (refer Table 1)
• EF	=	Effectiveness factor (refer Table 5)
• t_r	=	Length of time in days a channel is removed for the year in question, divided by the irrigation season length in days for the baseline year.
• CL	=	Ratio of length of channels to be removed to the total length of channel[1]
• D_{Year_x}	=	Customer deliveries to the irrigation distribution system in the year in question (ML)
• D_{Base}	=	Customer deliveries to the irrigation distribution system in the baseline year (ML)
• R	=	Residual losses if channel is replaced by pipeline (0.6 ML/km/year)[2]

Note 1 For the GMW Connections Project, S_{Base}, L_{Base} and E_{Base} are the losses on spur channels, and CL only applies to spur channels.

Note 2 This applies to low pressure pipelines (<15 m head) with diameter ≤1200 mm

8.4.3 Channel asset removal – PHASE 3 – for allocation

$$\mathbf{WS_{Year_x} = WS_{seepage} + WS_{bank\ leakage} + WS_{evaporation} - R}$$

Where:

$$\mathbf{WS_{seepage} = S_{Base} \times CL \times t_r \times EF}$$

$$\mathbf{WS_{bank\ leakage} = \left[(L_{Base} \times FL) + \left(L_{Base} \times VL \times \left(D_{Year_x}/D_{Base}\right)\right)\right] \times CL \times t_r \times EF}$$

$$\mathbf{WS_{evaporation} = E_{Base} \times CL \times t_r \times EF}$$

• WS_{Year_x}	=	Water savings estimate for the year in question (ML)
• S_{Base}	=	Seepage in the baseline year (ML)[1]
• L_{Base}	=	Bank leakage in the baseline year (ML)[1]
• E_{Base}	=	Net evaporation in the baseline year (ML)[1]
• FL	=	Proportion of bank leakage loss that is fixed – (refer Table 1)
• VL	=	Proportion of bank leakage loss that is variable – (refer Table 1)
• EF	=	Effectiveness factor (refer Table 5)
• t_r	=	Length of time in days a channel is removed for the year in question, divided by the irrigation season length in days for the baseline year.
• CL	=	Ratio of length of channels to be removed to the total length of channel[1]
• D_{Year_x}	=	Customer deliveries to the irrigation distribution system in the year in question (ML)
• D_{Base}	=	Customer deliveries to the irrigation distribution system in the baseline year (ML)
• R	=	Residual losses if channel is replaced by pipeline (0.6 ML/km/year)[2]

Note 1 For the GMW Connections Project, S_{Base}, L_{Base} and E_{Base} are the losses on spur channels, and CL only applies to spur channels.

Note 2 This applies to low pressure pipelines (<15 m head) with diameter ≤1200 mm

8.4.4 Channel asset removal – PHASE 4 – long-term

$$\mathbf{WS_{LTCE}} = \mathbf{WS_{seepage(LTCE)}} + \mathbf{WS_{bank\ leakage(LTCE)}} + \mathbf{WS_{evaporation(LTCE)}} - \mathbf{R}$$

Where:

$$\mathbf{WS_{seepage\ (LTCE)}} = \mathbf{S_{Base}} \times \mathbf{CL} \times \mathbf{EF} \times \mathbf{DF}$$

$$\mathbf{WS_{bank\ leakage\ (LTCE)}} = [(\mathbf{L_{Base}} \times \mathbf{FL}) + (\mathbf{L_{Base}} \times \mathbf{VL} \times \mathbf{F(LTCE_{Base})})] \times \mathbf{CL} \times \mathbf{EF} \times \mathbf{DF}$$

$$\mathbf{WS_{evaporation\ (LTCE)}} = \mathbf{E_{Base}} \times \mathbf{CL} \times \mathbf{EF} \times \mathbf{DF}$$

- WS_{LTCE} = Estimate of long-term water savings (ML LTCE)
- S_{Base} = Seepage in the baseline year (ML)[1]
- L_{Base} = Bank leakage in the baseline year (ML)[1]
- E_{Base} = Net evaporation in the baseline year (ML)[1]
- FL = Proportion of bank leakage loss that is fixed – (refer Table 1)
- VL = Proportion of bank leakage loss that is variable – (refer Table 1)
- EF = Effectiveness factor – (refer Table 5)
- DF = Durability factor to account for the durability of water saving intervention
- CL = Ratio of length of channels to be removed to the total length of channel[1]
- $F(LTCE_{Base})$ = Conversion factor for long-term cap equivalent
- R = Residual losses if channel is replaced by pipeline (0.6 ML/km/year)[2]

Note 1 For the GMW Connections Project, S_{Base}, L_{Base} and E_{Base} are the losses on spur channels, and CL only applies to spur channels.

Note 2 This applies to low pressure pipelines (<15 m head) with diameter ≤1200 mm

9. Channel automation

9.1 Distribution losses

Automating channels will reduce outfall losses and possibly upper bank leakage. Automation is defined as provision of regulator gates that can be operated in real time in a network either remotely by operators, or by using a control strategy and system, to regulate a series of channel pool levels to meet customer demands with significantly reduced need for on-site manual intervention. A key benefit of automating open channel systems is the ability to continuously measure and control water levels at each regulating structure.

The water savings attributed to channel automation can be calculated per the following sections.

9.2 Effectiveness

For planning purposes, network-controlled channel automation is estimated to be **85% effective** in reducing variable (customer delivery-dependent) outfall losses. As discussed in Section 4.1 and in Appendix C, variable outfall losses can be classified as either operational outfall volumes or rainfall rejections.

A reduction in operational outfall volumes is dependent on the lag time taken for the system to respond to changes in water demand. The installation of remote controlled automated regulators and flume gates shortens the response time and increases the certainty/accuracy of system inflow rates and flow control within the irrigation distribution system.

Reduction of rainfall rejections is dependent on the time required to safely close regulators when a rainfall event occurs. This rate of reduction is limited by the within-system storage capacity and the speed with which inflows can be stopped. Storage capacity generally varies from channel to channel depending on the difference between the channel supply level and the hydraulic grade line (wedge), the number of pipe structures, the length of each pool and the extent of bank. However, replacing manually operated drop bar style regulators with automated gates significantly decreases the channel shutdown and ramp up response time, and therefore eliminates a significant portion of rainfall rejections.

In analysing outfall losses in the GMID from 1996 to 2004, Marsden Jacobs Associates (MJA)[7] and SKM[8] concluded that the best estimate is that on average 50% of the variable outfall losses can be attributed to rainfall rejections and 50% attributed to operational activities. MJA adopted a 98% effectiveness factor for operational outfall losses and 75% for rainfall rejection in the Shepparton Irrigation Area modernisation business case[8]. Therefore, the volume weighted average of the MJA effectiveness figures for total outfall loss reduction was approximately 85%. The subsequent modelling undertaken by SKM for the Shepparton Irrigation Area also assumed 85% effectiveness[9]. During the first two years of the modernised CG1-4 system, 2,900 ML per year of outfall savings were achieved, and this is also 85% of the baseline estimate outfall losses (3,390 ML).

In the absence of better information, channel automation can therefore be considered to effectively reduce rainfall rejections by 75% and operational loss rejections by 95%. If data is also not available to effectively categorise operational outfall losses and rainfall rejections, then it is assumed pre-modernisation outfall losses are split 50:50 between these two categories. Combining the two aspects results in an average effectiveness of 85% for the reduction of outfall losses from channel automation.

Network-controlled channel automation is 0% effective in reducing fixed (delivery-independent) outfall losses. This is because automating a channel system is unlikely to reduce the volume of water that is lost due to activities that cause these delivery-independent losses (e.g. draining a channel to perform maintenance).

[8] *Shepparton Irrigation Area Modernisation Business Case*, MJA, 2005.

[9] *Shepparton Irrigation Area Water Savings Project: Regression Analysis Method and Preliminary Results*, SKM, 2006

9.3 Durability

The durability of water savings achieved by reducing delivery-dependent outfalls using channel automation is estimated to be **95%**.

A high level of durability (such as 100%) is achievable for operational outfall losses if channel automation operates correctly and always maintains the water level within design levels. However, given the dynamic nature of system operations and the possibility of periodic malfunctions, a durability of 95% is recommended. This lower durability will accommodate equipment malfunctions, and wetter years when the channels may be operated at higher water levels (thus reducing the storage available for capturing rainfall rejections).

A durability factor is not required to estimate the savings of fixed (delivery-independent) outfall losses from channel automation, because automation is not effective at saving these types of losses.

9.4 Water savings equations for channel automation

Data should be collected for each channel network supplying each outfall structure as automation is implemented across the irrigation distribution system. Data defining the extent of automation of the channels leading to each outfall structure is required at the end of each irrigation season to estimate the savings at each outfall structure. The savings attributable to automation are calculated based on the extent of upstream channel automation.

The extent of network upstream of each outfall structure or collection of outfall structures should be agreed with system operators on a case by case basis. A channel system requires more than 25% of its length to be automated before any water savings can be claimed from automation. Therefore, where the ratio of channel length automated to total channel length upstream of outfall structures is < 25%, an effectiveness of 0% should be adopted for automation.

The annual volumes of mitigation water delivered through individual outfall structures (refer to Section 5.2) are classified in accordance with Table 2 when estimating the gross savings attributable to channel automation. The volume of mitigation water required to pass through each outfall structure is specified in wetland and waterway specific Environmental Watering Plans (EWP). The EWP must account for the expected outfall volumes post-modernisation, and be approved by the Minister for Water.

Outfall losses should be treated collectively for parts of the irrigation distribution system where outfall operations are interrelated, and where discharge from individual outfall structures is highly variable and dependent on operational discretion. Compared with treating outfall structures individually, grouping outfall structures in this manner will reduce potential circumstances where outfall volumes in a given year exceed those of the baseline year. However, if this situation does still occur, the outfall savings for the given year should be set to zero.

In some instances, the losses recorded for some outfall structures in the baseline year may underestimate the true loss. This may be because of:

- Outfall measuring structures not recording high flows (e.g. bypassing Dethridge meters)
- New structures being installed after the baseline year
- Spot recordings not accurately representing flow rates and flows.

In some instances where baseline year losses are under recorded, post automation recording of outfall losses (which accurately measure all flows) can result in negative water savings being calculated. Therefore, as part of the water savings calculation process, the accuracy of the baseline year should be assessed and recorded. If the under recording of baseline year losses can be shown to be the reason for negative estimates of outfalls savings, the savings can be assumed to be zero.

9.4.1 Channel automation – PHASE 1 – business case

$$\mathbf{WS_{LTCE}} = \mathbf{WS_{outfalls(LTCE)}}$$

Where:

$$\mathbf{WS_{outfalls}} = (\mathbf{O_{Base}} \times \mathbf{V_b} \times \mathbf{F(LTCE_{Base})} \times \mathbf{EF_{Variable}} \times \mathbf{DF_{Variable}}) + (\mathbf{O_{Base}} \times (\mathbf{1} - \mathbf{V_B}) \times \mathbf{EF_{Fixed}})$$

- WS_{LTCE} = Estimate of long-term water savings (ML LTCE)
- O_{Base} = Outfall loss in the baseline year (ML)
- V_B = Proportion of baseline year outfall losses that are delivery-dependent (i.e. variable)
- $EF_{Variable}$ = Effectiveness factor for variable outfall losses – (refer Table 5)
- EF_{Fixed} = Effectiveness factor for fixed outfall losses – (refer Table 5)
- $DF_{Variable}$ = Durability factor for savings of variable outfall losses – (refer Table 5)
- $F(LTCE_{Base})$ = Conversion factor for long-term cap equivalent

9.4.2 Channel automation – PHASE 2 – setting aside

$$\mathbf{WS_{Year_x}} = \mathbf{WS_{outfalls}}$$

Where:

$$\mathbf{WS_{outfalls}} = \left(\mathbf{O_{Base}} \times \mathbf{V_b} \times \mathbf{A} \times \mathbf{t_a} \times \left(\frac{\mathbf{D_{Year_x}}}{\mathbf{D_{Base}}}\right) \times \mathbf{EF_{Variable}}\right) + (\mathbf{O_{Base}} \times (\mathbf{1} - \mathbf{V_B}) \times \mathbf{EF_{Fixed}})$$

- WS_{Year_x} = Water savings estimate for the year in question[1] (ML)
- O_{Base} = Outfall loss in the baseline year (ML)
- V_B = Proportion of baseline year outfall losses that are delivery-dependent (i.e. variable)
- $EF_{Variable}$ = Effectiveness factor for variable outfall losses – (refer Table 5)
- EF_{Fixed} = Effectiveness factor for fixed outfall losses – (refer Table 5)
- A = Ratio of the length of channel automated to the total length of channel
- t_a = Ratio of the length of time a channel has been automated in the year in question, relative to the irrigation season length in the baseline year
- D_{Year_x} = Customer deliveries to the irrigation distribution system in the year in question (ML)
- D_{Base} = Customer deliveries to the irrigation distribution system in the baseline year[2] (ML)

Note 1 This equation may be applied for an individual outfall, or on a collective basis for an irrigation distribution system or part thereof (e.g. pod). However, application must be on an outfall by outfall basis for sites supplied with mitigating flows. At sites receiving mitigating flows this equation must result in outfall savings ≥ 0 (i.e. mitigation water can never be greater than outfall volumes in any one year).

Note 2 If delivery data for the baseline year is not available, assume D_{Base} is the water share volume multiplied by the baseline year allocation.

9.4.3 Channel automation – PHASE 3 – for allocation

$$\mathbf{WS_{Year_x}} = \mathbf{WS_{outfalls}}$$

Where:

$$\mathbf{WS_{outfalls}} = \left[\left(\mathbf{O_{Base_{Variable}}} \times \left(\frac{\mathbf{D_{Year_x}}}{\mathbf{D_{Base}}}\right)\right) - \mathbf{O_{Year_{x_{Variable}}}}\right] + \left[\mathbf{O_{Base_{Fixed}}} - \mathbf{O_{Year_{x_{Fixed}}}}\right]$$

- WS_{Year_x} = Water savings estimate for the year in question[1,2] (ML)
- $O_{Base_{Variable}}$ = Variable outfall loss in the baseline year (ML)
- $O_{Year_{x_{Variable}}}$ = Variable outfall loss in the year in question (ML)
- $O_{Base_{Fixed}}$ = Fixed outfall loss in the baseline year (ML)
- $O_{Year_{x_{Fixed}}}$ = Fixed outfall loss in the year in question (ML)
- D_{Base} = Customer deliveries to the irrigation distribution system in baseline year (ML)
- D_{Year_x} = Customer deliveries to the irrigation distribution system in the year in question[3] (ML)

Note 1 Where WS_{YearX} is negative, it may be treated as zero if under recording in the baseline year can be proven.

Note 2 This equation may be applied for an individual outfall, or on a collective basis for an irrigation distribution system or part thereof (e.g. pod). However, application must be on an outfall by outfall basis for sites supplied with mitigating flows. At sites receiving mitigating flows this equation must result in outfall savings ≥ 0 (i.e. mitigation water can never be greater than outfall volumes in any one year).

Note 3 If delivery data for the baseline year is not available, assume D_{Base} is the water share volume multiplied by the baseline year allocation.

9.4.4 Channel automation – PHASE 4 – long-term

$$\mathbf{WS_{LTCE}} = \mathbf{WS_{outfalls(LTCE)}}$$

Where:

$$\mathbf{WS_{outfalls(LTCE)}} = \left(\left(\mathbf{O_{Base_{Variable}}} \times \mathbf{F(LTCE_{Base})}\right) - \left(\mathbf{O_{Year_{x_{Variable}}}} \times \mathbf{F(LTCE_{Year_x})}\right) \times \mathbf{DF_{Variable}}\right) + \left(\mathbf{O_{Base_{Fixed}}} - \mathbf{O_{Year_{x_{Fixed}}}}\right)$$

- WS_{LTCE} = Estimate of long-term water savings[1,2] (ML LTCE)
- $O_{Base_{Variable}}$ = Variable outfall loss in the baseline year (ML)
- $O_{Year_{x_{Variable}}}$ = Variable outfall loss in the year in question (ML)
- $O_{Base_{Fixed}}$ = Fixed outfall loss in the baseline year (ML)
- $O_{Year_{x_{Fixed}}}$ = Fixed outfall loss in the year in question (ML)
- $DF_{Variable}$ = Durability factor for variable loss savings – (refer Table 5)
- $F(LTCE_{Base})$ = Conversion factor for long-term cap equivalent, for the baseline year
- $F(LTCE_{Year_x})$ = Conversion factor for long-term cap equivalent, for the year in question

Note 1 Where WS_{LTCE} is negative, it may be treated as zero if under recording in the baseline year can be proven.

Note 2 This equation may be applied for an individual outfall, or on a collective basis for an irrigation distribution system or part thereof (e.g. pod). However, application must be on an outfall by outfall basis for sites supplied with mitigating flows. At sites receiving mitigating flows this equation must result in outfall savings ≥ 0 (i.e. mitigation water can never be greater than outfall volumes in any one year).

10. Service point replacement

10.1 Distribution losses

A service point is a location where water is taken from the irrigation distribution system by a customer. Customers may have more than one service point, and service points may or may not be metered. Upgrading (i.e. replacing) service points will result in a reduction in the following losses:

- Meter error
- Leakage through and around service points
- Unmetered use
- Unauthorised use

The water savings attributed to service point replacement can be calculated as detailed in the following sections.

In addition, the water savings estimated from service point removal, where the delivery share for a service point is transferred to another Dethridge metered service point which is then in turn replaced with an accurate meter, are attributable to phase 3 and phase 4 estimates for service point replacement rather than removal. Therefore, care should be taken to avoid double counting savings because of the definitions or tracking of service point relocations or removal. For these calculations service points may be:

- **Replaced**. In this case an old meter at an existing service point is replaced with an upgraded meter at or near the service point. For example, if a customer has two existing service points at which two new meters are installed, then two replacements have occurred.
- **Removed**. This only occurs if the total number of service points on a property is reduced. For example, if a customer has two existing service points, and one service point is upgraded and one is retired and physically removed, then one replacement and one removal has occurred.

Not all new meter installations involve replacement of pre-modernisation meters. For example, if a customer with an existing service point has two new meters installed (one at the existing service point, and one at a new service point), then only one replacement has occurred.

Accounting for water savings based on the records of all newly installed service points and meters, without careful tracking of the history of the service points and meters, can lead to water savings being overstated. Occasionally, during the relocation of service points the old service point identifiers (or numbers) have been cancelled and new identifiers created. In this example, it may appear that a new service point has been created; however, for water savings purposes it is a replacement. The simplest method to account for service point related savings, is to track what physical work has occurred to the pre-modernised service points and meters.

10.2 Effectiveness

10.2.1 Meter error

Replacing Dethridge meters, and the metering of unmetered service points, are **100% effective** in reducing meter error. This is on the basis that the newly installed meters are compliant with National Metering Standards.

The replacement of Dethridge meters with National Metering Standards compliant meters, will reduce meter error by 8% within the northern region of Victoria (resulting in an MCF of 1.086). The newly installed meters must measure flow within ± 5%, with an average flow weighted bias of 0%.

10.2.2 Leakage through service points

Replacing service points with meters that are compliant with the National Metering Standards is **100% effective** at reducing leakage through automated service points, and **90%** for those manually operated. The lower effectiveness for manually operated service points reflects the higher probability of operator error causing leakage losses post modernisation, compared with automated service points.

System operators and/or project proponents need to continue to inspect replaced service points post installation, to ensure these effectiveness levels are achieved, and the water savings claimed are maintained.

10.2.3 Leakage around service points

Replacing service points with meters that are compliant with the National Metering Standards is **100% effective** at reducing leakage around meters.

The replacement of existing service points with appropriately designed cut-offs and head walls of at least 700 mm and 1,000 mm respectively into a solid bank, results in an immediate reduction in leakage around the meters. An inspection of new service points in the Central Goulburn Channel No 2, installed under the CG 1-4 irrigation modernisation program, showed no evidence of leakage around the replaced service points.

System operators and/or project proponents need to inspect replaced service points, to ensure appropriate design and construction standards are used, and the water savings claimed are maintainable.

10.2.4 Unauthorised use

Replacing service points using new meters is estimated to be **80% effective** in reducing unauthorised use. Anecdotally, the replacement of service points reduces the volume of unauthorised use, because better water balance information enables system operators to more readily identify unauthorised use.

10.3 Durability

10.3.1 Meter error

Replacing old meters with new meters that are compliant with the National Metering Standards, will result in meter error water savings that are **100% durable**. This is because new meters installed and maintained in accordance with the standards should, on a flow weighted basis, have no measurement bias and retain their calibration.

10.3.2 Leakage through service points

The water savings of leakage through service points via service point replacement will be **80% durable**.

Over time, leakage rates through service points are expected to return to 20% of pre-modernisation rates, through deterioration of the gate seals that sit before the meters at service points. This assumption is based on the currently best available knowledge.

10.3.3 Leakage around service points

The durability of water savings of leakage around service points varies in accordance with the engineering standard employed to replace service points. Table 6 shows the durability factors for three levels of engineering standards.

Table 6: Durability of reduction in leakage around service points, based on the engineering standards employed

Engineering Standard	Durability (%)	Details
Designed to Ideal Engineering Standards	**95%**	• Appropriate depth/length of cut off and head walls (approximately 700 mm and 1,000 mm respectively into solid ground) • Cut off walls designed and constructed to match service point dimensions and service needs • Appropriate rock beaching underlain by geotextile to maintain channel bank profile • High level of construction supervision and sign off (i.e. high-quality assurance focus) • Ongoing maintenance of channel profiles
Designed to Lower Engineering Standards	**85%**	• Cut off wall not appropriately designed and constructed to match service point dimensions and service needs • Less than appropriate level of rock beaching to maintain channel bank profile • No ongoing maintenance of channel profiles
Unsuitable	**0%**	• No cut off walls • No rock beaching to maintain channel bank profile • No ongoing maintenance

10.3.4 Unauthorised use

Replacing old meters with new meters will have **100% durability** in reducing unauthorised use.

This is assuming the replaced service points operate correctly, and the modernised system allows operators to better detect unauthorised use (through remote read facilities) and respond accordingly.

10.4 Water saving equations for service point replacement

10.4.1 Service point replacement – PHASE 1 – business case

$$\mathbf{WS_{LTCE}} = \mathbf{WS_{meter\ error(LTCE)}} + \mathbf{WS_{unmetered(LTCE)}} + \mathbf{WS_{leakage\ through(LTCE)}} + \mathbf{WS_{leakage\ around(LTCE)}} + \mathbf{WS_{unauthorised(LTCE)}}$$

Where:

$$\mathbf{WS_{meter\ error(LTCE)}} = \mathbf{D_{MBase}} \times (\mathbf{MCF} - \mathbf{1}) \times \mathbf{EF} \times \mathbf{DF} \times \mathbf{F(LTCE_{Base})}$$

$$\mathbf{WS_{unmetered(LTCE)}} = \mathbf{D_{UBase}} \times (\mathbf{MCF} - \mathbf{1}) \times \mathbf{EF} \times \mathbf{DF} \times \mathbf{F(LTCE_{Base})}$$

$$\mathbf{WS_{leakage\ through\ (LTCE)}} = \mathbf{N_{replaced}} \times \mathbf{LTT} \times \mathbf{EF} \times \mathbf{DF}$$

$$\mathbf{WS_{leakage\ around\ (LTCE)}} = \mathbf{N_{replaced}} \times \mathbf{LTA} \times \mathbf{EF} \times \mathbf{DF}$$

$$\mathbf{WS_{unauthorised(LTCE)}} = \mathbf{N_{replaced}} \times \mathbf{U_{Base}} \times \mathbf{EF} \times \mathbf{DF} \times \mathbf{F(LTCE_{Base})}$$

- WS_{LTCE} = Estimate of long-term water savings (ML LTCE)
- D_{MBase} = Baseline year customer deliveries as measured by the original Dethridge meters that are planned to be replaced[1] (ML)
- D_{UBase} = Baseline year customer deliveries through open outlet or unmetered service points ('deemed volumes' or an appropriate estimate) that will be metered in future (ML)
- MCF = Meter correction factor to correct the indicated volumes measured by Dethridge meters, or deemed at open outlet or unmetered service points
- EF = Effectiveness factor – (refer Table 5)
- DF = Durability factor – (refer Table 5)
- $N_{replaced}$ = Number of Dethridge meter, open outlet or unmetered service points planned to be replaced[2]
- LTT = Leakage through service points in the baseline year – nominally 1.9 ML/SP/year
- LTA = Leakage around service points in the baseline year – nominally 0.4 ML/SP/year
- U_{Base} = Unauthorised use per service point in the baseline year – nominally 0.9 ML/SP/year
- $F(LTCE_{Base})$ = Conversion factor for long-term cap equivalent

Note 1 If delivery data for the baseline year is not available, use the water share volume multiplied by the baseline year allocation.

Note 2 Care is required to avoid double counting the water savings from service point replacement with those claimed for service point removal.

