Transfer Function Presentation

Development of transfer functions and guidance for simulating irrigation recharge in salinity assessment models

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09 May 2023

CDM Smith

GROUNDED IN WATER

Overview

1. Summary of transfer function research program and outputs
2. Description of transfer functions and their application to groundwater models
3. Recommendations for future salinity modelling assessments

Mildura Orchards
https://www.nma.gov.au/defining-moments/resources/murray-river-irrigation-begins

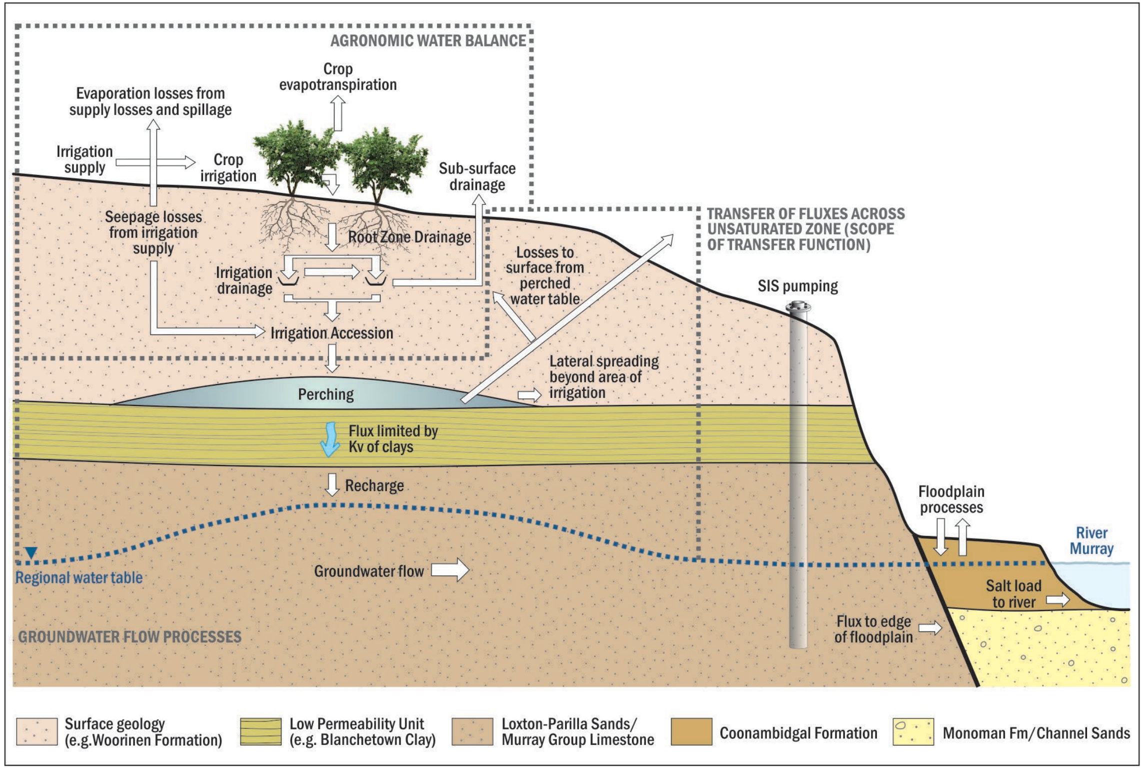
Summary of works conducted

Project Background & Objectives

- In 2017, a review of approaches to modelling irrigation recharge found:
  - A lack of suitable modelling tools available to account for unsaturated processes (e.g. perching) that affect timing and magnitude of salt loads
  - Inconsistent approach to deriving irrigation recharge using forward or inverse modelling approaches
- These issues can lead to:
  - A disconnect between cause (irrigation actions) and effect (salt loads to river)
  - Lack of transparency & bias

- Objectives of the transfer function program framed around addressing these knowledge gaps,
  I. To develop and test transfer functions / recharge models suitable for salinity assessment modelling
  II. To develop and test hybrid / joint calibration (JC) modelling techniques that use recharge models developed