10.4.2 Service point replacement – PHASE 2 – setting aside

$$\mathbf{WS_{Year_x} = WS_{meter\ error} + WS_{leakage\ through} + WS_{leakage\ around} + WS_{unmetered} + WS_{unauthorised}}$$

Where:

$$\mathbf{WS_{meter\ error} = D_{MYear_x} \times (MCF - 1) \times EF \times N_D}$$

$$\mathbf{WS_{leakage\ through} = N_{replaced} \times LTT \times EF \times t_m}$$

$$\mathbf{WS_{leakage\ around} = N_{replaced} \times LTA \times EF \times t_m}$$

$$\mathbf{WS_{unmetered} = D_{UYear_X} \times (MCF - 1) \times EF \times N_U}$$

$$\mathbf{WS_{unauthorised} = N_{replaced} \times U_{Base} \times EF \times \left(D_{Year_x}/D_{Base}\right) \times t_m}$$

- WS_{Year_x} = Water savings for the year in question (ML)
- D_{MYear_x} = Year in question customer deliveries predicted to occur through the original Dethridge meter service points that will be replaced[1] (ML)
- D_{UYear_X} = Year in question customer deliveries predicted (or deemed) to be delivered through open outlet or unmetered service points that will be replaced (ML)
- MCF = Meter correction factor to correct the indicated volumes measured by Dethridge meters, or deemed at open outlet or unmetered service points
- EF = Effectiveness factor – (refer Table 5)
- N_D = Ratio of the cumulative number of Dethridge meter service points replaced (time weighted) to the total number of Dethridge meters in the defined system
- $N_{replaced}$ = Number of Dethridge meter, open outlet or unmetered service points replaced during the year in question[2]
- LTT = Leakage through service points in the baseline year – nominally 1.9 ML/SP/year
- LTA = Leakage around service points in the baseline year – nominally 0.4 ML/SP/year
- t_m = Proportion of time replaced service points were operating for irrigation purposes during the year in question, relative to the standard length of the irrigation season
- N_U = Ratio of the cumulative number of unmetered service points replaced (time weighted) to the total number of unmetered service points in the defined system
- U_{Base} = Unauthorised use per service point in the baseline year – nominally 0.9 ML/SP/year
- D_{Year_x} = Customer deliveries to the irrigation distribution system in the year in question (ML)
- D_{Base} = Customer deliveries to the irrigation distribution system in the baseline year (ML)

Note 1 If the deliveries through unmetered service points and Dethridge meters being replaced can be accurately predicted for the year in question, the phase 3 method can be used to provide a better measure of the estimated water savings.

Note 2 Care is required to avoid double counting the water savings from service point replacement with those claimed for service point removal.

10.4.3 Service point replacement – PHASE 3 – for allocation

$$\mathbf{WS_{Year_x}} = \mathbf{WS_{meter\ error}} + \mathbf{WS_{unmetered}} + \mathbf{WS_{leakage\ through}} + \mathbf{WS_{leakage\ around}} + \mathbf{WS_{unauthorised}}$$

Where:

$$\mathbf{WS_{meter\ error}} = \mathbf{D_{MYear_x}} \times (\mathbf{1/MCF}) \times (\mathbf{MCF - 1}) \times \mathbf{EF}$$

$$\mathbf{WS_{unmetered}} = \mathbf{D_{MYear_x}} \times (\mathbf{1/MCF}) \times (\mathbf{MCF - 1}) \times \mathbf{EF}$$

$$\mathbf{WS_{leakage\ through}} = \mathbf{N_{replaced}} \times \mathbf{LTT} \times \mathbf{EF} \times \mathbf{t_m}$$

$$\mathbf{WS_{leakage\ around}} = \mathbf{N_{replaced}} \times \mathbf{LTA} \times \mathbf{EF} \times \mathbf{t_m}$$

$$\mathbf{WS_{unauthorised}} = \mathbf{N_{replaced}} \times \mathbf{U_{Base}} \times \mathbf{EF} \times \left(\mathbf{D_{Year_x}}/\mathbf{D_{Base}}\right) \times \mathbf{t_m}$$

- WS_{Year_x} = Water savings for the year in question (ML)
- D_{MYear_x} (ML) = Metered deliveries through replaced service points during the year in question[1]
- MCF = Meter correction factor to correct the indicated volumes measured by Dethridge meters, or deemed at open outlet or unmetered service points
- EF = Effectiveness factor – (refer Table 5)
- $N_{replaced}$ = Number of Dethridge meter, open outlet or unmetered service points replaced during the year in question[2]
- LTT = Leakage through service points in the baseline year – nominally 1.9 ML/SP/year
- LTA = Leakage around service points in the baseline year – nominally 0.4 ML/SP/year
- t_m = Proportion of time replaced service points were operating for irrigation purposes during the year in question, relative to the standard length of the irrigation season
- U_{Base} = Unauthorised use per service point in the baseline year – nominally 0.9 ML/SP/year
- D_{Year_x} = Customer deliveries to the irrigation distribution system in the year in question (ML)
- D_{Base} = Customer deliveries to the irrigation distribution system in the baseline year (ML)

Note 1 When estimating $WS_{meter\ error}$, D_{MYearX} is the deliveries through the service points where accurate meters have replaced Dethridge meters. When estimating $WS_{unmetered}$, D_{MYearX} is the deliveries through the previously unmetered service points that now have accurate meters.

Note 2 Care is required to avoid double counting the water savings from service point replacement with those claimed for service point removal.

10.4.4 Service point replacement – PHASE 4 – long-term

$$\mathbf{WS_{LTCE}} = \mathbf{WS_{meter\ error(LTCE)}} + \mathbf{WS_{unmetered(LTCE)}} + \mathbf{WS_{leakage\ through(LTCE)}} + \mathbf{WS_{leakage\ around(LTCE)}} + \mathbf{WS_{unauthorised(LTCE)}}$$

Where:

$$\mathbf{WS_{meter\ error}} = \mathbf{D_{MYear_x}} \times (\mathbf{1/MCF}) \times (\mathbf{MCF - 1}) \times \mathbf{EF} \times \mathbf{DF} \times \mathbf{F(LTCE_{Year_x})}$$

$$\mathbf{WS_{unmetered}} = \mathbf{D_{MYear_x}} \times (\mathbf{1/MCF}) \times (\mathbf{MCF - 1}) \times \mathbf{EF} \times \mathbf{DF} \times \mathbf{F(LTCE_{Year_x})}$$

$$\mathbf{WS_{leakage\ through}} = \mathbf{N_{replaced}} \times \mathbf{LTT} \times \mathbf{EF} \times \mathbf{DF}$$

$$\mathbf{WS_{leakage\ around}} = \mathbf{N_{replaced}} \times \mathbf{LTA} \times \mathbf{EF} \times \mathbf{DF}$$

$$\mathbf{WS_{unauthorised}} = \mathbf{N_{replaced}} \times \mathbf{U_{Base}} \times \mathbf{EF} \times \mathbf{DF} \times \mathbf{F(LTCE_{Year_x})}$$

- WS_{LTCE} = Estimate of long-term water savings (ML LTCE)
- D_{MYear_x} (ML) = Metered deliveries through replaced service points during the year in question[1]
- MCF = Meter correction factor to correct the indicated volumes measured by Dethridge meters, or deemed at open outlet or unmetered service points
- EF = Effectiveness factor – (refer Table 5)
- DF = Durability factor – (refer Table 5)
- $N_{replaced}$ = Number of Dethridge meter, open outlet or unmetered service points replaced[2]
- LTT = Leakage through service points in the baseline year – nominally 1.9 ML/SP/year
- LTA = Leakage around service points in the baseline year – nominally 0.4 ML/SP/year
- U_{Base} = Unauthorised use per service point in the baseline year – nominally 0.9 ML/SP/year
- $F(LTCE_{Year_x})$ = Conversion factor for long-term cap equivalent[3]

Note 1 When estimating $WS_{meter\ error}$, D_{MYearX} is the deliveries through the service points where accurate meters have replaced Dethridge meters. When estimating $WS_{unmetered}$, D_{MYearX} is the deliveries through the previously unmetered service points that now have accurate meters.

Note 2 Care is required to avoid double counting the water savings from service point replacement with those claimed for service point removal.

Note 3 If $F(LTCE_{YearX})$ is not available, the phase 4 equation for service point removal can be used to estimate the savings from service point replacement.

11. Service point removal

11.1 Distribution losses

Service point removal on backbone channels results in water savings from reducing:

- Meter error
- Leakage through and around service points
- Unmetered use
- Unauthorised use.

A portion of losses through outfalls located on spur channels may also be saved by service point removal. However, for the purposes of simplicity and to avoid double counting, all outfall water savings are assumed to be attributable to channel automation (refer to Section 4.1 of this chapter).

Where the delivery share at a removed service point is moved to an accurate meter elsewhere on the system, the water savings from service point removal accrue at the new meter. If the delivery share is cancelled rather than transferred, the meter error savings are accounted for at the service point that is removed. Refer to Section 10.4 for more information on the care required to avoid double counting the water savings from service point removal and replacement.

11.2 Effectiveness

Service point removal is **100% effective** at reducing the losses attributable to meter error, leakage through and around service points, unmetered use and unauthorised use. This assumes that the deliveries that were previously passed through removed meters are not delivered via other Dethridge meters or open outlets.

11.3 Durability

Service point removal is similar to channel asset removal, in that it involves the removal rather than addition of modernised infrastructure to the irrigation distribution system. Service point removal is therefore a **100% durable** method of reducing meter error, leakage through and around service points, unmetered use and unauthorised use.

11.4 Water saving equations for service point removal

11.4.1 Service point removal – PHASE 1 – business case

$$\mathbf{WS_{LTCE}} = \mathbf{WS_{meter\ error(LTCE)}} + \mathbf{WS_{leakage\ through(LTCE)}} + \mathbf{WS_{leakage\ around(LTCE)}} + \mathbf{WS_{unmetered(LTCE)}} + \mathbf{WS_{unauthorised(LTCE)}}$$

Where:

$$\mathbf{WS_{meter\ error(LTCE)}} = \mathbf{D_{MBase}} \times (\mathbf{MCF} - \mathbf{1}) \times \mathbf{EF} \times \mathbf{DF} \times \mathbf{F(LTCE_{Base})}$$

$$\mathbf{WS_{leakage\ through\ (LTCE)}} = \mathbf{N_{rationalised}} \times \mathbf{LTT} \times \mathbf{EF} \times \mathbf{DF}$$

$$\mathbf{WS_{leakage\ around\ (LTCE)}} = \mathbf{N_{rationalised}} \times \mathbf{LTA} \times \mathbf{EF} \times \mathbf{DF}$$

$$\mathbf{WS_{unmetered(LTCE)}} = \mathbf{D_{UBase}} \times (\mathbf{MCF} - \mathbf{1}) \times \mathbf{EF} \times \mathbf{DF} \times \mathbf{F(LTCE_{Base})}$$

$$\mathbf{WS_{unauthorised(LTCE)}} = \mathbf{N_{rationalised}} \times \mathbf{U_{Base}} \times \mathbf{EF} \times \mathbf{DF} \times \mathbf{F(LTCE_{Base})}$$

- WS_{LTCE} = Estimate of long-term water savings (ML LTCE)
- D_{MBase} = Baseline year customer deliveries through meters planned to be removed[1] (ML)
- MCF = Meter correction factor to correct the indicated volumes measured by Dethridge meters, or deemed at open outlet or unmetered service points
- EF = Effectiveness factor – (refer Table 5)
- DF = Durability factor – (refer Table 5)
- $N_{removed}$ = Number of Dethridge meter or open outlet service points planned to be removed[2]
- LTT = Leakage through service points in the baseline year – nominally 1.9 ML/SP/year
- LTA = Leakage around service points in the baseline year – nominally 0.4 ML/SP/year
- D_{UBase} = Baseline year customer deliveries through open outlet or unmetered service points (‘deemed volumes’ or an appropriate estimate) planned to be removed (ML)
- U_{Base} = Unauthorised use losses in the baseline year – nominally 0.9 ML/SP/year
- $F(LTCE_{Base})$ = Conversion factor for long-term cap equivalent

Note 1 If delivery data for the baseline year is not available, use the water share volume multiplied by the baseline year allocation.

Note 2 Care is required to avoid double counting the water savings from service point removal with those claimed for service point replacement.

11.4.2 Service point removal – PHASE 2 – setting aside

$$\mathbf{WS_{Year_x}} = \mathbf{WS_{meter\ error}} + \mathbf{WS_{leakage\ through}} + \mathbf{WS_{leakage\ around}} + \mathbf{WS_{unmetered}} + \mathbf{WS_{unauthorised}}$$

Where:

$$\mathbf{WS_{meter\ error}} = \mathbf{D_{MBase}} \times (\mathbf{MCF} - \mathbf{1}) \times \mathbf{EF} \times \left(\mathbf{D_{Year_x}}/\mathbf{D_{Base}}\right) \times \mathbf{t_m}$$

$$\mathbf{WS_{leakage\ through}} = \mathbf{N_{rationalised}} \times \mathbf{LTT} \times \mathbf{EF} \times \mathbf{t_m}$$

$$\mathbf{WS_{leakage\ around}} = \mathbf{N_{rationalised}} \times \mathbf{LTA} \times \mathbf{EF} \times \mathbf{t_m}$$

$$\mathbf{WS_{unmetered}} = \mathbf{D_{UBase}} \times (\mathbf{MCF} - \mathbf{1}) \times \mathbf{EF} \times \left(\mathbf{D_{Year_x}}/\mathbf{D_{Base}}\right) \times \mathbf{t_m}$$

$$\mathbf{WS_{unauthorised}} = \mathbf{N_{rationalised}} \times \mathbf{U_{Base}} \times \mathbf{EF} \times \left(\mathbf{D_{Year_x}}/\mathbf{D_{Base}}\right) \times \mathbf{t_m}$$

- WS_{Year_x} = Water savings for the year in question (ML)
- D_{MBase} = Baseline year customer deliveries through meters that will be removed[1] (ML)
- MCF = Meter correction factor to correct the indicated volumes measured by Dethridge meters, or deemed at open outlet or unmetered service points
- EF = Effectiveness factor – (refer Table 5)
- $N_{removed}$ = Number of Dethridge meter or open outlet service points that will be removed[2]
- LTT = Leakage through service points in the baseline year – nominally 1.9 ML/SP/year
- LTA = Leakage around service points in the baseline year – nominally 0.4 ML/SP/year
- t_m = Proportion of time service points were removed for irrigation purposes during the year in question, relative to the standard length of the irrigation season
- D_{UBase} = Baseline year customer deliveries through open outlet or unmetered service points (‘deemed volumes’ or an appropriate estimate) that will be removed (ML)
- U_{Base} = Unauthorised use per service point in the baseline year – nominally 0.9 ML/SP/year
- D_{Year_x} = Customer deliveries to the irrigation distribution system in the year in question (ML)
- D_{Base} = Customer deliveries to the irrigation distribution system in the baseline year (ML)

Note 1 If delivery data for the baseline year is not available, use the water share volume multiplied by the baseline year allocation.

Note 2 Care is required to avoid double counting the water savings from service point removal with those claimed for service point replacement.

11.4.3 Service point removal – PHASE 3 – for allocation

$$\mathbf{WS_{Year_x}} = \mathbf{WS_{meter\ error}} + \mathbf{WS_{leakage\ through}} + \mathbf{WS_{leakage\ around}} + \mathbf{WS_{unmetered}} + \mathbf{WS_{unauthorised}}$$

Where:

$$\mathbf{WS_{meter\ error}} = \mathbf{D_{MBase}} \times (\mathbf{MCF} - \mathbf{1}) \times \mathbf{EF} \times \left(\mathrm{D_{Year_x}}/\mathrm{D_{Base}}\right) \times \mathbf{t_m}$$

$$\mathbf{WS_{leakage\ through}} = \mathbf{N_{rationalised}} \times \mathbf{LTT} \times \mathbf{EF} \times \mathbf{t_m}$$

$$\mathbf{WS_{leakage\ around}} = \mathbf{N_{rationalised}} \times \mathbf{LTA} \times \mathbf{EF} \times \mathbf{t_m}$$

$$\mathbf{WS_{unmetered}} = \mathbf{D_{UBase}} \times (\mathbf{MCF} - \mathbf{1}) \times \mathbf{EF} \times \left(\mathrm{D_{Year_x}}/\mathrm{D_{Base}}\right) \times \mathbf{t_m}$$

$$\mathbf{WS_{unauthorised}} = \mathbf{N_{rationalised}} \times \mathbf{U_{Base}} \times \mathbf{EF} \times \left(\mathbf{D_{Year_x}}/\mathbf{D_{Base}}\right) \times \mathbf{t_m}$$

- $\mathrm{WS_{Year_x}}$ = Water savings for the year in question (ML)
- $\mathrm{D_{MBase}}$ = Baseline year customer deliveries through meters that will be removed[1] (ML)
- MCF = Meter correction factor to correct the indicated volumes measured by Dethridge meters, or deemed at open outlet or unmetered service points
- EF = Effectiveness factor – (refer Table 5)
- $\mathrm{N_{removed}}$ = Number of Dethridge meter or open outlet service points that will be removed[2]
- LTT = Leakage through service points in the baseline year – nominally 1.9 ML/SP/year
- LTA = Leakage around service points in the baseline year – nominally 0.4 ML/SP/year
- $\mathrm{t_m}$ = Proportion of time service points were removed for irrigation purposes during the year in question, relative to the standard length of the irrigation season
- $\mathrm{D_{UBase}}$ = Baseline year customer deliveries through open outlet or unmetered service points ('deemed volumes' or an appropriate estimate) that will be removed (ML)
- $\mathrm{U_{Base}}$ = Unauthorised use per service point in the baseline year – nominally 0.9 ML/SP/year
- $\mathrm{D_{Year_x}}$ = Customer deliveries to the irrigation distribution system in the year in question (ML)
- $\mathrm{D_{Base}}$ = Customer deliveries to the irrigation distribution system in the baseline year (ML)

Note 1 If delivery data for the baseline year is not available, use the water share volume multiplied by the baseline year allocation.

Note 2 Care is required to avoid double counting the water savings from service point removal with those claimed for service point replacement.

11.4.4 Service point removal – PHASE 4 – long-term

$$\mathbf{WS_{LTCE}} = \mathbf{WS_{meter\ error(LTCE)}} + \mathbf{WS_{leakage\ through(LTCE)}} + \mathbf{WS_{leakage\ around(LTCE)}} + \mathbf{WS_{unmetered(LTCE)}} + \mathbf{WS_{unauthorised(LTCE)}}$$

Where:

$$\mathbf{WS_{meter\ error(LTCE)}} = \mathbf{D_{MBase}} \times (\mathbf{MCF} - \mathbf{1}) \times \mathbf{EF} \times \mathbf{DF} \times \mathbf{F(LTCE_{Base})}$$

$$\mathbf{WS_{leakage\ through\ (LTCE)}} = \mathbf{N_{rationalised}} \times \mathbf{LTT} \times \mathbf{EF} \times \mathbf{DF}$$

$$\mathbf{WS_{leakage\ around\ (LTCE)}} = \mathbf{N_{rationalised}} \times \mathbf{LTA} \times \mathbf{EF} \times \mathbf{DF}$$

$$\mathbf{WS_{unmetered(LTCE)}} = \mathbf{D_{UBase}} \times (\mathbf{MCF} - \mathbf{1}) \times \mathbf{EF} \times \mathbf{DF} \times \mathbf{F(LTCE_{Base})}$$

$$\mathbf{WS_{unauthorised(LTCE)}} = \mathbf{N_{rationalised}} \times \mathbf{U_{Base}} \times \mathbf{EF} \times \mathbf{DF} \times \mathbf{F(LTCE_{Base})}$$

- $\mathrm{WS_{LTCE}}$ = Estimate of long-term water savings (ML LTCE)
- $\mathrm{D_{MBase}}$ = Baseline year customer deliveries through removed meters[1] (ML)
- MCF = Meter correction factor to correct the indicated volumes measured by Dethridge meters, or deemed at open outlet or unmetered service points
- EF = Effectiveness factor – (refer Table 5)
- DF = Durability factor – (refer Table 5)
- $\mathrm{N_{removed}}$ = Number of Dethridge meter or open outlet service points removed[2]
- LTT = Leakage through service points in the baseline year – nominally 1.9 ML/SP/year
- LTA = Leakage around service points in the baseline year – nominally 0.4 ML/SP/year
- $\mathrm{D_{UBase}}$ = Baseline year customer deliveries through open outlet or unmetered service points (‘deemed volumes’ or an appropriate estimate) that were removed (ML)
- $\mathrm{U_{Base}}$ = Unauthorised use losses in the baseline year – nominally 0.9 ML/SP/year
- $\mathrm{F(LTCE_{Base})}$ = Conversion factor for long-term cap equivalent

Note 1 If delivery data for the baseline year is not available, use the water share volume multiplied by the baseline year allocation.

Note 2 Care is required to avoid double counting the water savings from service point removal with those claimed for service point replacement.

12. Channel remediation

Channel remediation involves channel lining and/or bank remodelling of channels within irrigation distribution systems. The water savings associated with removing channels and replacing them with pipelines are covered in Section 8 of this chapter.

12.1 Distribution losses

Channel remediation can reduce losses from:

- Seepage (via channel lining)
- Bank leakage (via channel lining or bank remodelling)

12.2 Effectiveness

12.2.1 Channel lining with plastic or concrete

Current plastic lining practices use approximately 2 – 3 mm HDPE with welded joints for best effectiveness and longevity. This technique results in losses at structures and through holes in the untested sheets of HDPE. Therefore, an **effectiveness of 95%** in reducing seepage and bank leakage is recommended for plastic lining.

This same 95% effectiveness applies to concrete lined channels with water stops at all joints.

12.2.2 Channel lining with clay

The effectiveness of channel lining with clay depends on the thickness of lining, and the compaction and moisture content of the clay at compaction. A layer thickness of at least 0.5 m is recommended.

An **effectiveness of 85%** in reducing seepage and bank leakage should be adopted for well-placed clay channel lining when estimating the water savings.

12.2.3 Channel bank remodelling with clay

Bank remodelling is useful where leakage through banks needs to be rectified. It is assumed that best practice bank remodelling with good quality clay provides the same effectiveness in reducing bank leakage losses as that obtained via the clay lining of channels (i.e. **85% effectiveness**).

12.3 Durability

12.3.1 Channel lining with plastic or concrete

The current practice of some water corporations is to leave channel lining exposed to animals, radiation, operator and public intervention, and other damaging elements. In these instances, the estimated design life is 20 years, and the expected seepage and bank leakage savings **durability is 85%**.

Channel lining that is covered with soil is expected to have a longer design life (ranging from 20-50 years[10]). The water savings will also be more durable, and therefore a **95% durability** factor can be applied when estimating water savings attributable to covered channel lining.

12.3.2 Channel lining with clay

Deterioration of clay channel lining is caused by cracking when the channel is drained, puncturing by animals, and via erosion at the waterline and on filling. The seepage and bank leakage savings from channel

[10] Australian National Committee, International Commission on Irrigation and Drainage (ANCID) Best Practice reports

lining are estimated to be **80% durable**, based on a 20-year design life. That is, savings from clay lining are less durable compared with lining using plastic or concrete. The 80% durability estimate assumes that the waterway batters are not lined with rock beaching, and that the clay lining deteriorates uniformly over time.

12.3.3 Chanel bank remodelling with clay

The durability of bank leakage savings from channel bank remodelling with clay are assumed to be same as channel lining with clay (i.e. **80% durability**).

12.4 Water saving equations for channel remediation

The method used to estimate water savings from channel remediation depends on whether pondage tests of the seepage and bank leakage losses are undertaken pre- and/or post-works. If pondage tests are not done, then a theoretical estimate of the water savings is required. If pondage test results are available, the water savings can be estimated directly, but then need to be factored to account for the differences in losses between static pondage tests and dynamic operating conditions.

The direct measurement approach is preferred and encouraged. The results of these tests can also be analysed to inform the assumptions used in the theoretical estimates of water savings from remediating channels that have not been pondage tested. Both the theoretical and direct measurement methods are described further below.

Direct measurement

Pondage tests undertaken before and after channel remediation provide the most accurate estimate of the initial water savings. A pondage test uses a water balance to estimate the seepage and bank leakage in an isolated channel. More information on pondage tests is provided in Section 4 of this chapter.

If the only inflow to the isolated channel during the pondage test is rainfall (which is most often the case), the following equation can be used to estimate the combined seepage and bank leakage under static conditions:

$$\mathbf{PT} = [\,\mathbf{W} \times \mathbf{CPL} \times [\Delta\mathbf{d} - \mathbf{E} + \mathbf{R}] \times \mathbf{T} \times \mathbf{Y}] - \mathbf{N} \times (\mathbf{LTA} + \mathbf{LTT})$$

Where:

- PT = Total seepage and bank leakage loss as estimated via pondage testing (ML)
- W = Average channel surface width (m)
- CPL = Length of channel pool (m)
- $\Delta\mathrm{d}$ = Rate of change in water level at channel operating level, as per pondage test (m/d)
- E = Evaporation (m/d)
- R = Rainfall (m/d)
- T = Length of a standard irrigation season (days)
- Y = Factor to convert from m^3 to ML (0.001)
- N = Number of Dethridge meter and open outlet service points within channel section
- LTT = Leakage through service points – nominally 1.9 ML/SP/year
- LTA = Leakage around service points – nominally 0.4 ML/SP/year

The pondage test results can be analysed further to apportion the total losses to seepage and bank leakage, and the bank leakage to fixed and variable components. This is also described in Section 4.

To convert the pondage test results undertaken under static conditions to those representative of operating conditions, a pondage test adjustment factor (F(PA)) is used – as per the equations on the following pages that provide 'direct' estimates of water savings from channel remediation. The process for calculating F(PA) is described in Appendix G.

Theoretical estimate

It is unlikely to be cost or time effective to undertake pondage tests to estimate the water savings from channel remediation when business cases are being prepared for irrigation modernisation projects (phase 1). Therefore, at this stage theoretical estimates of the water savings will be required.

The theoretical estimates are based on the expected effectiveness and durability of the channel remediation in saving baseline year losses (seepage, bank leakage and net evaporation). However, it is important to consider that channel remediation will most likely target high loss pools (i.e. those that have higher than average seepage and/or bank leakage). The average baseline year seepage and bank leakage losses across the irrigation distribution system therefore need to be adjusted when using the theoretical approach to estimating water savings from channel remediation. The development and application of this adjustment factor is described in Appendix F.

An alternative approach to using irrigation distribution system averages to estimate baseline year seepage, bank leakage and net evaporation losses from channels that have not been pondage tested is to develop a channel loss model (e.g. which relates soil and other channel characteristics to expected losses). If baseline year losses are to be estimated using a channel loss model, then the project proponent must submit the model to DELWP for review and approval. Once approved, the model may be used to calculate the water savings from channel remediation. The channel loss model and estimated water savings will be subject to an annual audit process.

For phase 2-4 estimates, direct measurement of water savings from channel remediation is preferred to theoretical estimates. However, pondage test results pre- and/or post-channel remediation may not be available in all instances. Therefore, theoretical estimates of water savings may also be required for later phases. Table 7 summarises how the availability of pondage test data pre- and post-channel remediation determines whether direct measurement or theoretical estimates are used to quantify the water savings.

Table 7: Approaches for estimating water savings from channel remediation, depending on the availability of pondage test data

Phase	No pondage test data available	Only pre-works pondage test data available	Pre and post works pondage test data available
Phase 1	Use phase 1 theoretical estimate	n/a	n/a
Phase 2	Use phase 2 theoretical estimate	Use phase 2 direct estimate	Use phase 2 direct estimate
Phase 3	Use phase 2 theoretical estimate	Use phase 3 theoretical estimate	Use phase 3 direct estimate
Phase 4	Use phase 2 theoretical estimate multiplied by durability factors	Use phase 4 theoretical estimate	Use phase 4 direct estimate

12.4.1 Channel remediation – THEORETICAL PHASE 1 – business case

$$\mathbf{WS_{LTCE} = WS_{seepage(LTCE)} + WS_{bank\ leakage(LTCE)}}$$

Where:

$$\mathbf{WS_{seepage(LTCE)} = S_{Base} \times EF \times DF \times RL \times HLP^{1}}$$

$$\mathbf{WS_{bank\ leakage(LTCE)} = \left[(L_{Base} \times FL) + \left(L_{Base} \times VL \times F(LTCE_{Base})\right)\right] \times EF \times DF \times RL \times HLP^{2}}$$

- $\mathrm{WS_{LTCE}}$ = Estimate of long-term water savings (ML LTCE)
- $\mathrm{S_{Base}}$ = Seepage in the baseline year (ML)[3]
- $\mathrm{L_{Base}}$ = Bank leakage in the baseline year (ML)[3]
- FL = Proportion of bank leakage that is fixed – (refer Table 1)
- VL = Proportion of bank leakage loss that is variable – (refer Table 1)
- EF = Effectiveness factor – (refer Table 5)
- DF = Durability factor – (refer Table 5)
- RL = Ratio of length of channels to be remediated to the total length of channel
- HLP = High loss pool factor, to adjust average loss rates to those representative of the high loss pools targeted for remediation (Appendix F)
- $\mathrm{F(LTCE_{Base})}$ = Conversion factor for long-term cap equivalent

Note 1 Seepage savings are calculated for channel lining.

Note 2 Bank leakage savings are calculated for all channel remediation techniques.

Note 3 For the GMW Connections Project, S_{Base} and L_{Base} are losses on backbone channels, and RL applies to backbone channels.

12.4.2 Channel remediation – THEORETICAL PHASE 2 – setting aside

$$\mathbf{WS_{Year_x}} = \mathbf{WS_{seepage}} + \mathbf{WS_{bank\ leakage}}$$

Where:

$$\mathbf{WS_{seepage}}^{1} = \mathbf{S_{Base}} \times \mathbf{EF} \times \mathbf{RL} \times \mathbf{SHLP}$$

$$\mathbf{WS_{bank\ leakage}}^{2} = \left[(\mathbf{L_{Base}} \times \mathbf{FL}) + \left(\mathbf{L_{Base}} \times \mathbf{VL} \times \left(\mathbf{D_{Year_x}}/\mathbf{D_{Base}}\right)\right)\right] \times \mathbf{EF} \times \mathbf{RL} \times \mathbf{LHLP}$$

- $\mathrm{WS_{Year_X}}$ = Water savings for the year in question (ML)
- $\mathrm{S_{Base}}$ = Seepage in the baseline year (ML)[3]
- $\mathrm{L_{Base}}$ = Bank leakage in the baseline year (ML)[3]
- FL = Proportion of bank leakage that is fixed – (refer Table 1)
- VL = Proportion of bank leakage loss that is variable – (refer Table 1)
- EF = Effectiveness factor – (refer Table 5)
- RL = Ratio of length of channels to be remediated to the total length of channel
- SHLP = High loss pool factor, to adjust average seepage rates to those representative of the high loss pools targeted for remediation[4] (Appendix F)
- LHLP = High loss pool factor, to adjust average bank leakage rates to those representative of the high loss pools targeted for remediation[4] (Appendix F)
- $\mathrm{D_{Year_x}}$ = Customer deliveries to the irrigation distribution system in the year in question (ML)
- $\mathrm{D_{Base}}$ = Customer deliveries to the irrigation distribution system in the baseline year (ML)

Note 1 Seepage savings are calculated for channel lining.

Note 2 Bank leakage savings are calculated for all channel remediation techniques.

Note 3 For the GMW Connections Project, S_{Base} and L_{Base} are losses on backbone channels, and RL applies to backbone channels.

Note 4 This method assumes the channels were at, or above, supply level for 100% of the irrigation season, and the season length was normal. If this is not the case, the estimated high loss pool factor should be adjusted to account for the proportion of time the channels will be at, or above, supply level within the channel section that is remediated.

12.4.3 Channel remediation – THEORETICAL PHASE 3 – for allocation

$$\mathbf{WS}_{\mathbf{Year}_x} = \mathbf{WS}_{\mathbf{seepage}} + \mathbf{WS}_{\mathbf{bank\ leakage}}$$

Where:

$$\mathbf{WS}_{\mathbf{seepage}}{}^{1} = \mathbf{S}^{\mathbf{Pre\ Works}} \times \mathbf{EF}$$

$$\mathbf{WS}_{\mathbf{bank\ leakage}}{}^{2} = \left(\left(\mathbf{PT}^{\mathbf{Pre\ Works}} \times \mathbf{F(PA)} - \mathbf{S}^{\mathbf{Pre\ Works}}\right) \times \left(\mathbf{VL} \times \left(\mathbf{D}_{\mathbf{Year}_x}/\mathbf{D}_{\mathbf{Base}}\right) + \mathbf{FL}\right)\right) \times \mathbf{EF}$$

- WS_{Year_x} = Water savings for the year in question (ML)
- $S^{Pre\ Works}$ = Seepage prior to channel remediation, as determined from pondage testing (ML)
- $PT^{Pre\ Works}$ = Total seepage and bank leakage loss at operating level prior to channel remediation, as determined from pondage testing (ML)
- $F(PA)$ = Factor to adjust pondage test data to account for additional losses under operating conditions (Appendix G)[3]
- FL = Proportion of bank leakage that is fixed – (refer Table 1)
- VL = Proportion of bank leakage loss that is variable – (refer Table 1)
- EF = Effectiveness factor – (refer Table 5)
- D_{Year_x} = Customer deliveries to the irrigation distribution system in the year in question (ML)
- D_{Base} = Customer deliveries to the irrigation distribution system in the baseline year (ML)

Note 1 Seepage savings are calculated for channel lining.

Note 2 Bank leakage savings are calculated for all channel remediation techniques.

Note 3 This method assumes the channels were at, or above, supply level for 100% of the irrigation season, and the season length was normal. If this is not the case, the estimated F(PA) factor should be adjusted to account for the proportion of time the channels will be at, or above, supply level within the channel section that is remediated.

12.4.4 Channel remediation – THEORETICAL PHASE 4 – long-term

$$\mathbf{WS_{LTCE}} = \mathbf{WS_{seepage(LTCE)}} + \mathbf{WS_{bank\ leakage(LTCE)}}$$

Where:

$$\mathbf{WS_{seepage(LTCE)}}^{1} = \mathbf{S^{Pre\ Works}} \times \mathbf{EF} \times \mathbf{DF}^{1}$$

$$\mathbf{WS_{bank\ leakage(LTCE)}}^{2} = \left(\left(\mathbf{PT^{Pre\ Works}} \times \mathbf{F(PA)} - \mathbf{S^{Pre\ Works}}\right) \times \left(\mathbf{VL} \times \mathbf{F(LTCE_{Base})} + \mathbf{FL}\right)\right) \times \mathbf{EF} \times \mathbf{DF}^{2}$$

- WS_{LTCE} = Estimate of long-term water savings (ML LTCE)
- $S^{Pre\ Works}$ = Seepage prior to channel remediation, as determined from pondage testing (ML)
- $PT^{Pre\ Works}$ = Total seepage and bank leakage loss at operating level prior to channel remediation, as determined from pondage testing (ML)
- $F(PA)$ = Factor to adjust pondage test data to account for additional losses under operating conditions (Appendix G)[3]
- FL = Proportion of bank leakage that is fixed – (refer Table 1)
- VL = Proportion of bank leakage loss that is variable – (refer Table 1)
- EF = Effectiveness factor – (refer Table 5)
- DF = Durability factor – (refer Table 5)
- $F(LTCE_{Base})$ = Conversion factor for long-term cap equivalent

Note 1 Seepage savings are calculated for channel lining.

Note 2 Bank leakage savings are calculated for all channel remediation techniques.

Note 3 This method assumes the channels were at, or above, supply level for 100% of the irrigation season, and the season length was normal. If this is not the case, the estimated F(PA) factor should be adjusted to account for the proportion of time the channels will be at, or above, supply level within the channel section that is remediated.

12.4.5 Channel remediation – DIRECT PHASE 2 – setting aside

$$\mathbf{WS}_{\mathbf{Year_x}} = \mathbf{WS}_{\mathbf{seepage}} + \mathbf{WS}_{\mathbf{bank\ leakage}}$$

Where:

$$\mathbf{WS}_{\mathbf{seepage}}{}^{1} = \mathbf{S}^{\mathbf{Pre\ Works}} \times \mathbf{EF}$$

$$\mathbf{WS}_{\mathbf{bank\ leakage}}{}^{2} = \left(\left(\mathbf{PT}^{\mathbf{Pre\ Works}} \times \mathbf{F(PA)} - \mathbf{S}^{\mathbf{Pre\ Works}}\right) \times \left(\mathbf{VL} \times \left(\mathbf{D}_{\mathbf{Year_x}}/\mathbf{D}_{\mathbf{Base}}\right) + \mathbf{FL}\right)\right) \times \mathbf{EF}$$

- $\mathrm{WS}_{\mathrm{Year_X}}$ = Water savings for the year in question (ML)
- $\mathrm{S}^{\mathrm{Pre\ Works}}$ = Seepage prior to channel remediation, as determined from pondage testing (ML)
- $\mathrm{PT}^{\mathrm{Pre\ Works}}$ = Total seepage and bank leakage loss at operating level prior to channel remediation, as determined from pondage testing (ML)
- $\mathrm{F(PA)}$ = Factor to adjust pondage test data to account for additional losses under operating conditions (Appendix G)[3]
- FL = Proportion of bank leakage that is fixed – (refer Table 1)
- VL = Proportion of bank leakage loss that is variable – (refer Table 1)
- EF = Effectiveness factor – (refer Table 5)
- $\mathrm{D}_{\mathrm{Year_x}}$ = Customer deliveries to the irrigation distribution system in the year in question (ML)
- $\mathrm{D}_{\mathrm{Base}}$ = Customer deliveries to the irrigation distribution system in the baseline year (ML)

Note 1 Seepage savings are calculated for pipelining and channel lining.

Note 2 Bank leakage savings are calculated for all channel remediation techniques.

Note 3 This method assumes the channels were at, or above, supply level for 100% of the irrigation season, and the season length was normal. If this is not the case, the estimated F(PA) factor should be adjusted to account for the proportion of time the channels will be at, or above, supply level within the channel section that is remediated.

12.4.6 Channel remediation – DIRECT PHASE 3 – for allocation

$$\mathbf{WS_{Year_x}} = \mathbf{WS_{seepage}} + \mathbf{WS_{bank\ leakage}}$$

Where:

$\mathbf{WS_{seepage}}^{1} = \mathbf{S^{Pre\ Works}} - \mathbf{S^{Post\ Works}}$

$\mathbf{WS_{bank\ leakage}}^{2} = \left(\left(\mathbf{PT^{Pre\ Works}} - \mathbf{PT^{Post\ Works}}\right) \times \mathbf{F(PA)} - \left(\mathbf{S^{Pre\ Works}} - \mathbf{S^{Post\ Works}}\right)\right) \times \left(\mathbf{VL} \times \left(\mathbf{D_{Year_x}}/\mathbf{D_{Base}}\right) + \mathbf{FL}\right)$

- WS_{Year_X} = Water savings for the year in question (ML)
- $S^{Pre\ Works}$ = Seepage prior to channel remediation, as determined from pondage testing (ML)
- $S^{Post\ Works}$ = Seepage after channel remediation, as determined from pondage testing (ML)
- $PT^{Pre\ Works}$ = Total seepage and bank leakage loss at operating level prior to channel remediation, as determined from pondage testing (ML)
- $PT^{Post\ Works}$ = Total seepage and bank leakage loss at operating level after channel remediation, as determined from pondage testing (ML)
- $F(PA)$ = Factor to adjust pondage test data to account for additional losses under operating conditions (Appendix G)[3]
- FL = Proportion of bank leakage that is fixed – (refer Table 1)
- VL = Proportion of bank leakage loss that is variable – (refer Table 1)
- D_{Year_x} = Customer deliveries to the irrigation distribution system in the year in question (ML)
- D_{Base} = Customer deliveries to the irrigation distribution system in the baseline year (ML)

Note 1 Seepage savings are calculated for pipelining and channel lining.

Note 2 Bank leakage savings are calculated for all channel remediation techniques.

Note 3 This method assumes the channels were at, or above, supply level for 100% of the irrigation season, and the season length was normal. If this is not the case, the estimated F(PA) factor should be adjusted to account for the proportion of time the channels will be at, or above, supply level within the channel section that is remediated.

12.4.7 Channel remediation – DIRECT PHASE 4 – long-term

$$\mathbf{WS_{LTCE}} = \mathbf{WS_{seepage(LTCE)}} + \mathbf{WS_{bank\ leakage(LTCE)}}$$

Where:

$$\mathbf{WS_{seepage(LTCE)}}^{1} = \left(\mathbf{S^{Pre\ Works}} - \mathbf{S^{Post\ Works}}\right) \times \mathbf{DF}$$

$$\mathbf{WS_{bank\ leakage(LTCE)}}^{2} = \left(\left(\mathbf{PT^{Pre\ Works}} - \mathbf{PT^{Post\ Works}}\right) \times \mathbf{F(PA)} - \left(\mathbf{S^{Pre\ Works}} - \mathbf{S^{Post\ Works}}\right)\right) \times \left(\mathbf{VL} \times \mathbf{F(LTCE_{Base})} + \mathbf{FL}\right) \times \mathbf{DF}$$

- $\mathrm{WS_{LTCE}}$ = Estimate of long-term water savings (ML LTCE)
- $\mathrm{S^{Pre\ Works}}$ = Seepage prior to channel remediation, as determined from pondage testing (ML)
- $\mathrm{S^{Post\ Works}}$ = Seepage after channel remediation, as determined from pondage testing (ML)
- $\mathrm{PT^{Pre\ Works}}$ = Total seepage and bank leakage loss at operating level prior to channel remediation, as determined from pondage testing (ML)
- $\mathrm{PT^{Post\ Works}}$ = Total seepage and bank leakage loss at operating level after channel remediation, as determined from pondage testing (ML)
- $\mathrm{F(PA)}$ = Factor to adjust pondage test data to account for additional losses under operating conditions (Appendix G)[3]
- FL = Proportion of bank leakage that is fixed – (refer Table 1)
- VL = Proportion of bank leakage loss that is variable – (refer Table 1)
- $\mathrm{F(LTCE_{Base})}$ = Conversion factor for long-term cap equivalent

Note 1 Seepage savings are calculated for channel lining.

Note 2 Bank leakage savings are calculated for all channel remediation techniques.

Note 3 This method assumes the channels were at, or above, supply level for 100% of the irrigation season, and the season length was normal. If this is not the case, the estimated F(PA) factor should be adjusted to account for the proportion of time the channels will be at, or above, supply level within the channel section that is remediated.

13. Water savings verification

The equations in Sections 8-12 of chapter D estimate the water savings from modernising irrigation distribution systems. An important task is to, where possible, check the accuracy of these estimates by comparing them with water balances for irrigation distribution systems before, during and after modernisation projects.

13.1 Water balances

A water balance for the irrigation distribution system should be undertaken for the baseline year, at the end of each irrigation modernisation project, and at interim points during implementation as required. These water balances will help to verify that the phase 3 and 4 estimates of water savings are consistent with observed changes in distribution losses (and hence efficiency). Total losses in an irrigation distribution system are:

$$\textbf{Losses} = \textbf{Inflows} - (\textbf{Metered Deliveries} + \textbf{Planned Passing Flows})$$

The delivery efficiency is calculated as:

$$\textbf{Efficiency}\ (\%) = \left[\frac{\textbf{Metered Deliveries} + \textbf{Planned Passing Flows}}{\textbf{Inflows}}\right] \times \textbf{100}$$

If the reduction in distribution losses during and immediately after completion of the irrigation modernisation project align with the phase 3 estimates of water savings, this provides confidence in both the water balance and the estimates of water savings. If there are significant differences, this should be a trigger for closer analysis of the water balance and/or estimates of water savings.

The distribution losses and hence efficiency from year to year will be influenced by the volumes of deliveries. This is because some losses are fixed, and others vary with deliveries. Therefore, comparisons of total system losses and efficiencies pre-, during and post-irrigation modernisation projects are simpler when comparing years with similar delivery volumes. Section 3 provides additional detail on how differences in annual deliveries are accounted for in the estimates of water savings. In particular, periods of low water allocation and the associated operational changes, are likely to exhibit loss behaviour that is different to the 'average' conditions on which the baseline year water balance is based.

Comparing changes in distribution losses and efficiency with estimates of phase 4 water savings is more challenging compared with phase 3 estimates, given the phase 4 calculations use durability factors that assume asset design lives of 20+ years. The conversion of the long-term water savings to high-reliability water shares (HRWS) and low-reliability water shares (LRWS) is the responsibility of the Minister for Water (with support from DELWP).

13.2 Monitoring

The losses within and efficiency of irrigation distribution systems needs to be monitored over time to:

- Ensure that water savings, and hence the security of water shares created from the savings are maintained.
- Assist with targeting interventions as the irrigation modernisation works deteriorate over time.

To monitor the efficiency of an irrigation distribution system, the total inflows, metered deliveries and planned passing flows all need to be measured. A minimum efficiency (standardised to account for variations in inflows from year to year) can then be set to trigger the investigation of asset replacement. When this target is reached:

- Micro scale monitoring is required to identify which parts of the system require renewal, or;
- System level water savings techniques or interventions should be enacted to maintain the overall system delivery efficiency above the target/trigger.

14. Glossary of equation symbols

Table 8 provides a summary of each of the equation symbols used within the calculations outlined in chapter D of this *Water Savings Protocol*.

Table 8: Glossary of equation symbols

Equation Symbol	Definition	Units
Δd	Rate of change in water level at channel operating level, as measured via a pondage test	m/d
A	Ratio of the length of channel automated, to the total length of channel	dimensionless
Area	Channel surface area	m^2
CL	Ratio of the length of channel removed, to the total channel length in the defined system	dimensionless
CPL	Length of channel pool	m
CWF	Channel Width Factor, calculated as the ratio of actual bank width to recorded bank width	dimensionless
D_{Base}	Customer deliveries within the irrigation distribution system in the baseline year **Note:** *Where customer delivery data is unavailable or unreliable, bulk diversions data can be substituted. However, it is important to maintain consistency throughout the water savings calculations as to the use of either customer deliveries or bulk diversions.*	ML
D_{MBase}	Customer deliveries in the baseline year as measured by the Dethridge meters that will be, or have been, replaced or removed	ML
D_{MYearX}	Year in question customer deliveries, predicted or measured to have occurred through the original Dethridge meter service points that will, or have been, replaced or removed	ML
D_{UBase}	Baseline year customer deliveries through open outlet or unmetered service points ('deemed volumes' or an appropriate estimate) that will be, or have been, removed or metered	ML
D_{UYearX}	Year in question customer deliveries predicted or measured to have occurred through open outlet or unmetered service points that will be, or have been, removed or metered	ML
D_{YearX}	Customer deliveries within the irrigation distribution system during the year in question **Note:** *Where customer delivery data is unavailable or unreliable, bulk diversions data can be substituted. However, it is important to maintain consistency throughout the water savings calculations as to the use of either customer deliveries or bulk diversions.*	ML
DF	The durability factor used for estimating long-term water savings	dimensionless
E	Evaporation	mm/d or m/d
E_{Base}	Net evaporation loss from the distribution system in the baseline year	ML
EF	The factor applied to losses, to estimate the potential savings from modernising irrigation distribution systems	dimensionless
$E^{POST\ WORKS}$	Net evaporation after channel remediation (for the relevant channel length)	ML

Equation Symbol	Definition	Units
$E^{PRE\ WORKS}$	Net evaporation prior to channel remediation (for the relevant channel length)	ML
E_{YearX}	Net evaporation from the distribution system during the year in question	ML
HLP	High loss pool factor, to adjust average loss rates to those representative of the high loss pools targeted for remediation	dimensionless
FL	Proportion of bank leakage loss recognised as fixed – nominally 35%	dimensionless
$F(LTCE_{Base})$	The factor to convert volumes from the baseline year to the long-term cap equivalent (i.e. long-term average)	dimensionless
$F(LTCE_{YearX})$	The factor to convert volumes from the year in question to the long-term cap equivalent (i.e. long-term average)	dimensionless
F(PA)	Factor to adjust pondage test data to account for the additional losses expected under operating conditions	dimensionless
L_{Base}	Bank leakage from the distribution system in the baseline year	ML
LHLP	High loss pool factor, to adjust average bank leakage rates to those representative of the high loss pools targeted for remediation	dimensionless
LTA	Leakage around service points – nominally 0.4 ML/SP/year	ML/SP/Year
LTT	Leakage through service points – nominally 1.9 ML/SP/year	ML/SP/Year
L_{YearX}	Bank leakage from the distribution system in the year in question	ML
MCF	The factor to adjust the volume measured through Dethridge meter service points, or associated with deemed service point volumes, to actual volumes	dimensionless
ML	Volume of water in megalitres (1,000,000 litres)	ML
N	Number of Dethridge meter and open outlet service points within a channel section	dimensionless
N_D	Ratio of the cumulative number of Dethridge meter service points replaced (time weighted) to the total number of Dethridge meters in the defined system	dimensionless
N_U	Ratio of the cumulative number of unmetered service points replaced (time weighted) to the total number of unmetered service points in the defined system	dimensionless
$N_{removed}$	Number of Dethridge meter or open outlet service points planned to be removed, or actually removed	number
$N_{replaced}$	Number of Dethridge meter or open outlet service points planned to be replaced, or actually replaced	number
O_{Base}	Outfall loss in the baseline year	ML
O_{YearX}	Outfall loss in the year in question	ML
$O_{Base_{Variable}}$	Variable outfall loss in the baseline year	ML
$O_{Year_{x_{Variable}}}$	Variable outfall loss in the year in question	ML
$O_{Base_{Fixed}}$	Fixed outfall loss in the baseline year	ML
$O_{Year_{x_{Fixed}}}$	Fixed outfall loss in the year in question	ML
PEF	A factor to convert pan evaporation measurements to actual evaporation	dimensionless
PT	Total seepage and bank leakage loss as estimated via pondage testing	ML

Equation Symbol	Definition	Units
$PT^{POST\ WORKS}$	Total seepage and bank leakage loss at operating level prior to channel remediation, as determined from pondage testing	ML
$PT^{PRE\ WORKS}$	Total seepage and bank leakage loss at operating level after channel remediation, as determined from pondage testing	ML
R	Rainfall	mm/d or m/d
RL	Ratio of the length of channels remediated to the total length of channel	dimensionless
S_{Base}	Seepage from the distribution system in the baseline year (ML)	ML
$S^{POST\ WORKS}$	Seepage after channel remediation, as determined from pondage testing (for the relevant channel length)	ML
$S^{PRE\ WORKS}$	Seepage prior to channel remediation, as determined from pondage testing (for the relevant channel length)	ML
S_{YearX}	Seepage from the distribution system in the year in question	ML
SHLP	High loss pool factor, to adjust the average seepage rates to those representative of the high loss pools targeted for remediation	dimensionless
SP	Customer service points	
T	Length of a standard irrigation season	days
t_a	Ratio of the length of time a channel has been automated in the year in question, relative to the irrigation season length in the baseline year	dimensionless
t_r	Length of time in days a channel has been removed during the year in question, divided by the irrigation season length in days for the baseline year	dimensionless
t_m	Proportion of time replaced service points were operating for irrigation purposes during the year in question, relative to the standard length of the irrigation season	dimensionless
time	Number of days (as used in calculation of evaporation losses)	days
U_{Base}	Unauthorised use in the baseline year – nominally 0.9 ML/SP/Year	ML/SP
U_{YearX}	Unauthorised use during the year in question	ML
V_a	Actual volume as determined by reference equipment (i.e. the volume of water passing through a reference meter)	ML
V_B	Proportion of outfall losses that are variable	percentage
V_i	Indicated volume by the meter under test (i.e. the volume of water measured by the meter being tested for meter error)	ML
VL	Proportion of bank leakage loss recognised as variable – nominally 65%	dimensionless
W	Average channel surface width	m
WS_{LTCE}	Estimated total long-term water savings	ML LTCE
$WSx_{(LTCE)}$	Estimated long-term savings of loss component x (e.g. seepage)	ML LTCE
WS_{Yearx}	Estimated total water savings for the year in question	ML
WSx_{Yearx}	Estimated savings of loss component x (e.g. seepage) for the year in question	ML
Y	Conversion factor from m^3 to ML	dimensionless

15. Glossary of terms

Table 9 defines some of the terms used throughout this *Water Savings Protocol*.