Initial conceptualisation of problem



Forward modelling

Agronomic Water Balance

- AWB Spreadsheet, assumptions on irrigation water use and efficiency

Irrigation recharge

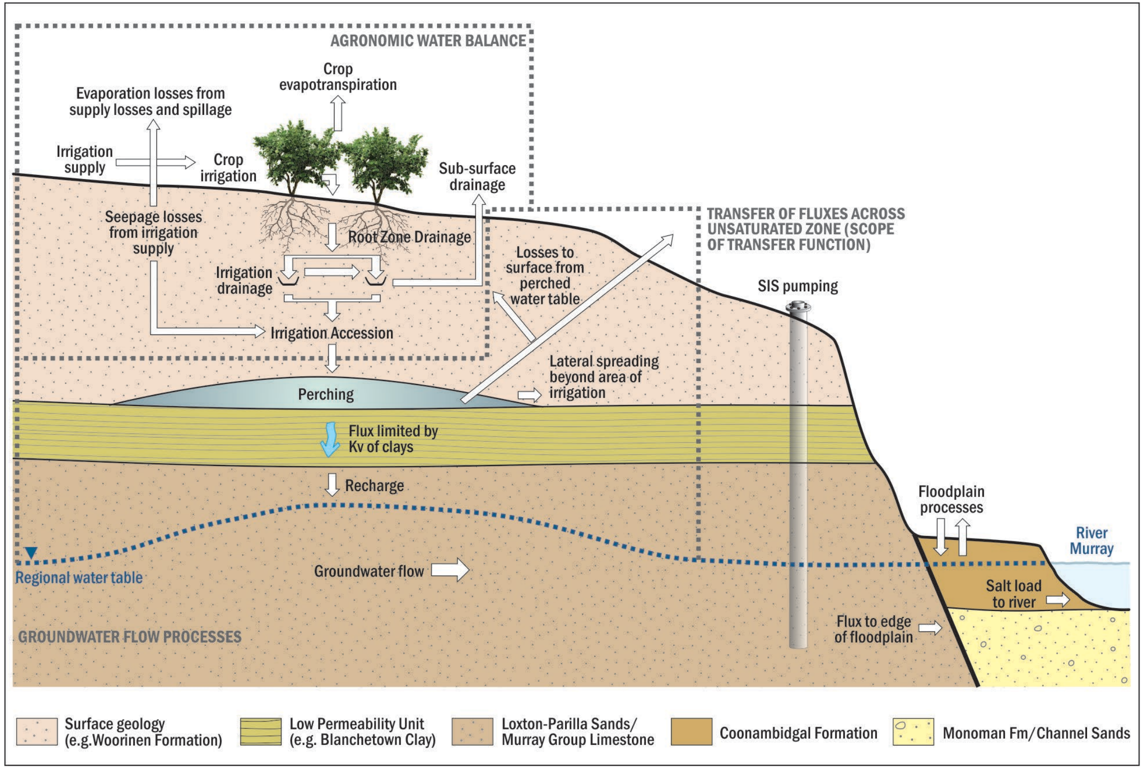
- No simulation of perching

Groundwater model

- Incorporating irrigation recharge, salt interception, river and floodplains

RIVER SALT LOAD

Initial conceptualisation of problem



Inverse modelling

Agronomic Water Balance

- Comparison post-calibration

Irrigation recharge

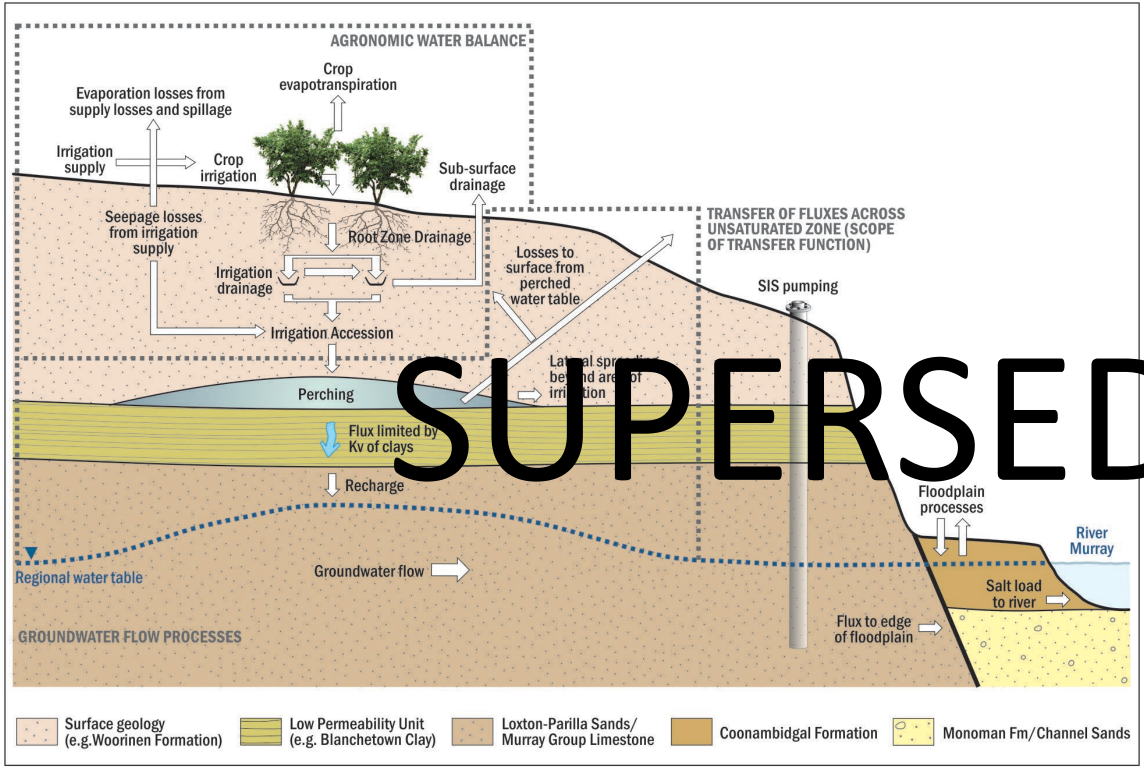
- Derived inversely by groundwater model calibration