Table 9: Glossary of terms

Term	Definition
Allocation / water allocation	The allocation of water for use in a particular irrigation season. Seasonal allocations will depend on how much water is available in storage, and the number of water shares. As an example, if a seasonal water allocation during a drought was only 50%, an entitlement holder with a 100 ML of high-reliability water shares would be allocated 50 ML of water for use.
Asset condition rating	A score between 1 and 6 used by Victorian water corporations to rate the condition of their assets, with 1 being new and 6 being non-functional.
Backbone	Larger water supply channels that will be upgraded to form the nucleus of a modernised water supply system to efficiently transport large volumes of water direct to customer supply points. These channels are generally automated.
Bank leakage	The water lost through holes and cracks in channel banks. Bank leakage is often the balancing component in water balances for irrigation distribution systems.
Baseline year	The year against which operational changes are compared at the completion of irrigation distribution system modernisation.
Benchmark year	The year against which condition and performance characteristics of the assets are compared at the completion of the irrigation distribution system modernisation.
Bulk diversions	The total volume of water diverted into an irrigation distribution system to supply demands and cover losses.
Bulk entitlement	A right under the *Water Act 1989* to use and supply water which may be granted to water corporations, the Victorian Environmental Water Holder and other Authorities (e.g. electricity retailers). The bulk entitlement defines the amount of water from a river or storage to which the holder is entitled, and may include the rate at which it may be taken, and the reliability of the entitlement.
Bulk inflow/outflow measurement error	The metering error associated with bulk diversions into and out of each irrigation distribution system.
Business case	A document outlining the proposed irrigation modernisation projects and cost, for the purpose of seeking funds and project approval (including the planned program of works).
Bulk carrier	A large channel that transports significant volumes of water to other storages or smaller channels.
Channel	A structure constructed to convey water from an upstream water source to farms.
Channel automation	A computerised system which automates the ordering, delivery control and measurement of water supply in irrigation distribution system channels, and operates in conjunction with a system of remotely controlled regulators, gates and possibly customer supply points (also referred to as Total Channel Control ® (TCC®)).
Channel remediation	A water savings intervention comprising the lining of the bed and banks of water supply channels, pipelining or the rebuilding (remodelling) of channel banks to reduce water loss.
Class A pan evaporation	Evaporation measured from a standard sized steel pan set on a wooden platform.

Term	Definition
Connections	Public or private, piped or open channels, that allow individual properties, or a cluster of properties, to be connected to the backbone.
Deemed volume / deeming	An indirect means of estimating the volume of water delivered for the purpose of billing.
Delivery share (DS)	Gives an irrigator an entitlement to have water delivered to land in an irrigation district, and a share of the available flow in a delivery system. Delivery Shares are linked to land and stay with the property if the water share is traded away, but may be traded to other landowners supplied from the same channel, or to channel systems where capacity is available.
Design life	The length of time an item is expected to function as designed (i.e. life expectancy).
Deterioration target	The long-term water savings from each initiative, defined for each intervention as Effectiveness multiplied by Durability.
Dethridge meter	Positive displacement flow measurement device used to measure the water volumes supplied from a supply channel to an individual farm. The meter is available in several sizes: the Large Meter Outlet (LMO) with 12 ML/day capacity, the Small Meter Outlet (SMO) with 5 ML/day capacity, and the Dethridge Long (DL) Meter which 20 ML/day capacity.
Deliveries	The total volume of water supplied via customer service points over the reporting period.
Distribution losses	Water losses that occur as a result of the delivery of water to farm gates via an irrigation distribution system. Causes of these losses include evaporation, seepage, metering error, outfalls and leaks in supply system infrastructure.
Domestic and stock (D&S) water	Water used for non-potable domestic house, garden and stock use. The associated water share is generally less than 10 ML, and most often 2 ML.
Durability	A measure of the deterioration in the effectiveness of a water savings intervention before that intervention is replaced or repeated.
Effectiveness	The initial percentage reduction in water losses due to the introduction of a water savings intervention (e.g. channel bank remediation).
Environmental entitlement	A right to water granted to the Minister for Environment under the *Water Act 1989* for the purpose of: • Maintaining the environmental water reserve in accordance with the environmental water reserve objective • Improving the environmental values and health of water ecosystems, including their biodiversity, ecological functioning and water quality, and the other uses that depend on environmental condition. Also referred to as environmental water.
Environmental watering plan	A plan to mitigate potential impacts on wetlands and waterways at risk from the implementation of irrigation modernisation projects.
Environmental water reserve	Water set aside for the environment as an environmental entitlement, or through the operation of conditions on bulk entitlements, licences, permits or regulations under the *Water Act 1989* and other applicable legislation.
Evaporation	The water lost from the surface of irrigation distribution systems.
Finish of irrigation season	The last day on which irrigation deliveries are scheduled to occur, excluding pumped irrigation supplies, and piped irrigation distribution systems (nominally 15 May).
Fixed losses	Distribution losses not dependent on the volume of water delivered through the irrigation distribution system.

Term	Definition
Gigalitre (GL)	1,000,000,000 litres
Goulburn Murray Irrigation District (GMID)	The water supply system operated by GMW, which extends from west of Swan Hill to west of Yarrawonga.
High-reliability water share (HRWS)	The highest reliability entitlement to a defined share of water. This water has reliability generally greater than 95% (i.e. is supplied on average 95 years in every 100 years).
Irrigation distribution system	The collection of waterways, channels, pipelines, regulating structures and service points used to distribute water to farm gates. The extent of each system will be defined and agreed between the project proponent and system operator.
Irrigation district	An area with definite geographic boundaries within which water is allocated for irrigation under the control of local or State authority (e.g. a Water Corporation such as GMW) or other body as defined in the *Water Act 1989*. For example, the GMID and the Campaspe Irrigation District.
Irrigation modernisation	An upgrade of the irrigation distribution system to reduce the amount of water required to operate the system, including infrastructure renewal and removal.
Leakage	Loss of water through the banks of a channel and via service points.
Low-reliability water share (LRWS)	A lower reliability entitlement to a defined share of water. This water is available after there is enough water to supply all high-reliability water share entitlements, losses and reserves. It was previously known as sales water.
Loss category	A type of loss within an irrigation distribution system (e.g. seepage, evaporation).
Long-term cap equivalent (LTCE)	The LTCE is calculated from models of a water system run over a long-term climatic sequence. It represents the average annual volume of water (e.g. deliveries, water losses and water savings), that would be expected if the system was operated over the long-term under current operating rules, with the existing cap on diversions, and a repeat of historical climate conditions. Alternatives which are similar, and may be interchanged with LTCE for the purposes of water savings calculation, are Long-Term Average (LTA), the Long-Term Average Annual Yield (LTAAY), or the long-term diversion limit equivalent (LTDLE).
Meter error	The volume of water that passes through a meter that is not accounted for due to the inaccuracy of the meter itself (usually expressed as a percentage of deliveries).
Megalitre (ML)	1,000,000 litres.
Mitigation water	The volume of water set aside for mitigating the impacts of the irrigation modernisation project on wetlands and waterways which contain high environmental values that may be affected by the reduction of unplanned water entering their systems.
National metering standards	As specified by the National Water Initiative agreement signed by the Council of Australian Governments in June 2004 (refer to https://www.water.vic.gov.au/water-for-agriculture/non-urban-water-metering for more detail).
Offtake	A structure at which water is diverted into an irrigation distribution system.
Outfall structure	A structure which allows surplus water to be safely spilled from the irrigation distribution system.
Outfall	The volume of water passed through an outfall structure.
Pan factor	The factor used to adjust evaporation data measured in a Class A pan to represent evaporation from an open water body.
Pondage test	A water balance approach to measuring seepage and bank leakage within an isolated reach of channel. A section of channel is blocked off with embankments or isolated with water-tight regulator doors and the section filled with water. The seepage and bank leakage rates are calculated from the rate of water level declines after corrections are

Term	Definition
	made for evaporation and rainfall.
Project proponent	The entity with the role of planning, designing and delivering the irrigation modernisation project including its various water savings interventions.
Rainfall rejection	Outfalls resulting from water orders being cancelled/unused by customers following rainfall.
Rationalisation	Removal or decommissioning of redundant assets, including meters and sections of channel.
Reconfiguration planning	An integral step in the irrigation modernisation program whereby appropriate planning occurs, redundant infrastructure is identified and customers are involved in the process of determining how these assets can be decommissioned.
Regulator	A permanent structure constructed across a channel and fitted with a means of controlling the rate of water flow along the channel and/or the upstream water level.
Relocation of service points	A service point that is relocated from a spur channel to the backbone, or from one location on the backbone to another. Such a service point is classified as being replaced not rationalised.
Remote electronic verification system	A large portable meter accuracy certification rig that is certified to the National Metering Standard, and collects data on the accuracy of meters in the field.
Seasonal determination	A determination by a water corporation for each season of the water that is available for each water share in each declared water supply system. See Allocation.
Seepage	Water lost through micro pores in channel beds and banks in earthen channel systems.
Service point	A location where water is taken from the irrigation distribution system by a customer. Customers may have more than one service point, and service points may or may not be metered. Also referred to as an outlet.
Spur channels	A channel downstream of the backbone. These channels will be targeted for decommissioning via replacement with new customer-owned connections to the backbone.
Standard length of irrigation season	The standard length of irrigation season is typically 15 August to 15 May (274 days), but may differ between distribution systems.
Start of irrigation season	The first day on which irrigation deliveries are scheduled to occur, excluding pumped irrigation supplies, and piped irrigation distribution systems (nominally 15 August).
Structure	See Outfall structure and Regulator; but 'structure' may also refer to other items (e.g. a piped culvert over or under a channel, or a bridge or fence across a channel)
Supply point / farm offtake / outlet	See Service point
System filling	The volume of water used to bring the channels to supply level prior to the start of the irrigation season.
System operating condition	A combination of system configuration and system asset condition. Significant operation conditions include climatic variations; water savings interventions implemented over time and lower water allocations than average.
System operating water	See Distribution losses.
System operator	The entity that operates the irrigation distribution system.
Technical manual	The technical manual for the quantification of water savings from modernising irrigation distribution systems, which is chapter D of this *Water Savings Protocol*.
Unallocated losses	The volume of distribution losses that remain in the water balance after all other loss

Term	Definition
	categories have been estimated.
Unauthorised use	Water taken from any part of the system without the authorisation to do so.
Un-metered use	Water received through an unmetered water supply point. The billing volumes are usually quantified by deeming or rule of thumb calculations. These are mainly irrigated properties which have traditionally held both Water Right for the farm and a parallel D&S right for the homestead. This second supply, usually about 2 ML/year, is commonly provided through a small poly-pipe, and is generally not metered. There are also a large number of un-metered small-scale D&S only services that have traditionally been provided with water from irrigation distribution system supply channels.
Variable losses	Distribution losses that vary with the volume of water delivered through the irrigation distribution system.
Water balance	An annual account of all the water flowing into and out of an irrigation distribution system (the change in volume stored within the system is generally assumed to be negligible). The outflows include all losses from the irrigation distribution system.
Water corporation	Organisations charged with administering water supply to people in towns, farmers and other water users across Victoria for urban, industrial and commercial use.
Water savings	For the purposes of this Protocol, water savings are defined as a permanent reduction of losses within an irrigation distribution system attributable to modernisation of that system.
Water savings intervention	An action taken to generate water savings. For example, channel remediation, channel automation, etc.
Water share	A legally recognised, secure share of the water, in storage or yielded in the catchment, available for use from a declared water system. Water shares can be traded either temporarily (Allocation trade) or permanently (Entitlement trade).

Appendix A

Document amendments

The following amendments have been made from Version 1 (June 2009) to this current version (Version 5) of the *Water Savings Protocol*.

Amendment No.	Version	Source of Issue	Protocol Reference	Parameter Affected	Wording in previous version	Issues Identified	Adopted Amendment
Versions 1 to 2 – Refer Version 2							
Versions 2 to 3 – Refer Version 3							
Versions 3 to 4 – Refer Version 4							

Amendment No.	Version	Source of Issue	Protocol Reference	Parameter Affected	Wording in previous version	Issues Identified	Adopted Amendment
Versions 4-5							
5.1	5	Addition	Section 8	NA	NA	Using average baseline year loss rates may not produce the best estimates of water savings	Introduced an alternative water saving loss model if pondage test data is unavailable
5.2	5	Correction	Section 12 & Appendix G	Channel remediation	Refer to Version 4	Incorrect application of F(PA)	Corrected such that the seepage component remains constant
5.3	5	Modification	Section 12 & Section 8	Channel remediation	Refer to Version 4	Savings from replacing channels with pipelines moved to channel asset removal section	Introduced the concept of residual losses for pipelines
5.4	5	Correction	Section 10	Meter error water savings	Refer to Version 4	Method is data intensive and has scaling issues	The phase 4 equation for service point removal can be used if required
5.5	5	Clarification	Section 4.3	NA	Refer to Version 4		Reworded to be clearer

Amendment No.	Version	Source of Issue	Protocol Reference	Parameter Affected	Wording in previous version	Issues Identified	Adopted Amendment
5.6	5	Clarification	Throughout	NA	Refer to Version 4	Variable terminology	Adopted consistent terminology for key concepts, e.g.: • Distribution system • Distribution losses • Channel asset removal
5.7	5	Clarification	Glossary of terms	NA	NA	Some definitions not included	Provision of additional definitions for key terms in Glossary
5.8	5	Correction	Section 7	Durability factor	Refer to Version 4	Inconsistency in durability factor between (previous) Table 2-3 and Table 2-4	Corrected durability factor for leakage around the service point in (previous) Table 2-3 to match range given in Table 2-4
5.9	5	Modification	Sections 4.1, Section 9 and Appendix C	Outfall losses and savings	Refer to Version 4	Some outfall losses are delivery-dependent, while others are independent of deliveries	Introduced the concept of fixed and variable outfall losses

Appendix B

Procedures for determining benchmark year and baseline year for water savings calculations

Date: February 2009

Hydro Environmental

Purpose

This paper summarises the recommended procedures to follow when:

1. Selecting the benchmark year for asset condition; and
2. Choosing a relevant baseline year for operation practices for the Assessment of Water Savings.

Determining the benchmark year for asset condition

The recommended procedure to follow when selecting the benchmark year for asset condition, and thus the benchmark asset conditions is as follows:

Step A:

Identify any strategic system or management changes over the period of asset condition record available. For example, within the GMID the Advanced Maintenance Program (AMP) began in 2005/06. Assess whether the influence of these strategic programs is enough to warrant the benchmark year being chosen based on these programs. Many regions may find that, due to limited data, the key change milestone years are the only indicator of asset condition change. This step is best represented in a timeline, noting the years which are relevant to the assessment.

Step B:

Determine the year in which the bulk entitlements (BEs) were issued. This represents the earliest date that could be chosen as the asset condition benchmark year.

Step C:

Assess all historic asset condition records[11] (focussing on the asset condition rating) available since the BEs were issued. Take a weighted average (based on number or lengths) of asset condition rating across all irrigation distribution systems within the region of water savings initiatives. This weighted average is taken because some areas may only have a relatively small number of channels and meters and therefore should not hold as much influence over the chosen representative year.

Step D:

Taking the weighted average obtained in Step C, take a further weighted average across the two asset types (channels and meters) based on predicted water savings contributions of each. This weighting split will depend upon the specific project objectives as well as the amount of investment into either automation or remediation of channels.

Step E:

These values should then be compared with the total average across the period of record. The most representative year, that is the benchmark asset condition, can then be selected based on the most recent and closest to this average.

Step F:

Assess all historic maintenance expenditure for leaks, bank remodelling and meter replacements. This provides an understanding on the level of investment and change within the system prior to the works commencing. If the weighted average asset condition is significantly changed by increased expenditure, assess whether the benchmark year should be influenced by this contributing factor.

[11] Asset condition records should be obtained for all channels and meters within the system. Existing pipelines are ignored in determining the benchmark year as they hold minimal influence over the system's water savings potential.

As mentioned above, the factors which should govern the breadth of analysis in the above procedure are:

1. Availability of data
2. Year in which the bulk entitlement was issued
3. Any major improvements to asset condition over time.

Once the representative benchmark asset condition year is selected, the corporation should accurately and comprehensively record the changes in the physical processes that relate to, or affect, water delivery efficiency in that chosen representative benchmark condition. This will facilitate the development of suitable modelling packages and to accurately measure change relative to that baseline year.

The year selected to best represent benchmark asset condition could vary between systems. The following case study shows how the guidelines would be used to establish a benchmark asset condition year for the Northern Victoria Irrigation Renewal Project (NVIRP)[12].

Case study 1: Determining benchmark year for asset condition for NVIRP – 2008

Steps A & B:

The following timeline gives an indication of the relevant programs and events which influence the choice of the representative asset year for NVIRP. This includes the years in which the bulk water entitlements were ordered.

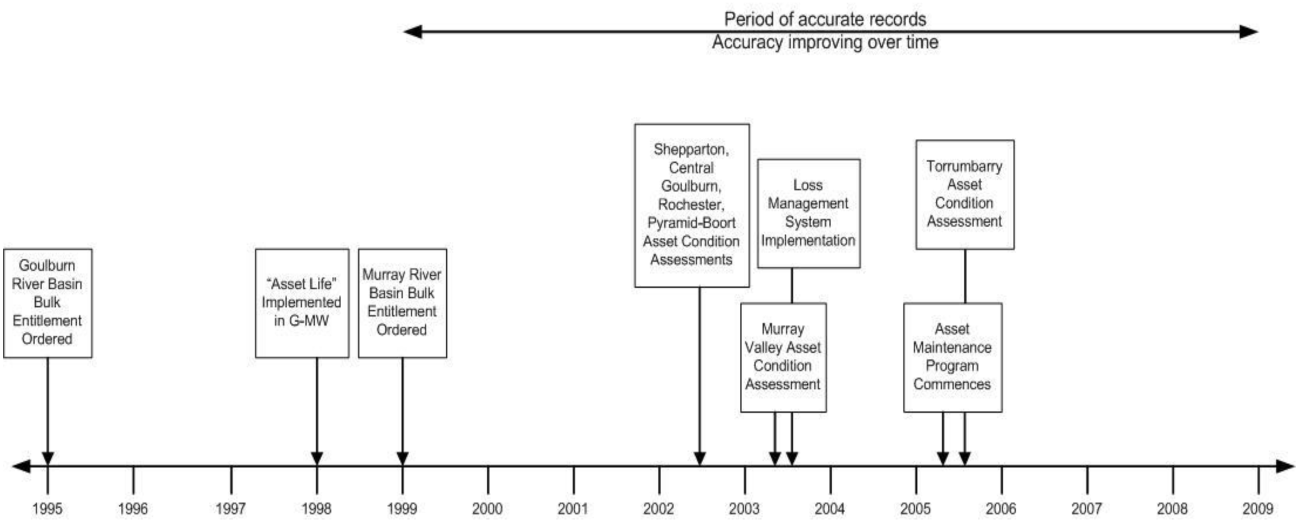

Figure B-1: Timeline of strategic system or management changes related to asset condition

Step C:

Data was collected for asset condition information including asset condition rating, asset remaining life, channel lining and remodelling information and maintenance costs. This data was apportioned by:

1. Different irrigation areas (Murray Valley, Central Goulburn, Shepparton, Rochester, Torrumbarry, Pyramid Boort and bulk carriers)
2. Different asset types (meters and channels).

The weighted average was taken across the areas as shown in Table B-1 and Table B-2. The bulk carriers were ignored due to lack of available information at the time of analysis. Weighting factors were obtained

[12] Now known as the GMW Connections Project

using the proportional lengths of channels within each of the irrigation areas, or the numbers of meters within each of the irrigation areas.

Table B-1: Weighted average of asset condition across all irrigation areas for channels

Irrigation Area	Weighting Factor	Average Condition Rating within Irrigation Areas					
		2001-02	2002-03	2003-04	2004-05	2005-06	2006-07
Murray Valley	16 %	3.01	3.04	3.06	3.13	3.10	3.10
Shepparton	11 %	2.70	2.96	2.97	2.98	2.97	2.97
Central Goulburn	22 %	3.21	3.29	3.27	3.26	3.26	3.26
Rochester	11 %	3.43	3.47	3.48	3.45	3.58	3.58
Pyramid Boort	20 %	2.43	2.57	2.57	2.59	2.54	2.54
Torrumbarry	20 %	2.88	2.87	2.87	2.88	3.09	3.14
AVERAGE	100 %	2.93	3.01	3.01	3.02	3.06	3.07

Table B-2: Weighted average of asset condition across all irrigation areas for meters

Irrigation Area	Weighting Factor	Average Condition Rating within Irrigation Areas					
		2001-02	2002-03	2003-04	2004-05	2005-06	2006-07
Murray Valley	15 %	2.92	2.93	2.96	3.07	3.04	3.03
Shepparton	13 %	2.31	2.76	2.82	2.77	2.75	2.67
Central Goulburn	28 %	3.07	3.05	2.98	2.93	2.89	2.87
Rochester	12 %	3.27	3.26	3.22	3.11	3.20	3.19
Pyramid Boort	11 %	2.39	2.88	2.87	2.85	2.82	2.81
Torrumbarry	21 %	2.44	2.42	2.42	2.41	2.72	3.01
AVERAGE	100 %	2.77	2.87	2.86	2.83	2.89	2.93

Step D:

To obtain a weighted average condition rating for each year, a further calculation needs to take place taking into account the relevant water savings contributions that both channels and meters will give to the project. The ratio of channel savings to meter savings is approximately 2:1 given that meters will make up approximately 1/3 of the overall savings within NVIRP. Table B-3 provides the average annual weighted condition across all irrigation areas, and all asset types.

Table B-3: Weighted average of asset condition across all irrigation areas for meters

Asset Type	Weighting Factor based on Meter Proportions	Average Condition Rating of all Irrigation Areas					
		2001-02	2002-03	2003-04	2004-05	2005-06	2006-07
Channels	67 %	2.926	3.008	3.008	3.022	3.062	3.071
Meters	33 %	2.771	2.870	2.857	2.834	2.890	2.932
AVERAGE	100 %	2.875	2.963	2.958	2.960	3.005	3.025

Step E:

The total average condition over the 6 years of records is approximately 2.965. The closest representative year to this average is 2002/03, with a weighted average condition rating of 2.963. 2004/05 is the second most representative year as per the above table with an annual average weighted average of 2.960 across all the irrigation areas. Given the uncertainty within the estimates, both 2002/03 and 2004/05 would be appropriate to use, based on this information, for a representative asset condition year.

Step F:

The maintenance expenditure information was gathered for the last ten years. The trend of maintenance expenditure increased significantly in the GMID. This is due to a few initiatives; however, it is mostly influenced by the Advanced Maintenance Program (AMP) expenditure beginning in 2005/06. The trend of asset maintenance expenditure is shown on the attached graph (Figure B-2). This is compared with the weighted average annual condition ratings over the past six years.

Figure B-2 shows how maintenance expenditure has increased over time, which correlates with a gradual increase in condition rating over time within the GMID. Given the large impact that AMP has on asset condition, the benchmark year chosen should be outside this period, for example prior to 2005/06.

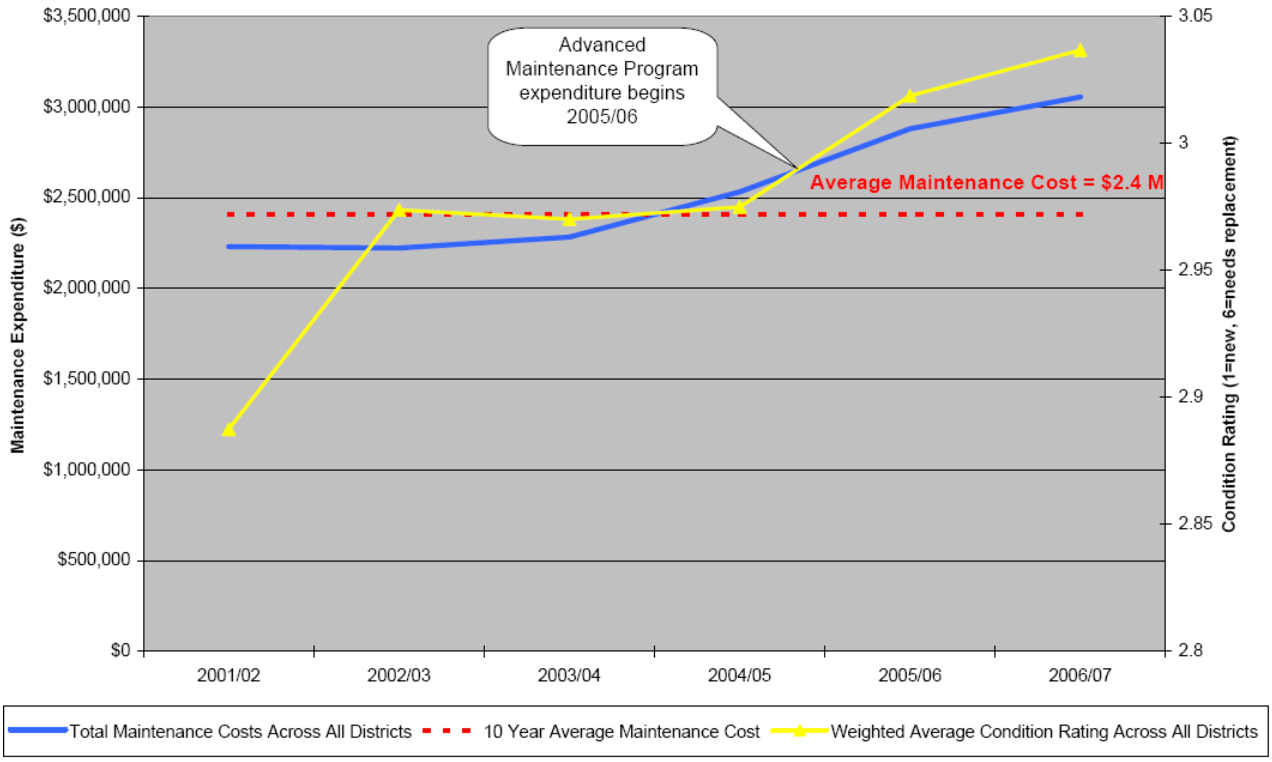

Figure B-2: Trends of Maintenance Expenditure over time for the GMID

Conclusion:

Given the above information, and the fact that most of the asset conditions ratings were undertaken within 2002/03, it would be appropriate to continue with the benchmark asset condition year of either 2002/03 or 2004/05. For NVIRP, 2004/05 was chosen due to the following:

- 2004/05 is the most recent of the two years
- 2004/05 was used as the baseline year for operational purposes, and therefore for consistency reasons it assists in having the same year for both benchmark asset condition and baseline operational year
- 2004/05 is prior to the large maintenance expenditure of AMP within 2005/06
- Recent information is more accurate and reliable than historical
- 2004/05 is representative of asset condition within the period of records analysed.

Determining baseline year for operational practices

The following generic procedures should be adopted when choosing a relevant baseline year for operational practices.

Step A:

Determine the years from which good records were kept of operating procedures and their relationship to water savings.

Step B:

Determine the years in which any significant operational changes have occurred within the system. The significant operations could include, but not be limited to:

1. Climatic variations
2. Any water savings initiatives that have been implemented over time
3. Lower water than average water allocations.

This step can utilise the timeline developed in Steps A & B of the Benchmark Asset Condition Analysis, including a more detailed focus on operational events. The timeline for determining the benchmark asset condition should be bounded by the years in which the BEs were ordered for the system and the date in which water savings initiatives were implemented.

Step C:

Based on the above information determine the baseline year which is:

1. Within the period between when the BEs were issued and the date of efficiency improvement works being scheduled
2. Representative of average climatic, water allocation and water deliveries over that period
3. Not affected by water savings initiatives already within the system. If it is affected, these should be quantified and analysed for relative significance
4. Following any significant change in water entitlements in the case in question.

Once the representative baseline year is chosen, the system operator should accurately and comprehensively record the operational attributes relating to, or affecting, water delivery efficiency as of the last day of the chosen representative year. This effectively sets the operating procedures and processes against which water savings initiatives will be measured.

The following case study examines the choice of the average of 2004/05 and 2005/06 as the representative baseline year for NVIRP to be used for water savings and loss analysis.

Case study 2: Determining benchmark year for operational condition for NVIRP – 2008

Step A:

Anecdotal evidence from GMW operators indicates that the most accurate period of record, and availability of data in relation to operational condition is from the past 10 years.

Step B:

The following timeline gives an indication of the relevant events that relate to operational changes within the NVIRP system for the period.

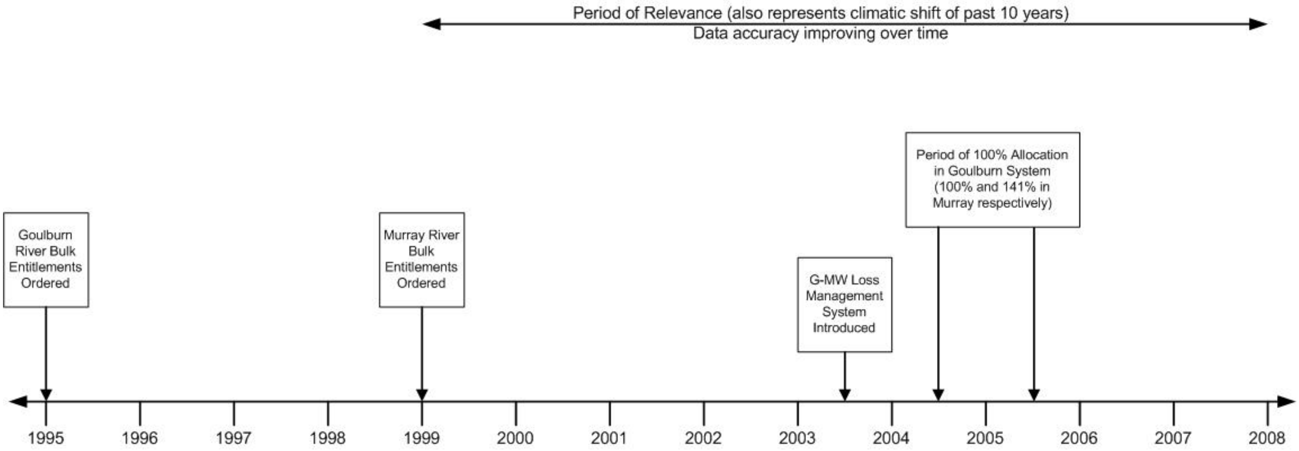

Figure B-3: Timeline of operational influences relative to defining baseline year for operational purposes

The period that is required to be analysed for the purposes of determining benchmark operational conditions in the GMID is between when the bulk entitlements were issued for the system and now. The original bulk entitlements for Goulburn River Basin were issued in August 1995 and for Murray River Basin in 1999. Since then many changes have been made to the original orders, many to take into account water savings initiatives. The last amendment was made in June 2006; however, this amendment has no impact on entitlements within the NVIRP region.

Table B-4 provides a summary of rainfall, water allocation and water deliveries from 2000 to 2007.

Table B-4: Summary of climatic and allocation information

Calendar Year		2003	2004	2005	2006
Annual Rainfall (mm/year)		482	368	488	229
Financial Year		**2003/04**	**2004/05**	**2005/06**	**2006/07**
Maximum Water Allocation	Murray	100 %	100 %	144 %	95 %
	Goulburn	100 %	100 %	100 %	29 %
Total Water Deliveries	Shepparton	155,512	157,085	158,495	69,203
	Central Goulburn	410,910	388,832	388,452	156,636
	Rochester	197,730	199,271	206,938	67,565
	Pyramid-Boort	211,729	221,668	235,781	67,424
	Murray Valley	281,773	283,483	308,827	266,118
	Torrumbarry	409,825	405,049	458,738	332,123
	Woorinen	10,078	9,029	9,735	8,546
	TOTAL NVIRP	1,511,967	1,498,303	1,598,736	889,866
	TOTAL GMID	1,677,557	1,664,417	1,766,966	967,615

As shown in the Table B-4, the actual water deliveries do not have a constant relationship/ correlation with water allocations, or annual rainfall. As most of the fixed water loss classes are related to weather conditions (evaporation and rainfall) and the variable losses are related to water deliveries, the perceived savings from particular actions will vary depending upon the year chosen as the base year for the analysis.

GMW introduced its Loss Management monitoring, recording and accounting system in 2003/04. 2004/05 is therefore post initiation and bedding down of the loss management system and the introduction of the strategic outfall measurement program. The losses in 2004/05 and 2005/06 are thought to be indicative of the system loss in years when the allocation is 100% (141% in the Murray System in 2004/05).

Significant water savings have been generated by virtue of the additional focus placed on improving supply system efficiency by GMW introducing its loss management process and publishing its Annual Loss Management Review. The first annual review was produced in 2003/04. Amongst other things, this process led to changes in operating procedures such that channel outfall losses were significantly reduced and hence water delivery efficiencies were improved.

Step C:

The average of 2004/05 and 2005/06 is to be selected as the baseline year against which any changes in the operational of physical conditions should be measured for the purpose of measuring changes in water savings/losses. Setting this base year effectively sets the channel operating procedures and processes against which changes should be measured.

Conclusion:

Where there are not large differences and to avoid confusion, the asset benchmark year and the operational baseline year should be the same. This case study found that for NVIRP the baseline year from an operating perspective from which to measure water savings against is 2004/05. This is consistent with the asset benchmark year.

Appendix C

Outfall water loss analysis

Date: February 2009, revised in July 2018

Hydro Environmental

Purpose

This paper summarises the further analysis that was completed during the development of the Water Savings Manual to confirm assumptions on the make-up of outfall water losses. The analysis summarises the technical basis for balance between operational outfalls and rainfall rejections as well as provide confirmation on the level of variability of outfall losses.

Analysis and findings

Daily analysis

An analysis was undertaken using daily outfall flow data on one of the outfalls off the Central Goulburn Channel No 6 (CG No 6). These outfall flows are graphically shown in Figure C-1. This analysis used the methodology developed by Marsden Jacobs & Associates (MJA) in 2006. The MJA approach assumed that if rainfall occurred on a particular day, or two days before, the outfall event is purely a rainfall rejection. If there was no rainfall on the particular day, or two days before, then the outfall is assumed to be for operational purposes.

It is noted, that for the CG No 6 outfalls, the resultant proportions of operational outfalls to rainfall rejection was 52:48. This supports the MJA methodology assumptions and the outcomes of an assumed 50:50 split between operational and rainfall rejections.

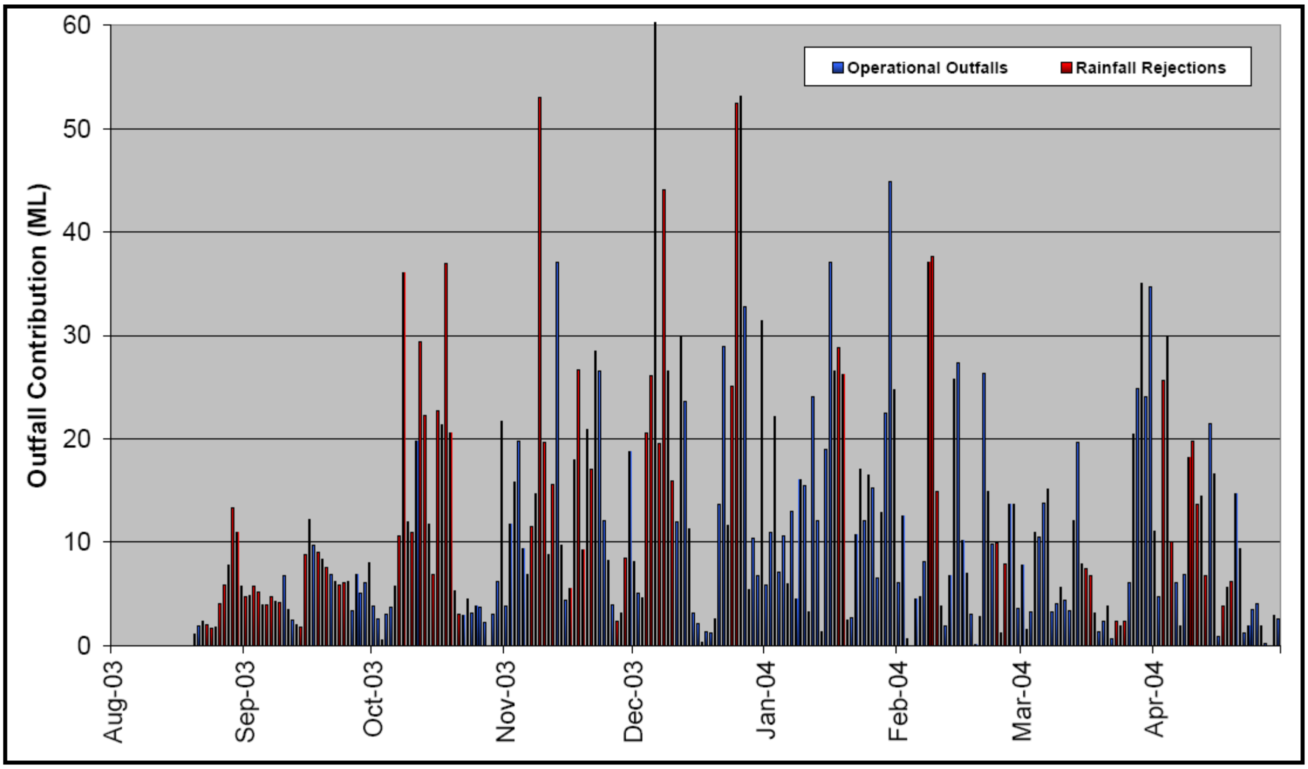

Figure C-1: 2003/04 outfall contribution for Central Goulburn 6 Channel outfall using Marsden Jacobs approach

Further work was completed on another 5 outfalls within the Central Goulburn irrigation area (CGIA). The analysis was completed over the same time period; however, the average findings resulted in a split between rainfall rejection and operational outfalls (using the MJA assumptions) of 60% operational and 40% rainfall rejections. This is displayed graphically within Figure C-2.

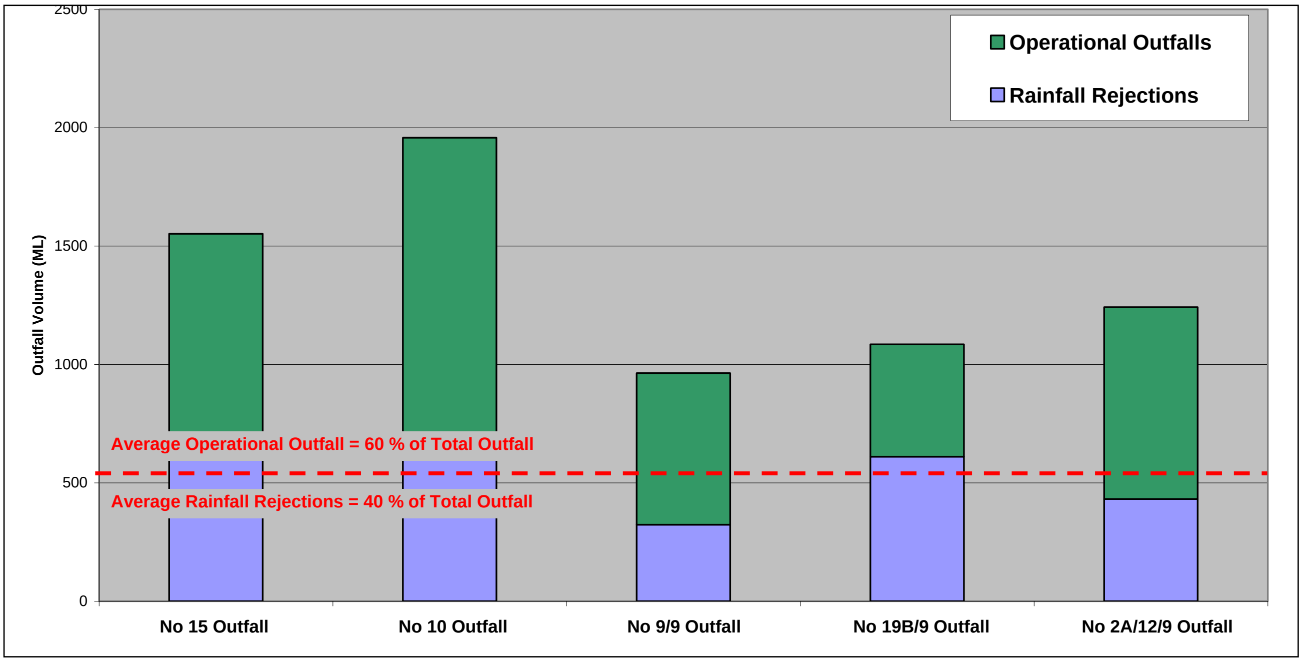

Figure C-2: Operational and rainfall rejection outfall analysis results using Marsden Jacobs methodology

Monthly analysis

Due to the disparity of the results of the daily analysis, further analysis was undertaken using the monthly 2005/06 irrigation season data available across the Irrigation Areas (using GMW loss management data). Hydro Environmental undertook an assessment based on the monthly outfall volumes and monthly deliveries in each irrigation area. For the purpose of this analysis, Shepparton Irrigation Area was not included because it was not then within the defined Northern Victoria Irrigation Renewal Project (NVIRP) geographic region.

The analysis undertaken found that:

1. There is a large difference between the proportions of deliveries that are outfalled in each of the irrigation areas. These proportions are summarised in Table C-1, with the annual average being 3%.
2. The outfall proportions, shown in Table C-1, include those outfalls that may be caused by both rainfall rejections and operational outfalls. When the data is broken into month by month data, it is easy to identify in which months there were minimal rainfall rejections (i.e. only operational escapes) and in which months there were significant rainfall events. From this, it is possible to identify the base proportion of deliveries to operational outfalls. This is shown through using the example of Pyramid Boort irrigation area (PBIA) within Table C-2. For PBIA the indicative baseline proportion for operational outfalls is assumed to be 1% whereas the overall average is 2%. The 1% is chosen for the baseline operational outfalls because it is the average minimum outfall that occurs in any month which is not dependent on the rainfall that was received within the month.

On the same basis as the dot point above, Table C-3 shows the proportion of operational and rainfall rejection outfalls adopted for the other irrigation areas.

Table C-1: Proportion of outfalls to deliveries

Irrigation Area	Total 2005/06 Outfall (ML)	Total 2005/06 Deliveries (ML)	Proportion of Total Outfalls to Deliveries
Central Goulburn	23,057	383,717	6 %
Rochester	7,428	205,327	4 %
Pyramid Boort	4,453	233,475	2 %
Murray Valley	7,599	281,576	3 %
Torrumbarry	8,187	458,515	2 %
TOTAL	50,724	1,562,611	3 %

Table C-2: Monthly proportion of outfalls to deliveries in Pyramid Boort

Pyramid Boort Irrigation Area	2004/05 Rainfall (mm)	2004/05 Outfall Volumes (ML)	2004/05 Delivered Volumes (ML)	Proportion of Outfalls to Deliveries
September	31.6	375	16,280	2 %
October	41.0	519	31,569	2 %
November	34.2	870	8,835	10 %
December	36.8	425	17,427	2 %
January	20.2	254	24,938	1 %
February	7.4	412	24,130	2 %
March	10.0	321	25,537	1 %
April	27.8	330	40,135	1 %
May	15.6	434	36,295	1 %
June	18.9	513	8,330	6 %
TOTAL	243.5	4,453	233,476	2 %

Table C-3: Total proportion of outfall volume that is either an operational outfall or a rainfall rejection

Irrigation Area	Operational Outfall Component	Rainfall Rejection Outfall Component
Central Goulburn	67 %	33 %
Rochester	55 %	45 %
Pyramid Boort	51 %	49 %
Murray Valley	70 %	30 %
Torrumbarry	55 %	45 %
AVERAGE	59 %	41 %

The overall finding of this very simplistic analysis was that the proportions of operational outfalls to rainfall rejections should be 60:40 rather than the previously adopted 50:50. These findings correlate with the additional daily analysis findings undertaken by Hydro Environmental which are based on daily rainfall and outfalls for one year (2005/2006).

Prior to adopting revised figures, it would be worthwhile completing this analysis on other years to assess the variability and dependencies. 2005/06, however, does represent a year of 100 % water allocation in the Goulburn irrigation system and a 144 % allocation within the Murray irrigation system. This could explain the higher proportion of operational outfalls within the Murray Valley irrigation area, which when analysed, could result in the average proportion being closer to the presented adopted 50:50 assumptions. Another reason for the higher than average operational outfalls within Central Goulburn and Murray Valley could be due to the planned passing flows necessary to meet downstream demand being included in the outfall volumes.

Recommendation

Recent analysis shows that the split of operational outfalls to rainfall rejections is likely to be between 55:45 and 60:40. However, until further analysis, using more daily and monthly data from different years is completed the technical manual should adopt the more conservative 50:50 split, as the materiality of the change is not significant in the short term.

Recent analysis also shows that on a month to month basis, the outfall losses are quite variable.

Appendix D

Proposed leakage: seepage loss ratio and leakage fixed: variable ratio to be adopted for water savings calculations

Date: February 2009

Hydro Environmental

Purpose

The purpose of this analysis is to:

1. Confirm the current leakage and seepage loss ratio; and
2. Confirm the ratio of fixed: variable bank leakage losses for Water Savings calculations proposed by Hydro Environmental on the basis of data supplied and the results of Simon Lang's (Sinclair Knight Merz) study titled: *"The use of Total Channel Control© data to characterise the spatial and temporal distribution of leakage and seepage losses in Central Goulburn Channel No. 2"*.

Background

The Central Goulburn irrigation area is an irrigation distribution system located near Tatura in Northern Victoria comprising nine major water supply channels. In 2002, Rubicon Systems Australia and the Department of Sustainability and Environment (DSE)[13] carried out an irrigation modernisation project on the Central Goulburn Channel No 2 (CG-2) on behalf of Water for Rivers. CG-2 is a small channel system near Murchison, which is used to supply irrigation water.

The project included the installation of Total Channel Control (TCC™) and centrally controlled tilt gates, which is a network control system developed by Rubicon Systems Australia Pty Ltd in conjunction with the University of Melbourne. The TCC™ system on CG-2 comprises a range of automatically controlled regulation gates (136 Flume Gates) to regulate flow between channel pools so that water levels remain at supply level and allow irrigation water to be delivered on demand. All of the service points on the CG-2 Channel are also 24/7 constantly controlled automated service points.

Simon Lang's study, commissioned by DSE for support to the development of the Technical Manual, examined data available for the CG-2 between 2003/04 and 2008/09 (to date) to investigate the ability of TCC™ to characterise the spatial and temporal distribution of leakage and seepage losses on a sub-yearly time-step.

For the purpose of the study, leakage and seepage (combined) is defined as all water lost through or over channel banks and beds. Leakage refers to the water lost at discrete locations (e.g. through structures or holes and cracks in channel banks) while seepage is the water lost via diffusion through soil types that comprise low channel banks and beds (with most being through the bed).

Summary of report results

Simon Lang's study highlighted the inherent difficulties in using average daily pool losses reported by the TCC™ (inflow to pool from upstream regulators minus outflow from pool via service points and regulators) to characterise the spatial and temporal distribution of leakage and seepage losses. Reliable outcomes could not be obtained because of the inflow and outflow regulation measurement inaccuracies. A different approach was therefore trialed; using a total system loss calculation and a water balance approach.

The daily total of metered deliveries passing the 136 Flume Gates™ that regulate flow onto farms was compared with the daily CG-2 inflows. In theory, the difference between these two numbers (as shown in Figure D-1) is a daily record of the water lost to evaporation, leakage and seepage assuming:

- Unauthorised use of water is negligible
- The installation of TCC™ has eliminated losses due to bias in meter inaccuracies
- Once channels are filled, the volume of water stored in the system remains the same throughout the irrigation season
- The un-metered use of water is minimal compared to the metered use of water.

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[13] Now known as the Department of Environment, Land, Water and Planning (DELWP)

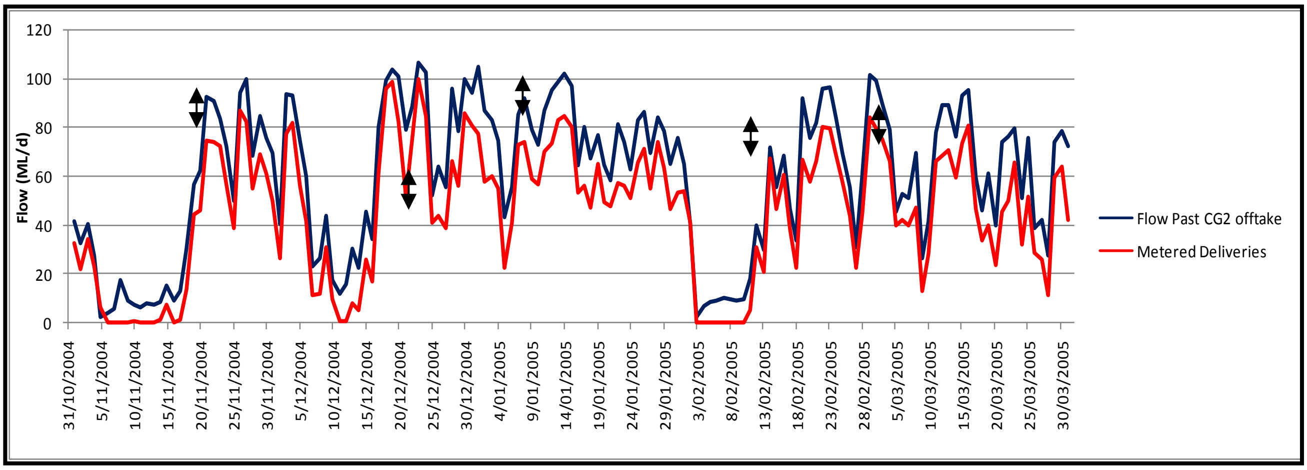

Figure D-1: CG-2 Total water loss 2004/05

To examine the losses in CG-2 attributable to leakage and seepage, net evaporation losses were separated from the total water loss figure. Over the periods of data analysed, net evaporation losses were between eight and ten times less than losses to leakage and seepage in 2003/04, 2004/05 and 2005/06, and five to six times less in 2006/07 and 2007/08. This is shown in Figure D-2.

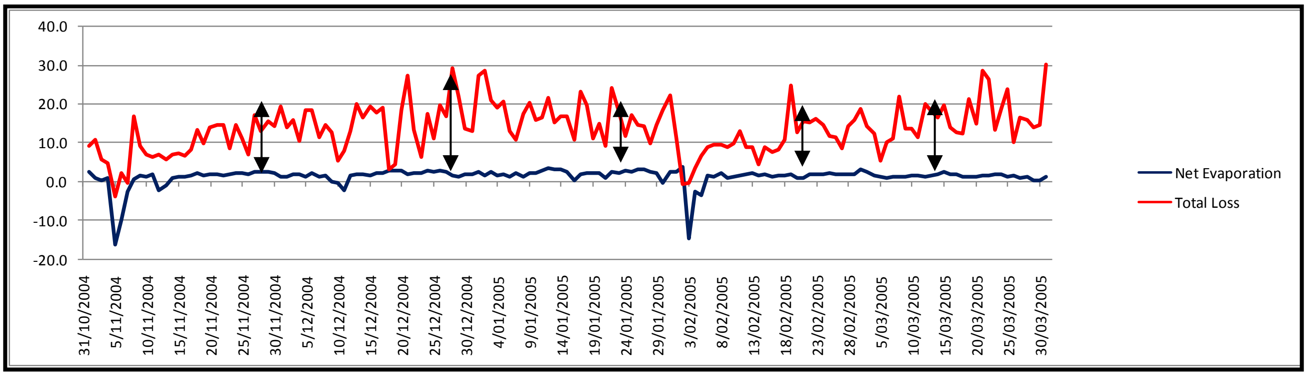

Figure D-2: Relationship between net evaporation and total water loss 2004/05

To characterise the behavior of leakage and seepage losses, subsets of each irrigation season were chosen for the study. These can be seen in Table D-1. The subsets were formed to remove perceived periods of erratic results as a result of channel filling and end of season fluctuations.

To investigate the proportion of loss attribute to leakage and seepage, a fixed seepage loss was assumed. The fixed seepage loss assumed was derived from weighted averages of the seepage rates from GMW measurements taken in June 2006 and May 2007 pondage tests. The weighted average of seepage rates for pools within the CG-2 system is 6 mm/d, assuming the channel dimensions used in the evaporation calculations above.

Table D-1: Irrigation season subsets

Season	Analysis Period
2003/04	1st November – 15th May
2004/05	1st November – 31st March
2005/06	1st November – 31st March
2006/07	1st September – 30th April
2007/08	1st September – 15th May

The results (Figure D-3) indicate that leakage losses are typically several times greater than seepage losses, but estimates of leakage vary considerably from day to day, suggesting that on a daily time-step measurement accuracy is quite variable and leakage behaviour is possibly more variable than fixed. The results of the analysis shown in Table D-2 shows that for the 2003/04, 2004/05 and 2005/06 periods analysed, leakage losses were four times the seepage losses, indicating a leakage:seepage split of 80%:20%, while in 2006/07 and 2007/08 the split was 70%:30%.

This change in leakage: seepage split over time indicates that leakage losses are variable not only from day to day, but also from year to year. The reduced proportions of leakage over time may be a result of the reduced water allocations in 2006/07 and 2007/08 and may also be a result of automation of the system, reducing the variability of channel flow and therefore losses from upper bank leakage.

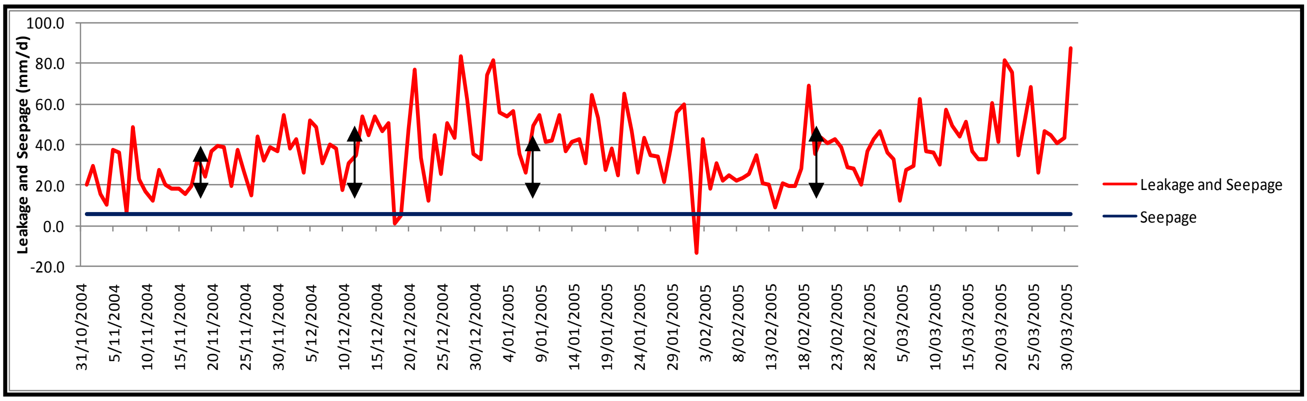

Figure D-3: Seepage and leakage relationship 2004/05

Table D-2: Leakage : seepage ratio

Season	Leakage: Seepage Ratio
2003/04	**82% : 18%**
2004/05	**81% : 19%**
2005/06	**83% : 17%**
2006/07	**71% : 29%**
2007/08	**68% : 32%**

Due to the absence of water level data for pools in the CG 1, 3 and 4 systems, the study used diversions into CG-2 diversions as a predictor of leakage. The results presented in Figure D-4 show a relationship between average leakage (in mm/d or ML/d) versus CG-2 diversions on a monthly time step (Figure D-4).

Figure D-4 indicates that as the diversions from CG-2 increase, leakage losses increase in absolute terms, but decrease as a proportion of flow. From these results, this relationship could be used to satisfactorily predict leakage losses in the CG-2.

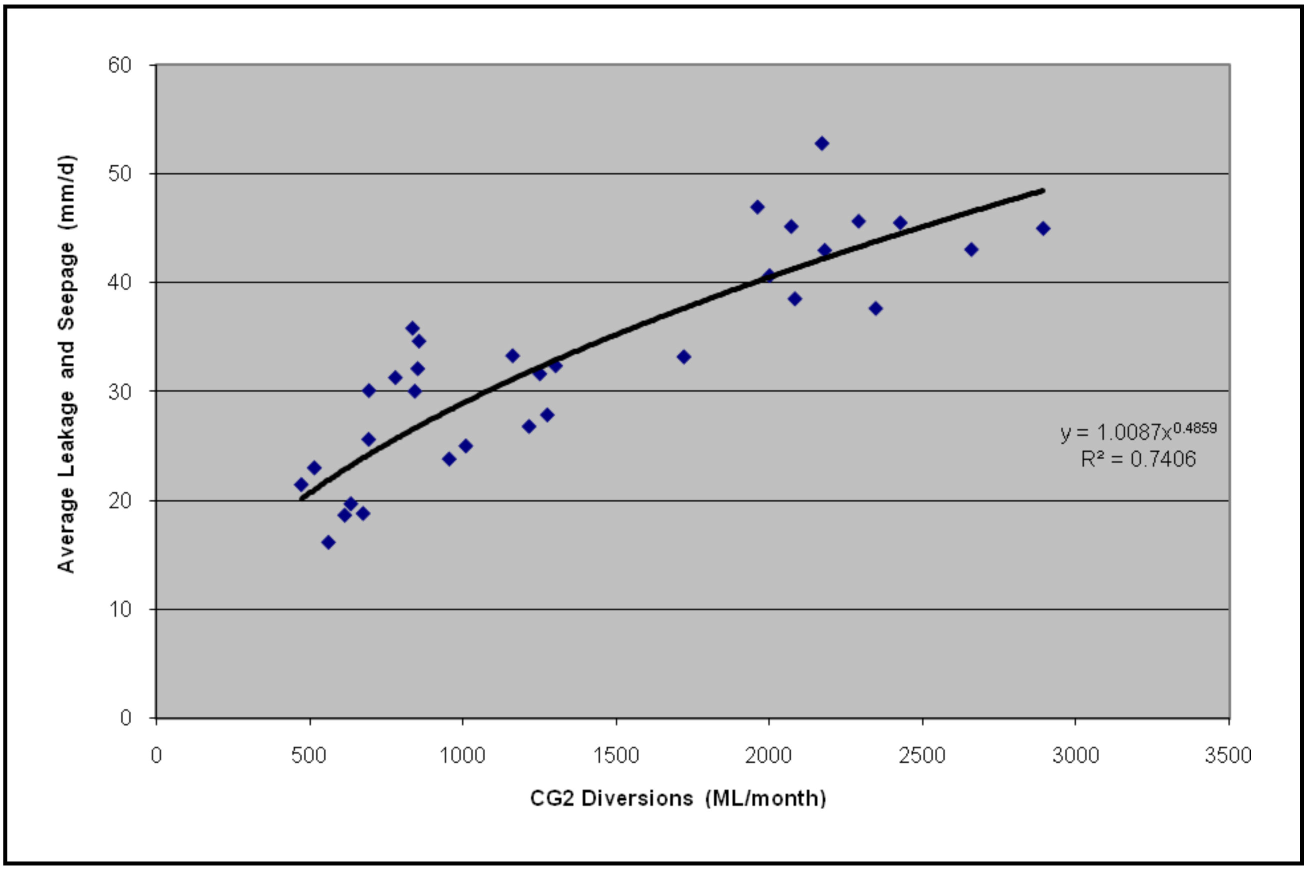

Figure D-4: Average leakage losses versus diversions to CG-2 on a monthly time-step

Verification of relationship by Hydro Environmental

Further analysis was required to determine the fixed: variable relationship and to confirm the leakage: seepage ratio. The fixed seepage value used in Simon Lang's study was 6 mm/d, taken from CG channel 2 2006 and 2007 pondage test data.

However, for the Hydro Environmental analysis calculations, data from the whole of the CG 1-4 system was used as it is more representative of the whole Goulburn Murray irrigation district (GMID). From analysis of data derived from the GMW document # 2345437 (Shultz, 2009), an average seepage rate for CG 1-4 was determined. The report outlines the relationship between the average and most permeable soil groups (derived from GIS analysis) of the 200 pools in the CG 1-4 and pondage test results from the same pools in 2006 and 2007. The results are presented in Figure D-5.

From the data used to develop Figure D-5, the average soil group of the CG 1-4 area was soil group 2. Therefore, the representative seepage value is assumed to be the average seepage rate of soil group 2. As shown in Figure D-6 the average seepage rate of soil group 2 is 6.6 mm/d. Given the level of confidence in the results this value was rounded up to 7 mm/d to reduce complexity in further analysis.

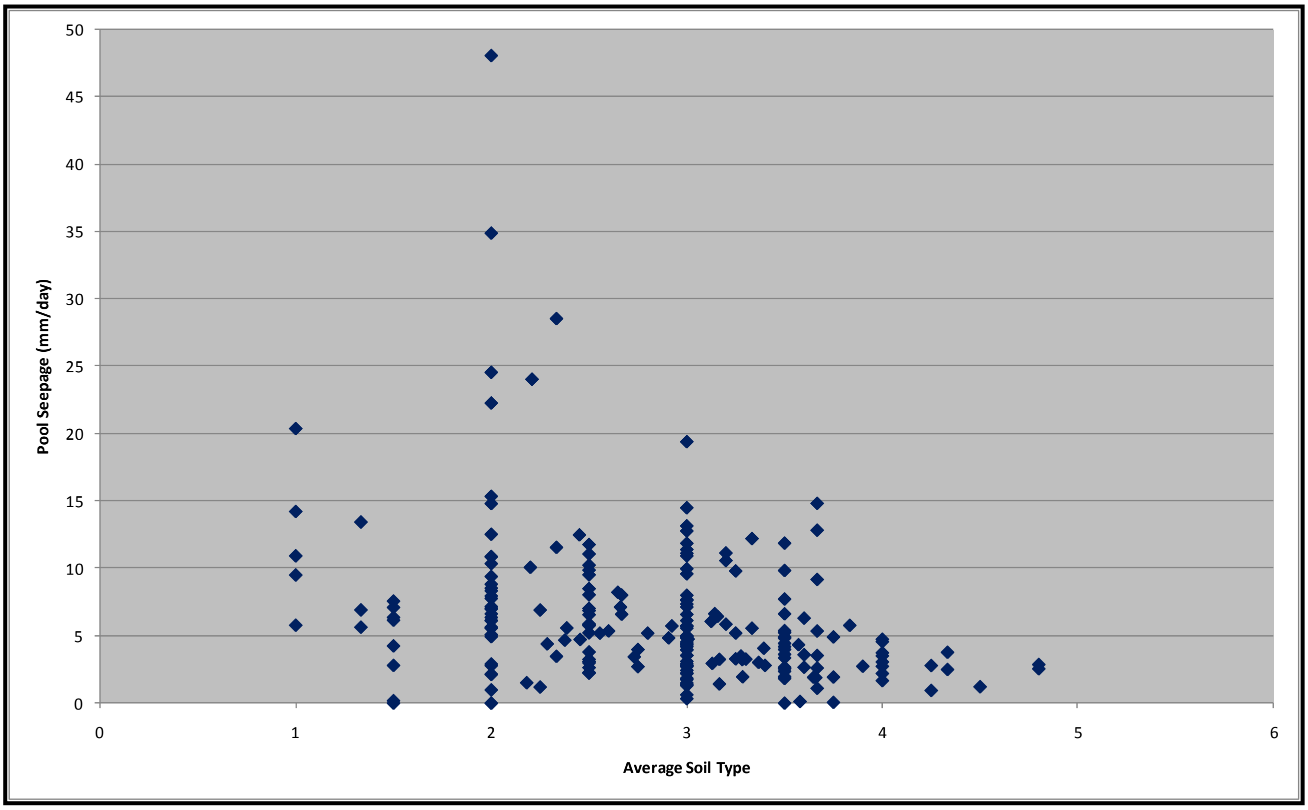

Figure D-5: Relationship between average soil group and pool seepage for CG 1-4 pools 2006 and 2007

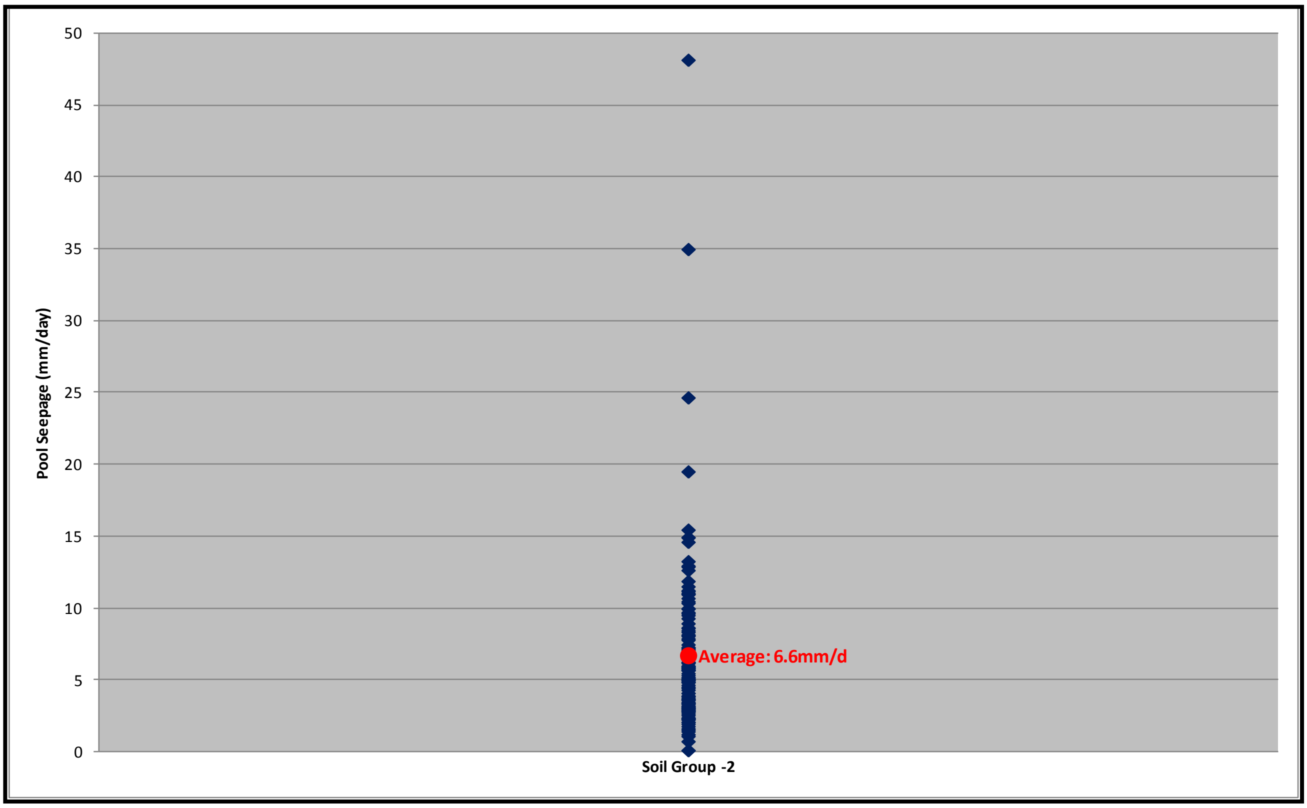

Figure D-6: CG 1-4 Pool seepage 2006 and 2007 data – soil group 2

This representative fixed seepage value was applied to the data (plotted in Figure D-4) to determine the leakage: seepage split proposed to use in the Technical Manual. The results plotted in Figure D-7 confirm that the Leakage : Seepage Loss Ratio is approximately 80%:20% for 2004/2005 average data.

Using the average combined seepage and leakage monthly figures from 2003/04 to 2007/08 a line of best fit was developed. Where this line intercepts the y-axis, at the point where delivery losses are not flow dependant, this point or seepage and leakage rate represents the delineation between fixed and variable losses. As shown in Figure D-7, below, this is at 17.3 mm/d.

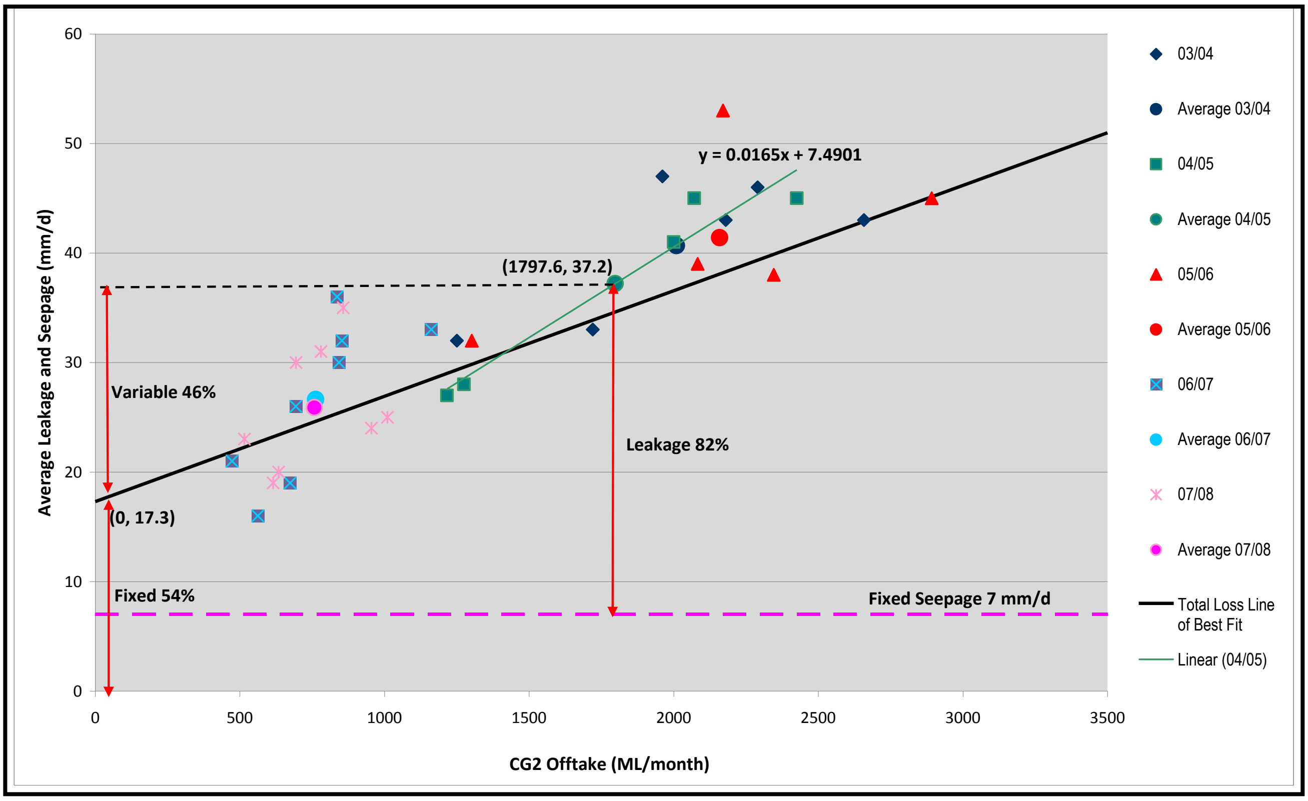

Figure D-7: CG-2 Average leakage and seepage loss versus diversions using monthly time-steps

Using this data Hydro Environmental developed an idealised relationship of ***y = 17.5 + 0.01x*** to represent the leakage and seepage relationship to annual diversions in order to establish clearer delineation lines. This relationship is compared with the established line of best fit within Figure D-8.

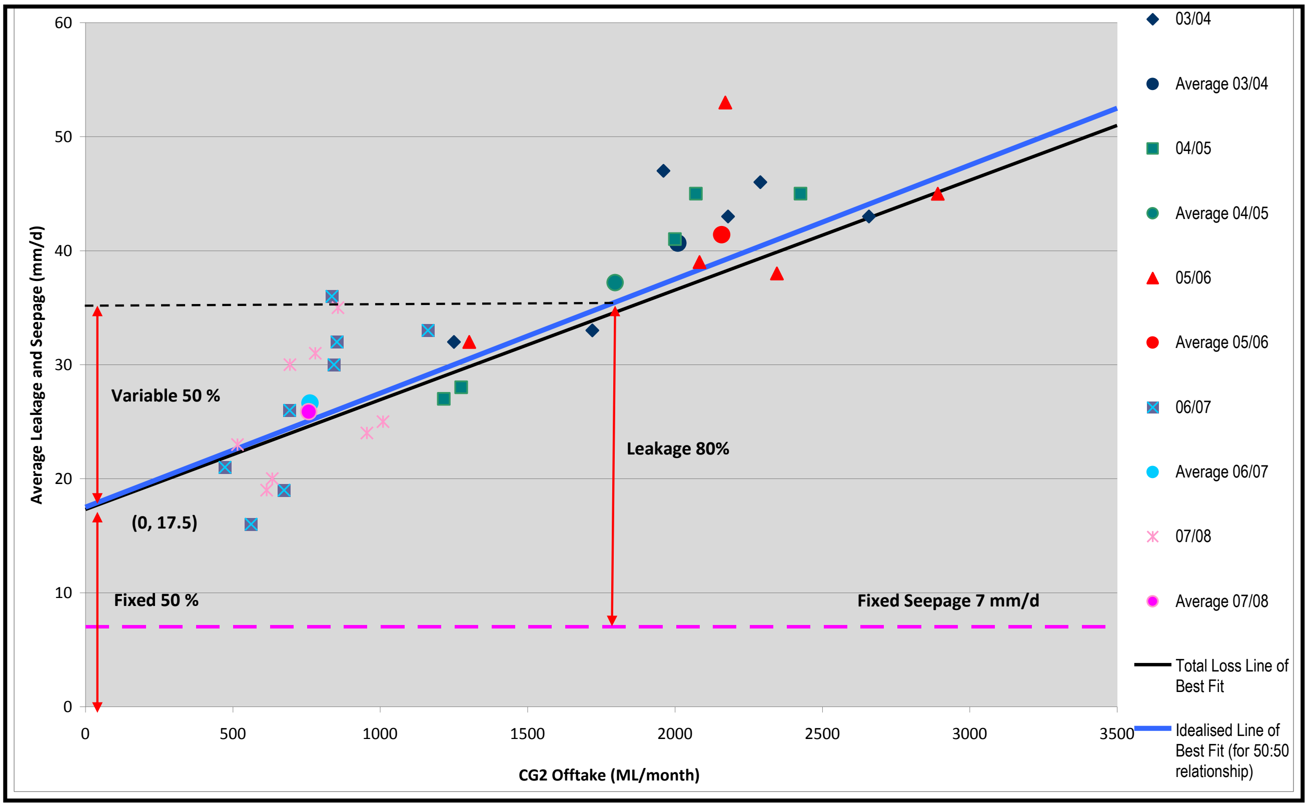

Figure D-8: Representation of idealised seepage to leakage and fixed to variable relationship

In summary, using 2004/05 as the baseline data:

- Total Fixed loss = 17.3 mm/d = 47% of total loss (say 50%)
- Total Variable loss = (37.2 mm/d – 173 mm/d) = 53% of total loss (say 50%)
- Fixed Seepage loss = 7 mm/d = 20% of total losses
- Total Leakage loss = 30.2 mm/d = 80% of total losses
  - Fixed Leakage loss = 10.3 mm/d (17.3mm/d – 7mm/d) = 35% of leakage loss
  - Variable leakage loss = 19.9 mm/d (37.2mm/d - 10.3 mm/d – 7 mm/d) = 65% of leakage loss.

Recommendation

Based on the above analysis and the findings of Simon Lang's report, it is recommended that until further analysis is undertaken:

1. A leakage and seepage loss ratio of 80%:20% is to be applied
2. The fixed: variable relationship of 50%:50% for leakage plus seepage should be applied
3. The fixed: variable relationship for leakage assumed at 35%:65%.

Appendix E

Water savings: Technical basis for water loss and water savings through and around service points

Date: 24 January 2009

Extract from GMW Document Number: 2476026

Introduction

Loss through and around service points was first identified as an issue in the research study 'Benchmarking Distribution Efficiency' (GMW document #335268), which suggested some 10% of loss was through water being lost through irrigation service points. A subsequent study by GMW Area Operations staff confirmed that similar loss rates were experienced in all GMW irrigation areas. The issue of loss around meter service points was analysed in the *Water Systems Operational Review* (2002).

As part of the study into loss components in the CG1234 system more rigorous studies were undertaken to analyse loss through service points. Pondage test analysis confirmed that bank leakage and loss around service points was a significant proportion of loss in the CG1234 system. Investigation of high loss pools suggested that in some pools the leakage around service points was the main cause of loss through leakage.

This report summarises the technical basis for assumptions of system loss and water savings through and around service points. The recommendations form the basis for various water saving projects that GMW is involved with including, asset rationalisation, reconfiguration, Shepparton/CG1234 modernisation and NVIRP[14].

Leakage through service points

Leaks through service points account for a large part of system loss. For instance, leakage through service points account for about 8% of loss in the CG134 system, and loss through service points occur in about 20% of service points (GMW document #1943471). About half of the loss is a result of customers allowing a flow of water through doors, at a rate greater than 20,000 L/h (0.5 ML/day). This practice is considered 'unauthorised use' and is not considered as 'leakage through service points' in this report.

GMW Area Operations staff has improved surveillance of leaking service points as part of the loss measurement program. This resulted in water savings through a GMW investment in improved operations. However, leakage is due to poorly maintained neoprene seals and improper closing of the door by customers. During the 2006/07 season a program to locate and repair neoprene seals was undertaken by GMW.

Loss estimation

From the experience in CG1234 (GMW document #1943471):

- Average loss through service points (CG134) – 3.8 ML/yr/service point
- Discounting service points with loss rates >20,000 L/hr – 2.1 ML/yr/service point
- Assuming service points are non-operating 90% of time – 1.9 ML/yr/service points
- The average leak rate for service points leaking <20,000 L/h – 400 L/hr.

This technical basis established the estimate of loss in the CG1234 water balance study. The result has been extrapolated to other GMW areas. While there is potential that different standards of maintenance have occurred in different irrigation areas, investigations by GMW area operations staff in 1998 on selected spur channels suggested similar loss rates occur throughout GMW. In response to drought, GMW has been making continual investment in loss management since 2002/03. The finding of significant losses through irrigation service points triggered a special purpose program to repair neoprene seals and improve maintenance on meters.

In CG134, of Dethridge Meter service points with leak rates in the 500-20,000 L/h range, 36% required new gate seals, 25% required removal of debris from under the gate and 29% were not leaking on re-inspection.

[14] Now known as the GMW Connections Project

Subsequently, as part of the 2006/07 meter maintenance program, neoprene seals were replaced on service points found to be leaking in all irrigation areas. The results are shown in Table E-1.

Table E-1: Results of meter rehabilitation program

Area	Area DMOs	2006/07 maintenance program			
		rubbers	doors	sum	
	#	#	#	#	%
Shepparton[1]	2,197	264	0	264	12.0%
Central Goulburn	4,084	32	3	35	0.9%
Rochester	2,251	0	0	0	0.0%
Pyramid-Boort[2]	2,198	4	0	4	0.2%
Murray Valley	2,735	56	24	80	2.9%
Torrumbarry[3]	3,485	14	5	19	0.5%
TOTAL GMID	**16,950**			**402**	**2.4%**
TOTAL NVIRP	**14,753**			**138**	**0.9%**

Note 1 Recorded as "required" (no record of "replaced", therefore assumed that required = replaced)

Note 2 Recorded as "1" or "Y" in Rubbers or Doors fields (no records of "replaced", therefore assumed that 1 = Y = replaced)

Note 3 Recorded as "replaced"

Assuming that each NVIRP service point repaired gave a sustained saving of 4 ML/y (GMW document #1943471) the overall saving is 552 ML. The total leakage through NVIRP Dethridge meter service points was estimated to be 28,031 ML in 2004/05. The 2006/07 meter maintenance program would have reduced this loss rate to 27,479 ML or 1.86 ML/service point (27,479/14,753). However, the number of seals and/or doors replaced was relatively small and this activity could be similar to routine maintenance. It is likely there was no sustained benefit because a similar number of seals/doors on other service points could become damaged at the same rate.

This analysis suggests GMW Area Operations staff is unable to repair the majority of leaking service points. It is likely the major cause of leaking service points is due to improper closure or detritus in the water (sticks, weeds) that inadvertently cause the service points to leak.

Recommendation

The loss rate through service points should be assumed as 1.9 ML/service points.

Water saving estimation

The water savings estimation will depend on the initial 'effectiveness' and longer term 'durability' of the change that occurs to the GMW infrastructure (GMW document #2315603v3). Where service points are removed, as part of an asset rationalisation program, the water saving is considered 100% effective and 100% durable into the future. It is therefore assumed that the water loss associated with the service points removed will result in a water saving over time of 1.9 ML/service point, regardless of whether the service point was found to be leaking. Where a service point is replaced it is considered there will be no leaks immediately after replacement (that is effectiveness is 100%). Further, new meters will have penstocks, low flow rates will be measured and surveillance will be improved.

Advice provided by Bill Heslop suggests:

- Magflow meters (450 mm diameter) will measure low flows through service points >20,000 L/hr (0.5 ML/day), but will have software set to ignore water flows below this value, to avoid a spurious flow being registered.

- Penstocks will be designed to reduce leakage to below 50 L/hr, if correctly closed down by customers. Flume gates will also be maintained to ensure leaks are less than 50 L/hr. However, there may be a difference in effectiveness between automatic and manual service points, because automatic service points will close to a pre-set pressure level, in contrast to manual operation of a penstock to achieve closure.
- Under the national metering framework, maintenance schedules will be part of an annual audit requirement and this has been allowed for in all meter costing calculations. Maintenance consists of an annual check, meter validation and a replacement interval for the gate. This will be recorded in an Asset management system.

Leakage through meters will be substantially reduced in the future, but not eliminated. It is therefore assumed:

- Incidence of leakage will continue to occur in 20% of service points, but leaks greater than 100 L/hr will be repaired.
- Loss rate of leaking service points will in the future be 80 L/hr.
- Loss rate of leaking service points in the past was 400 L/hr; this is the rate found in the CG134 area, excluding the five service points with leak rates over 20,000 L/hr considered to be unauthorised use.

The overall leak rate will therefore be 80%[15] lower than the rate that occurred prior to modernisation (that is, a durability of 80%).

Recommendations

It is recommended that the following be adopted:

1. Loss through service points – 1.9 ML/y with the effectiveness and durability of savings being shown in Table E-2
2. Water savings associated with rationalisation[16] – 1.9 ML/service point
3. Water savings associated with replacement (automatic) – 1.52 ML/service point
4. Water savings associated with replacement (manual) – 1.37 ML/service point.

Table E-2: Effectiveness and durability for loss through meters

	Effectiveness (%)	Durability (%)	Eff x Durability (%)
Removal	100	100	100
Replacement (automatic)	100	80	80
Replacement (manual)	90	80	72

Loss and savings around service points

Leaks around service points makes up a large part of the routine leaks repaired by operational staff. About half the total numbers of leaks repaired are leaks around service points. The loss rate for individual leaks is thought to be between 2.4-11.8 ML/y in 2002 (GMW document #900407), based on area estimates, which compares with 1.9-4.9 ML/yr in 2006 (GMW document #1814829), based on actual field measurements in the CG134 area.

[15] Corrected from 20% in the previous version of the *Water Savings Protocol*

[16] Referred to as service point removal in this version of the *Water Savings Protocol*

Loss estimation

Before February 2008, a conservative approach was taken and each service point was assumed to have a leak rate of 0.1 ML/yr around service points. This value was adopted subsequently by Hydro Environmental (GMW document #2315603v2) and also in GMW programs, such as reconfiguration and the loss measurement program.

This approach has now been updated based on the following consideration. Table E-3 shows the number of Dethridge style service points in the GMW system.

Table E-3: Service points by type and irrigation area[17]

Data	Central Goulburn	CG1234	CG (NVIRP)	Rochester	Pyramid-Boort	Murray Valley	Torrumbarry	Shepparton
Channel Evaporation	12,325	2,137	10,188	8,802	9,853	16,274	16,214	7,542
Channel Seepage	15,571	3,004	12,567	9,264	9,518	21,998	14,649	9,179
Undeemed D&S Use	350	200	150	60	120	170	420	230
Length (km)	1,482	263	1,219	579	1,254	959	1,234	678
Open Outlets	362	50	312	165	30	64	313	205
Magflow Outlets	61	15	46	35	7	14	27	18
Flume Gates	143	143	-	-	-	-	-	0
DLMOs	63	6	57	55	68	17	13	20
LMOs & SMOs	4,842	815	4,027	2,196	2,130	2,718	3,472	2,177
Outlets that Leak	5,471	1.029	4,442	2,451	2,235	2,813	3,825	2,420
All other Outlets	2,934	405	2,529	1,535	528	1,750	2,314	2,006

In 2004/05 there were 15,637 NVIRP service points which had a potential for leakage through the service points (excludes Magflow and FlumeGates), and 15,766 with potential for leakage around the service points.

There were 1,890 service points with a leak around the service points (10.7% of all service points) reported by Moorhouse (GMW document #900407) between 1999/00 - 2000/01. The loss for service points found to be leaking was reported as 4.6 ML/yr (GMW document #900407) and 3.6 ML/yr (GMW document #1814829), which is a mean of 4.1 ML/yr over two studies. This represents a total loss of 7.75 GL/yr in the GMID. Over the 19,215 service points that had a potential for leakage in the GMID, this represents a 0.4 ML/yr loss for each service point that has the potential for leakage.

[17] Prior to modernisation

Water saving estimation

The following approach is proposed based on discussion with DSE consultant Hydro Environmental:

Rationalisation[18]

Effectiveness = 100% (service point has been removed and therefore no leakage can occur around the emplacement, assuming that the bank has been adequately re-compacted following removal)

Durability = 100% (service point remains removed, and therefore no leakage can occur around the emplacement, and any leakage that did occur due to inadequate compaction would be attributed to bank leakage)

Savings = 100% x 100% x 0.4 = 0.4 ML/yr for each service point rationalised.

Replacement

Effectiveness equals 100% (that is we can assume that a service point is replaced with adequate backfill and to adequate engineering standards to eliminate all leakage immediately). It is further assumed that the warranty period associated with works is at least 12 months, so that any work completed and found to be leaking, will be required to be reinstated so it is not leaking. If the warranty period is less than 12 months, an effectiveness of 100% is not appropriate.

Durability depends on the engineering standard of the replacement works. It is likely that in the future, there will be a certain amount of leakage that will occur around the emplacement headwall, depending on the extent of the cutoff wall installed or the length of the pipe. It is considered that if the replacement is consistent with ideal engineering standards (for instance cut off walls 2.5x the width of the emplacement) the durability is 95% (consistent with Lanes formula). It is assumed adequate cut off walls will be used to both increase the seepage path, and to provide an effective barrier for yabby (crustacean) damage. It is assumed the emplacement will be installed consistent with approved GMW engineering standards, in good foundation soil, in the centre of the bank, with protection from erosion with rock beaching. Appropriate construction standards will be used regarding the placement and setting of concrete, and compaction of soil around the emplacement. Failure to follow any aspect of this procedure will result in reduced durability, and hence lower water savings.

However, if engineering standards are less than ideal, perhaps to reduce cost, a durability value of 85% should be used. If no cut off walls are used then the durability is zero; that is there is no benefit beyond current leakage rates around meters. Table E-4 shows the relationship between engineering standards and water-tightness effectiveness and durability.

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[18] Referred to as service point removal in this version of the *Water Savings Protocol*

Table E-4: Effectiveness and durability for loss around meters

Engineering Standard	% Effectiveness	% Durability	Details
Ideal	100 %	95 %	• Appropriate depth/length of cut off walls • Cut off walls designed and constructed to match service point dimensions • Appropriate rock beaching • Ongoing maintenance of channel profiles through Asset Maintenance Program (AMP), or equivalent • Construction standards, and quality control during construction appropriate
Less than Ideal	100 %	<85 %	• Cut off wall designed to a lower standard and constructed to match service point dimensions • Less than appropriate level of rock beaching • No ongoing maintenance of channel profiles through AMP or equivalent • Construction standards, and quality control during construction not appropriate
Unsuitable	100 %	0 %	• No cut off walls • No rock beaching • No ongoing maintenance through AMP or equivalent • Construction standards, and quality control during construction not used during construction

** This will vary depending on the diameter of the new meter service point.*

Executive summary

The appropriate factors associated with water savings estimates for service points with the potential for leakage are as follows:

System Loss

1. Around the meter: 0.4 ML/y/service point
2. Through the meter: 1.9 ML/y/service point
3. Around and through the meter, prior to 2006/07: 2.3 ML/y/service points.

Effectiveness and Durability

1. Rationlisation: 100% effective and 100% durability
2. Replacement:
    a. for savings around meters, refer to Table E-5
    b. for savings through meters refer to Table E-6.

Table E-5: Savings of leakage around meters

Engineering Standard	% Effectiveness	% Durability
Ideal	100	95
Less than Ideal	100	85
Unsuitable	100	0

Table E-6: Savings of leakage through meters

Type of replacement	% Effectiveness	% Durability
Automatic	100	80
Manual	90	80

Recommendation(s)

It is recommended that:

1. The engineering standard associated with replacement of new meters be investigated and new standards recommended for each meter type to ensure water savings effectiveness and durability is maintained.
2. GMW set standards for the minimum flow rate that can be detected through different meter types. Water savings associated with loss through meters be revised based, in part, on this standard.
3. The values of system loss shown in this report be adopted for business case development and water savings project implementation.

Appendix F

High loss pool water savings calculation factors for channel remediation

Date: August 2009

Hydro Environmental

Purpose

This paper summarises the findings of analysis to develop factors to apply to theoretical water savings calculations when targeting high loss pools (HLP) rather than average loss pools in channel remediation water savings interventions. The HLP factor represents the additional loss in high loss pools compared to average loss pools and is required to calculate theoretical water savings estimates as shown in Section 12 of the technical manual.

Process and discussion

High loss pool factors for phase 1 theoretical water savings calculations

The HLP factor to be used for phase 1 water savings calculations was determined by analysing the Central Goulburn (CG) channels 1-4 pondage and remediation pool loss data supplied by G-MW. The data identified specific loss rates (ML/km) for each of the pools within CG channels 1-4.

The data that represents the point loss data for each length was plotted against the corresponding accumulated proportion of the total CG1-4 pool length, and is shown in Figure F-1. The relationship shows, that on a whole of system basis, there are greater savings available per km if a smaller proportion of the overall length is targeted for remediation. From this information it was possible to determine the relationship between the total loss and the proportion of the system remediated. The average loss of the CG 1-4 pool data is 21.2 ML/km, which corresponds to 100 % accumulative total channel system length targeted. An average ML/km loss rate line from which the total loss is to be determined for each change in length of channel was fitted to Figure F-1.

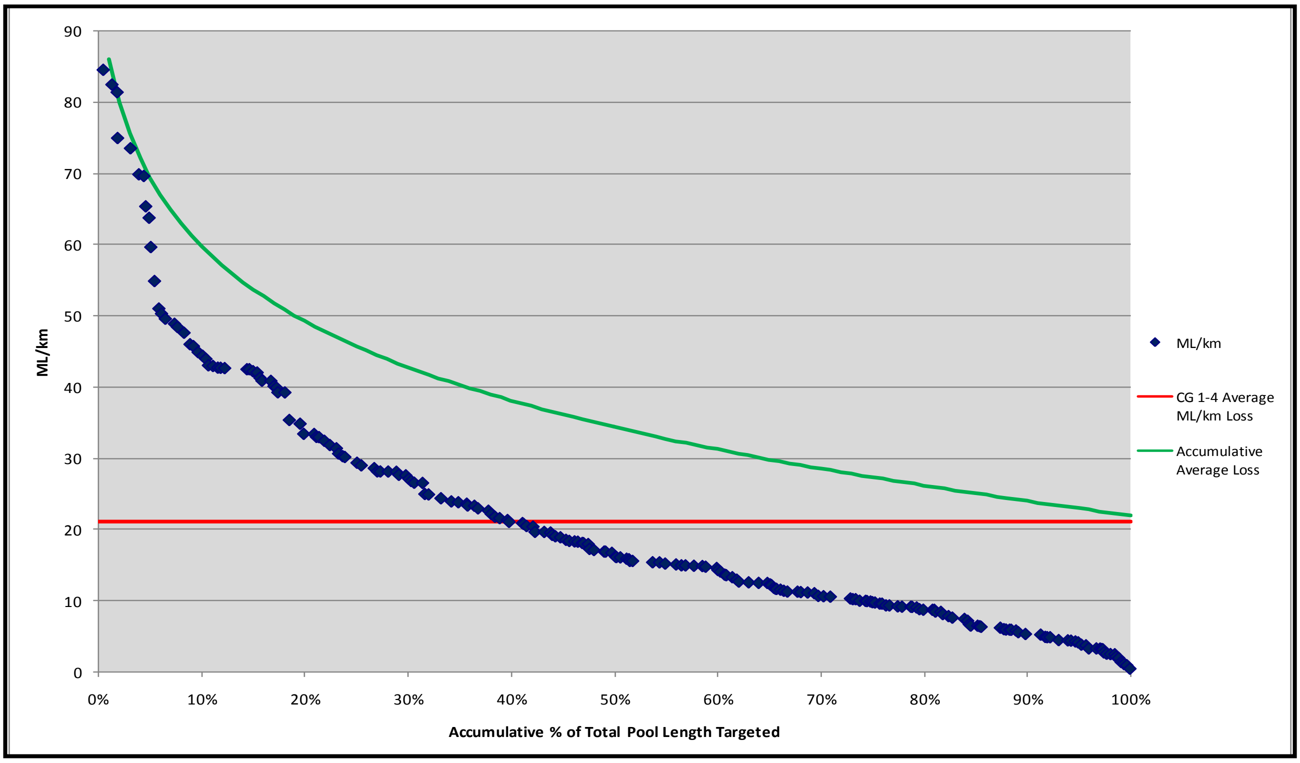

Figure F-1: Relationship between ML/km loss and proportion of total length targeted

It is assumed for the proportion of total length targeted below the average ML/km line (21.2 ML/km), remediation will not take place as it will not be cost effective. Therefore, a relationship curve was developed for ML/km and the proportion of length targeted ranging from 0% to 50%. This data is shown in Figure F-2.

A logarithmic best fit line was applied to the data to determine the relationship between the two variables. The logarithmic equation used to fit this line was $y = 6 - 17.3\ln(x)$, which has an R^2 value of 0.97. Applying the above correlation equation, ML/km values were calculated for every 1% proportion of length targeted for channel remediation, from 0% to 50% as it is unlikely to remediate more than 50% of the channel system. From this data the accumulative average loss for each percentage of total pool length targeted from remediation was calculated and plotted in Figure F-1 and Figure F-2.

An HLP factor was then calculated based on the relationship between the accumulative average loss for each pool length to the CG 1-4 average loss per km. That is; the multiplication factor required for the accumulated loss per km assigned to each proportion remediated to equate to the average. These factors can be seen in Table F-1.

In adopting these factors on a whole of system basis, it is assumed that the seepage and leakage loss relationships relative to length of channel system apply the same as they did in the CG 1-4 system. Although extremely unlikely, in the case of remediating more than 50% of a channel system, a linear best fit line was fitted to all data not included in Figure F-2. The linear equation fitted was ***y = 31.14 -28.8x***.

The application of the phase 1 HLP factors are on a whole of system basis, applying directly to proportions of remediation. The HLP factors to be used in phase 1 calculations have been summarised in Table F-1.

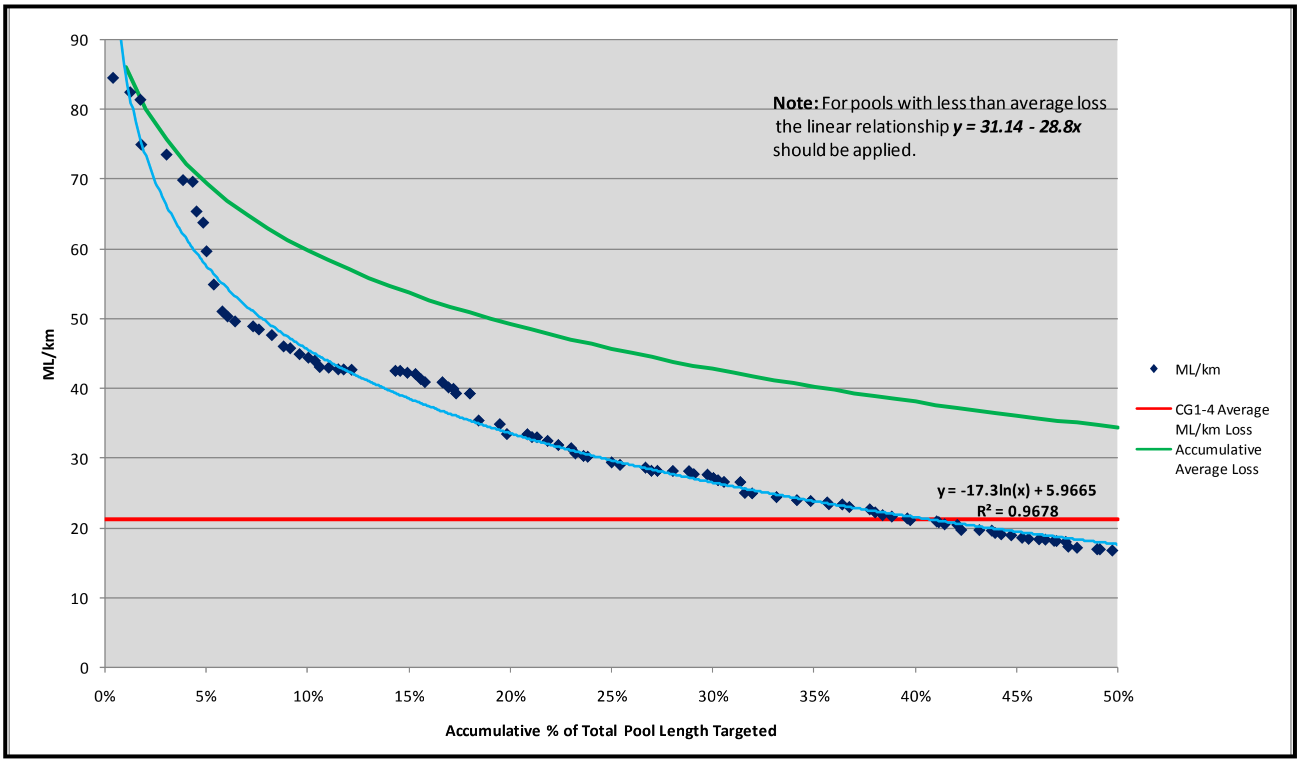

Figure F-2: Relationship between ML/km and proportion of length targeted (0% to 50%)

High loss pool factors for phase 2 theoretical water savings calculations

In order to account for theoretical channel remediation savings on a channel section or pool length, it is necessary to determine a corresponding HLP factor. This individual theoretical calculation is utilised in phase 2 estimates of interim year to year water savings, with HLP factors being the relationship which differentiates high loss pools. HLP factors were developed for both leakage (LHLP) and seepage (SHLP) losses based on the relationship between these losses with the underlying soil group of the pools tested.

High loss pool factors for leakage (LHLP)

The LHLP factors to be used for phase 2 water savings calculations was determined based on actual GMID channel cross section data which included dimensions, underlying soil group data and leak repair data for the base year (2003/2004 for the Campaspe irrigation district and 2004/2005 for all other irrigation areas). To develop the LHLP factors for individual pools it was recognised that there is a correlation between soil groups and the number of repaired leaks as reported by G-MW. This correlation was used as the basis for developing the LHLP factors for individual pools.

The number of leaks repaired/km/year data was plotted against the corresponding average soil group data, and is shown in Figure F-3. The average annual leakage repair rate (km/yr) for all the data is 0.86 km/yr. This is shown as an overall average annual leakage repair rate line fitted to the graph in Figure F-3. For each soil type, the average number of leaks/km/year was calculated and also plotted on the graph in Figure F-3. The original data set shows that many of the pool soil groups (weighted by pool area underlying each soil type) are in between soil groups; this represents pools that may be made up of one, two or more different soil groups. When calculating the averages for each soil group the following was assumed:

- Soil group 1 includes weighted soil group 1 to 1.49
- Soil group 2 includes weighted soil group 1.5 to 2.49
- Soil group 3 includes weighted soil group 2.5 to 3.49
- Soil group 4 includes weighted soil group 3.5 to 4.49
- Soil group 5 includes weighted soil group 4.5 to 5.49
- Soil group 6 includes weighted soil group 5.5 to 6.

As soil groups increase from group 1 to group 6 they progressively contain more clay, become more impermeable and become less suitable for irrigation.

From this analysis and information it was possible to determine the relationship between the annual leak repair rate (km/yr) and area weighted soil group. A linear best fit line was fitted to the average number of leaks/km/yr data for each soil group and is shown in Figure F-4. The linear equation used to fit this line was **$y = 1.36 - 0.15x$**, which has an R^2 value of 0.95.

Applying the above linear equation, leaks repaired/km/yr values were calculated for each soil group and LHLP factors were then determined based on the relationship between the leaks repaired/km/yr for each soil group and the overall average number of leaks repaired/km/yr (0.86 km/yr). That is; the multiplication factor required for the leaks repaired/km/yr for each soil group to equate the overall average system wide leaks repaired/km/yr to the expected leak repairs for the area weighted soil type in the pool in question. These LHLP factors can be seen in Table F-2.

As an example, if the system wide average leak repairs are X and the pool in question has an area weighted soil type of 5 the average number of leaks/km/year = X x 0.69.

When calculating water savings on a pool to pool basis, the area weighted average soil group of the actual section remediated should be used, therefore this LHLP factor is only representative of the remediated section of the channel.

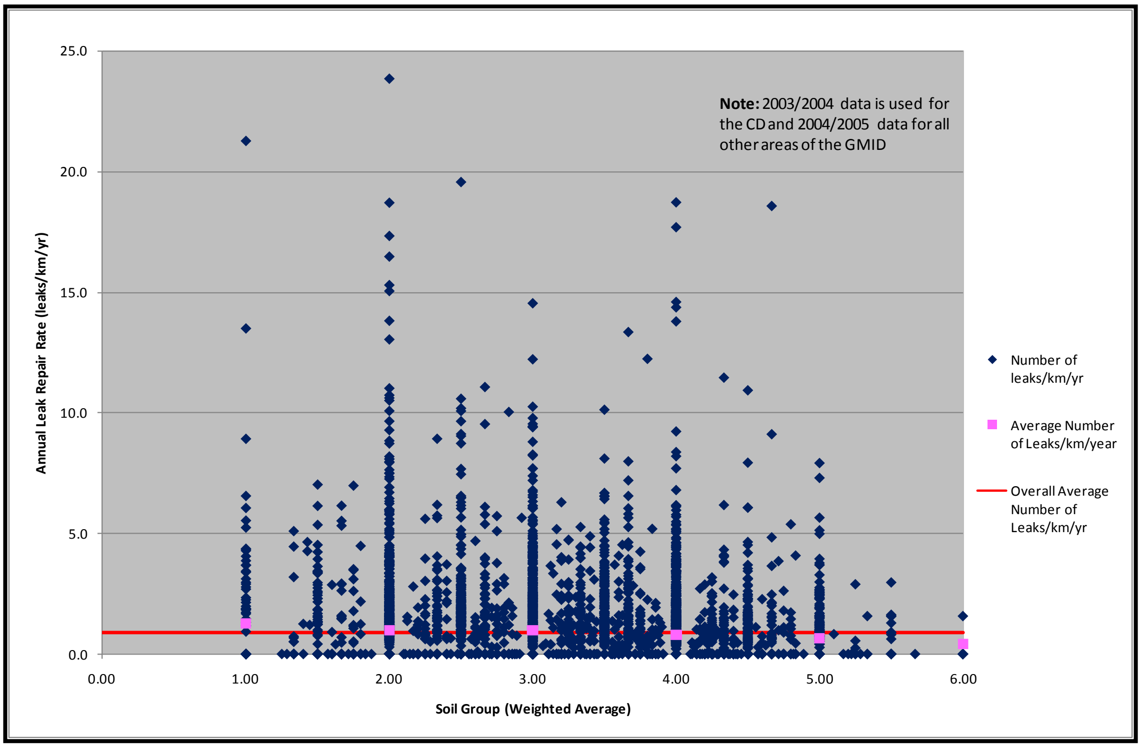

Figure F-3: Relationship between average annual leaks repaired (km/yr) and soil group

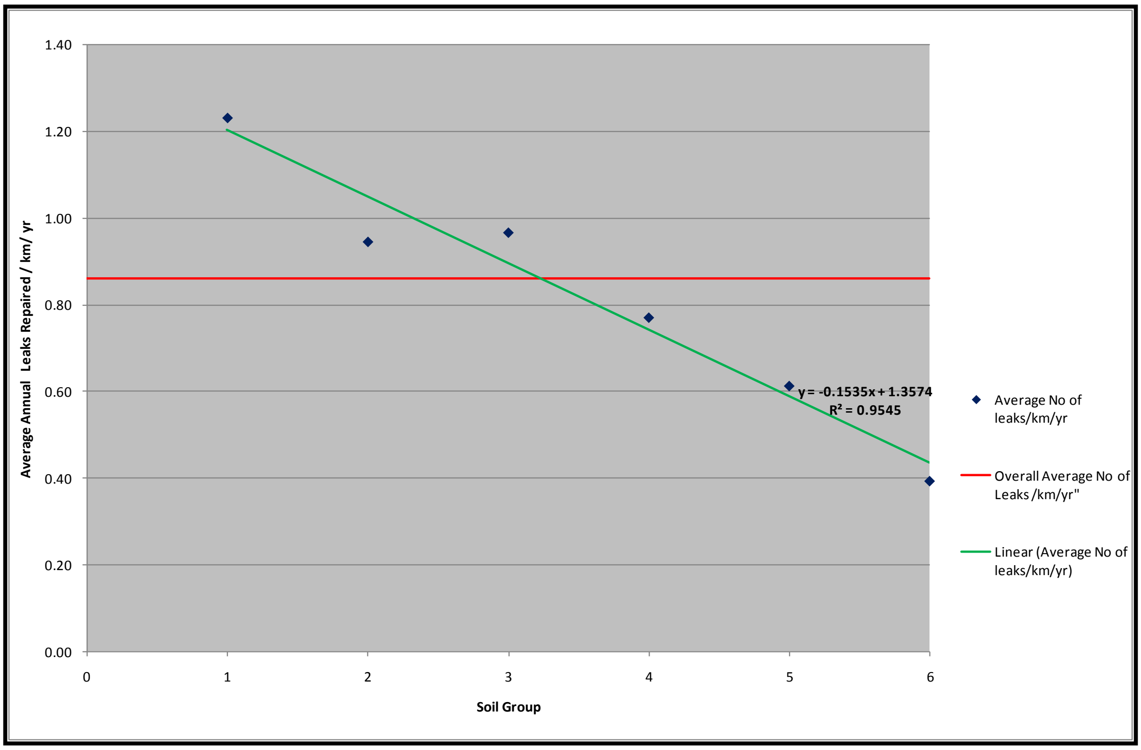

Figure F-4: Relationship between average annual leaks repaired (km/yr) and soil group for 2004/2005 (2003/2004 data for CD)

High loss pool factors for seepage (SHLP)

The SHLP factors to be used for phase 2 water savings calculations were determined based on CG 1-4 data which included underlying soil group data and pondage test seepage data for 2006 and 2007 adjusted to account for pool dimensions. To develop the SHLP factors for individual pools it was recognised that there is a correlation between soil groups and the seepage rates determined from pondage tests. This correlation was used as the basis for developing the SHLP factors for individual pools.

The pondage test seepage data (mm/day) was plotted against the corresponding weighted average soil group data, and is shown in Figure F-5. The average seepage rate for all the data is 6.28 mm/ day. This is shown as an overall average seepage rate line fitted to the graph in Figure F-5. For each soil type the average seepage rate (mm/day) was calculated and also plotted on the graph in Figure F-5.

As was the case of the average leaks repaired/km/year, the original data set shows that many of the pool soil groups are in between soil groups; this represents pools that may be made up of one, two or more different soil groups. Therefore, to be consistent with the development of leakage SHLP factors, when calculating the average seepage rate (mm/day) for each soil group the following was assumed:

- Soil group 1 includes weighted soil group 1 to 1.49
- Soil group 2 includes weighted soil group 1.5 to 2.49
- Soil group 3 includes weighted soil group 2.5 to 3.49
- Soil group 4 includes weighted soil group 3.5 to 4.49
- Soil group 5 includes weighted soil group 4.5 to 5.49
- Soil group 6 includes weighted soil group 5.5 to 6.

From this analysis and information it was possible to determine the relationship between seepage rate (mm/day) and weighted soil group. A linear best fit line was fitted to the average seepage rate (mm/day) for each soil group and is shown in Figure F-6. The linear equation used to fit this line was ***y = 12.92 – 2.19x***, which has an R^2 value of 0.99. The G-MW pondage test data used in this analysis did not include seepage rates for soil group 6. Based on the high impermeable nature of soil group 6, it was assumed that the average seepage rate for soil group 6 was 0 mm/day. This seepage rate assumption is considered to be conservative.

Applying the above linear equation, seepage rates (mm/day) were calculated for each soil group and SHLP factors were then determined based on the relationship between the seepage rate (mm/day) for each soil group and the overall average seepage rate (mm/day). That is; the multiplication factor required for the seepage rate (mm/day) for each soil group to equate to the overall average system wide seepage rate (mm/day) to the expected seepage rate for the area weighted soil type in the pool in question. These SHLP factors can be seen in Table F-2.

As an example, if the system wide average seepage rate (mm/day) is X and the pool in question has an area weighted soil type of 5 the average seepage rate (mm/day) is = X x 0.33. Consistent with the LHLP factors, when calculating water savings on a pool to pool basis, the area weighted average soil group of the actual section remediated should be used, therefore the SHLP factors are only representative of the remediated section of the channel. The application of the phase 2 SHLP factors are on pool by pool basis. The SHLP factors to be used in phase 2 calculations are summarised in Table F-2.

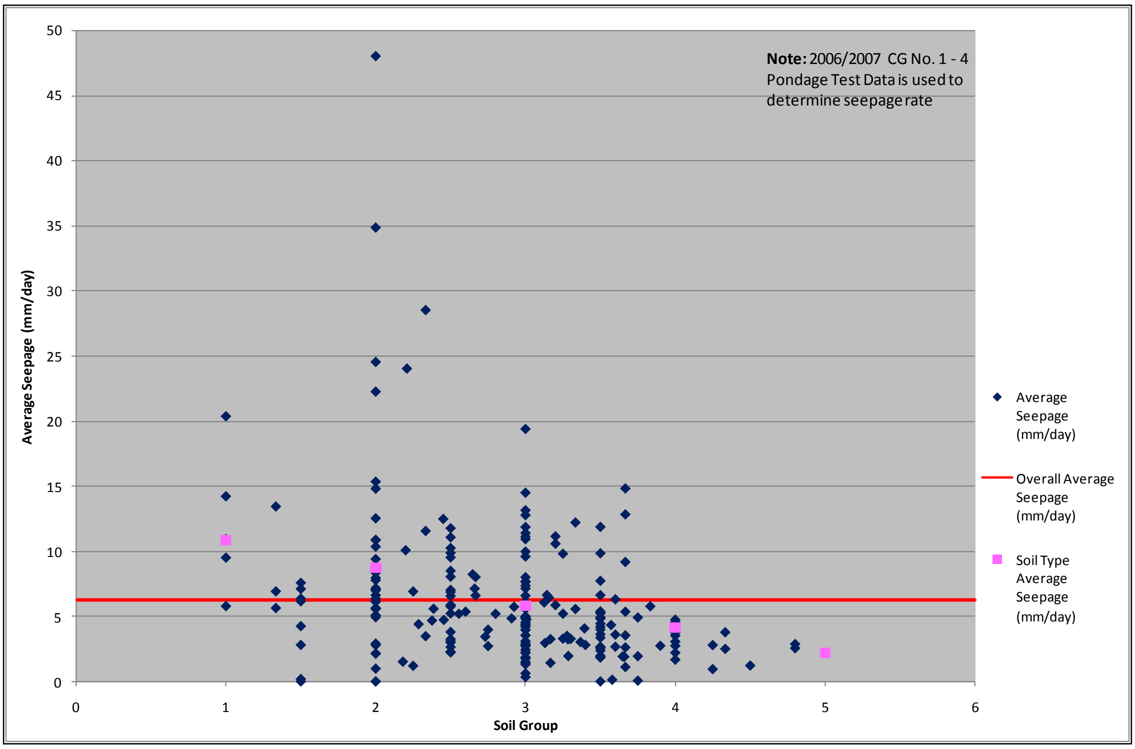

Figure F-5: Relationship between pondage test seepage rate (mm/day) and soil group (CG 1-4)

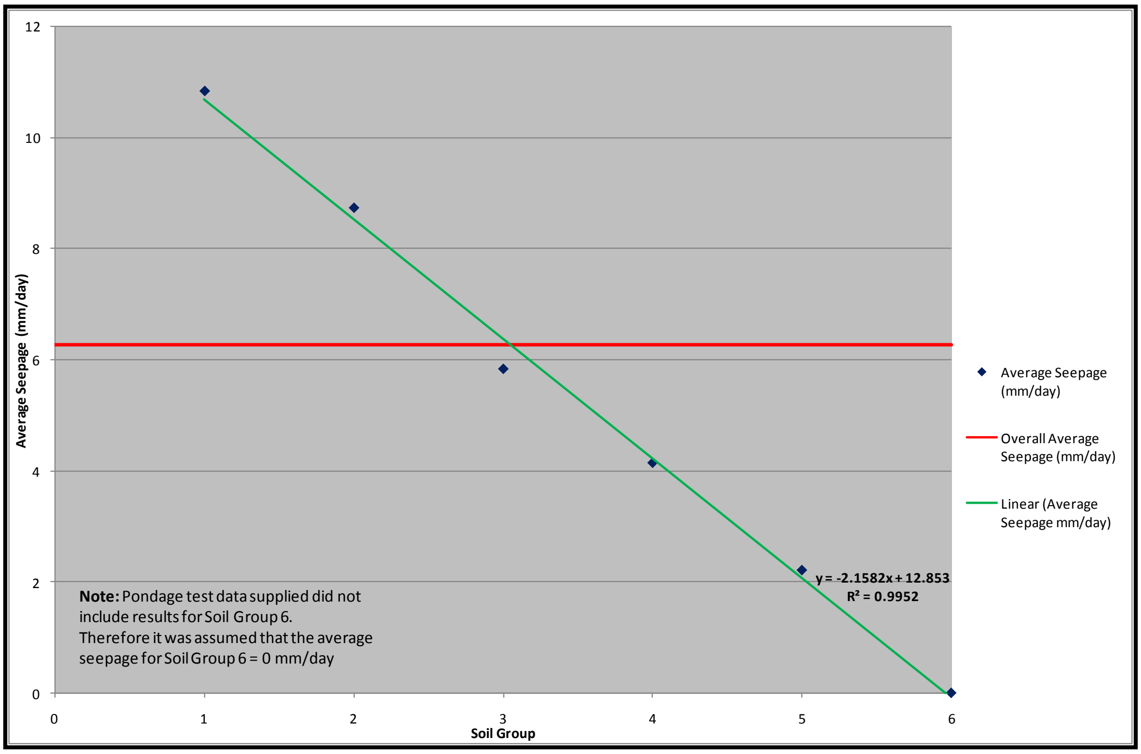

Figure F-6: Relationship between average seepage rate (mm/day) and soil group for 2006/2007 (CG 1-4)

Recommendation

It is recommended that:

- On a whole of system basis high loss pool (HLP) factors for phase 1 are calculated based on the relationship of the accumulative average loss for each pool length to the CG 1-4 average loss per km. The HLP factors for phase 1 are shown in Table F-1.
- On a pool by pool basis high loss pool leakage factors (LHLP) for phase 2 are calculated based on the relationship of the soil type to the annual average leak repair rate (km/year). The LHLP factors for phase 2 are shown in Table F-2.
- On a pool by pool basis High Loss Pool Seepage factors (SHLP) for Phase 2 are calculated based on the relationship of the soil type to pondage test seepage rates (mm/day). The SHLP factors for phase 2 are shown in Table F-2.

Table F-1: HLP Factors (phase 1) established based on relationship to the average (in ML/km)

Proportion of Length Targeted (%)	HLP Factor	Proportion of Length Targeted (%)	Proportion of Length Targeted (%)
1	4.06	26	2.13
2	3.77	27	2.10
3	3.57	28	2.07
4	3.41	29	2.04
5	3.27	30	2.02
6	3.16	31	1.99
7	3.06	32	1.97
8	2.97	33	1.95
9	2.89	34	1.92
10	2.82	35	1.90
11	2.75	36	1.88
12	2.69	37	1.86
13	2.64	38	1.84
14	2.58	39	1.82
15	2.53	40	1.80
16	2.49	41	1.78
17	2.44	42	1.76
18	2.40	43	1.74
19	2.36	44	1.72
20	2.32	45	1.71
21	2.29	46	1.69
22	2.25	47	1.67
23	2.22	48	1.66
24	2.19	49	1.64
25	2.16	50	1.62

Table F-2: HLP Factors (phase 2) established based on soil group

Soil Group (for interpolation see note below)	Leakage (LHLP Factor) (i)	Seepage (SHLP Factor) (ii)
1	1.40	1.70
2	1.22	1.36
3	1.04	1.01
4	0.87	0.67
5	0.69	0.33
6	0.51	0.00

Note:

i. To interpolate between the soil groups stated, use $LHLP = 1.578 - 0.178\,x$, where x = area weighted average soil group.

ii. To interpolate between the soil groups stated, use $SHLP = 2.06 - 0.35\,x$, where x = area weighted average soil group.

Appendix G

Pondage test adjustments to allow for additional variable losses

Date: August 2009 (Hydro Environmental) and amended in October 2014 (GHD) and July 2018 (HARC)

Hydro Environmental

Purpose

This appendix describes how to adjust static pondage test results to account for the additional bank leakage expected from channels when irrigation water is being delivered through the distribution system. The adjustment is applied when estimating the water savings from channel remediation.

Discussion

Pondage tests are done under static conditions, and hence are a measure of fixed (i.e. delivery-independent) losses. Therefore, the variable losses caused when pool water levels change in response to deliveries are not measured in a pondage test. An adjustment to the pondage test results is therefore required to make allowance for these additional flow-related losses. This is done using an F(PA) factor.

The F(PA) factor is calculated by dividing the bank leakage and seepage estimates obtained from water balances for the irrigation distribution system, by the bank leakage and seepage estimates from pondage tests:

$$\mathbf{F\ (PA)} = \frac{[\mathbf{Water\ Balance\ Data}]}{[\mathbf{Pondage\ Test\ Data}]} = \frac{[\mathbf{System\ Bank\ Leakage\ and\ Seepage\ Loss\ Rate}]}{[\mathbf{Pondage\ Test\ Loss\ Rate\ for\ System}]}$$

The F(PA) factor applies only to estimates of bank leakage when estimating water savings from channel remediation. However, pondage test results include both bank leakage and seepage, and therefore seepage rates need to be accounted for in the calculation of F(PA).

When calculating the F(PA) factor, care is required that assumptions in the water balance and pondage test estimates of bank leakage and seepage are consistent, for example by:

- Where appropriate, excluding leakage through and/or around service points, and any unauthorised use from the pondage test results; and
- Understanding that accurate pondage tests will be undertaken only on automated channel sections, and therefore the comparisons with water balance estimates of seepage and bank leakage need to be for the same channel sections.

The F(PA) factor is expected to be greater than 1.0. If the estimates of seepage and bank leakage from the pondage tests are greater than from the water balance, both sets of data should be checked and revised where necessary.

If sufficient data is not available to calculate the F(PA) factor, a known F(PA) factor from a channel system with similar characteristics can be used until an F(PA) factor for the local irrigation distribution system is established.

Figure G-1 shows how the F(PA) factor is applied to individual pondage test results when estimating the water savings from channel remediation. This is reflected in the water saving equations in Part 2 of the technical manual included within this *Water Savings Protocol*.

Recommendation

It is recommended that static pondage test results be adjusted using the ratio of bank leakage and seepage estimates obtained from water balances for the irrigation distribution system, to the bank leakage and seepage estimates from pondage tests (for the same length(s) of channel).

This ratio is referred to as F(PA), and accounts for the additional bank leakage caused by higher water levels and fluctuations in water level when irrigation water is being delivered through the distribution system.

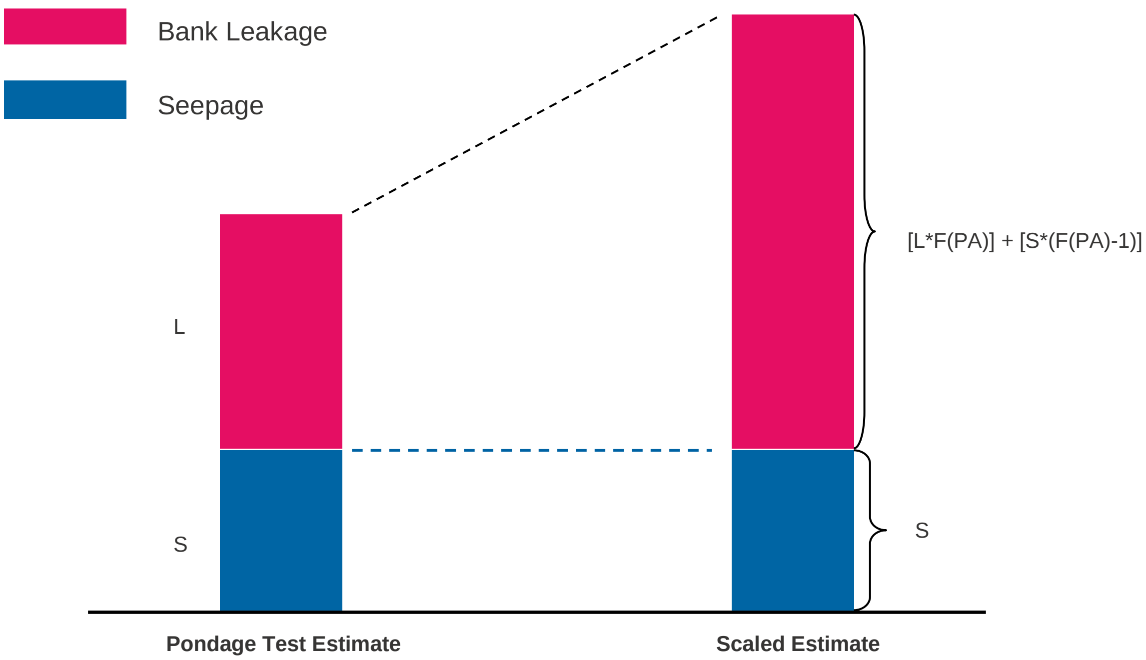

Figure G-1: Scaling up the bank leakage (L) measured in pondage tests using the F(PA) factor

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