Groundwater model

- Incorporating irrigation recharge, salt interception, river and floodplains

RIVER SALT LOAD

Initial conceptualisation of problem



Hybrid modelling

Agronomic Water Balance

- AWB Spreadsheet, key parameters included in calibration

Transfer function to calculate irrigation recharge

- Based on setting, accounts for perching

Groundwater model

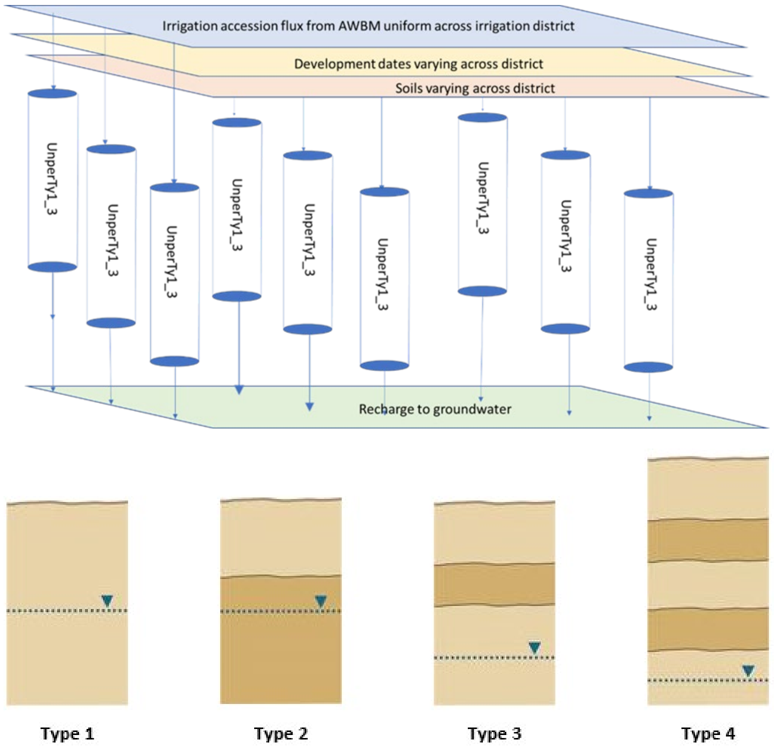
- Incorporating irrigation recharge, salt interception, river and floodplains

RIVER SALT LOAD

Phase 1 works, 2018

2018 study, development and testing of discrete TF models

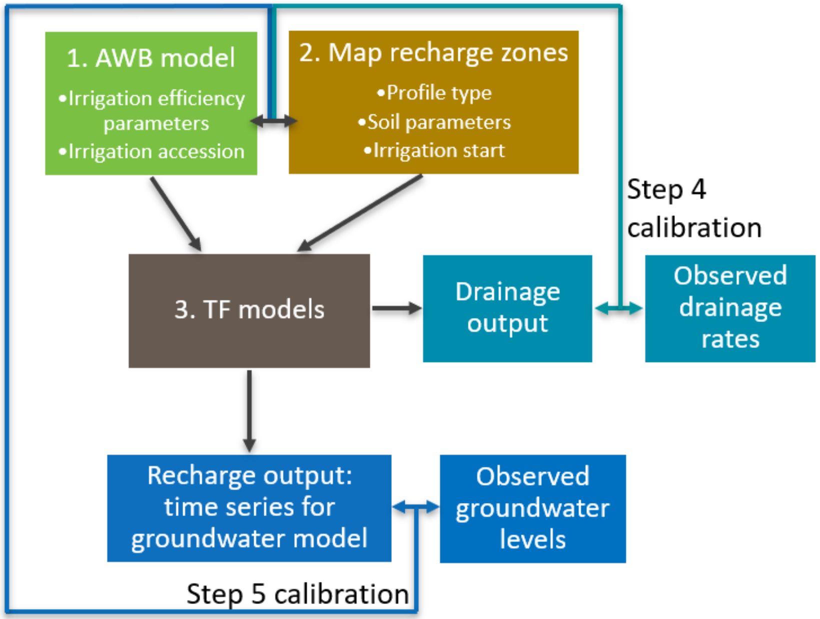
- Framework established in which TF designed to operate at single points in space and time for a given action
- Typology developed
- Transfer function models developed using semi-analytical functions for Type 1 and Type 3 situations
- Models benchmarked against Feflow for wetting and drying scenarios
- Transfer functions tested with analytical model of groundwater



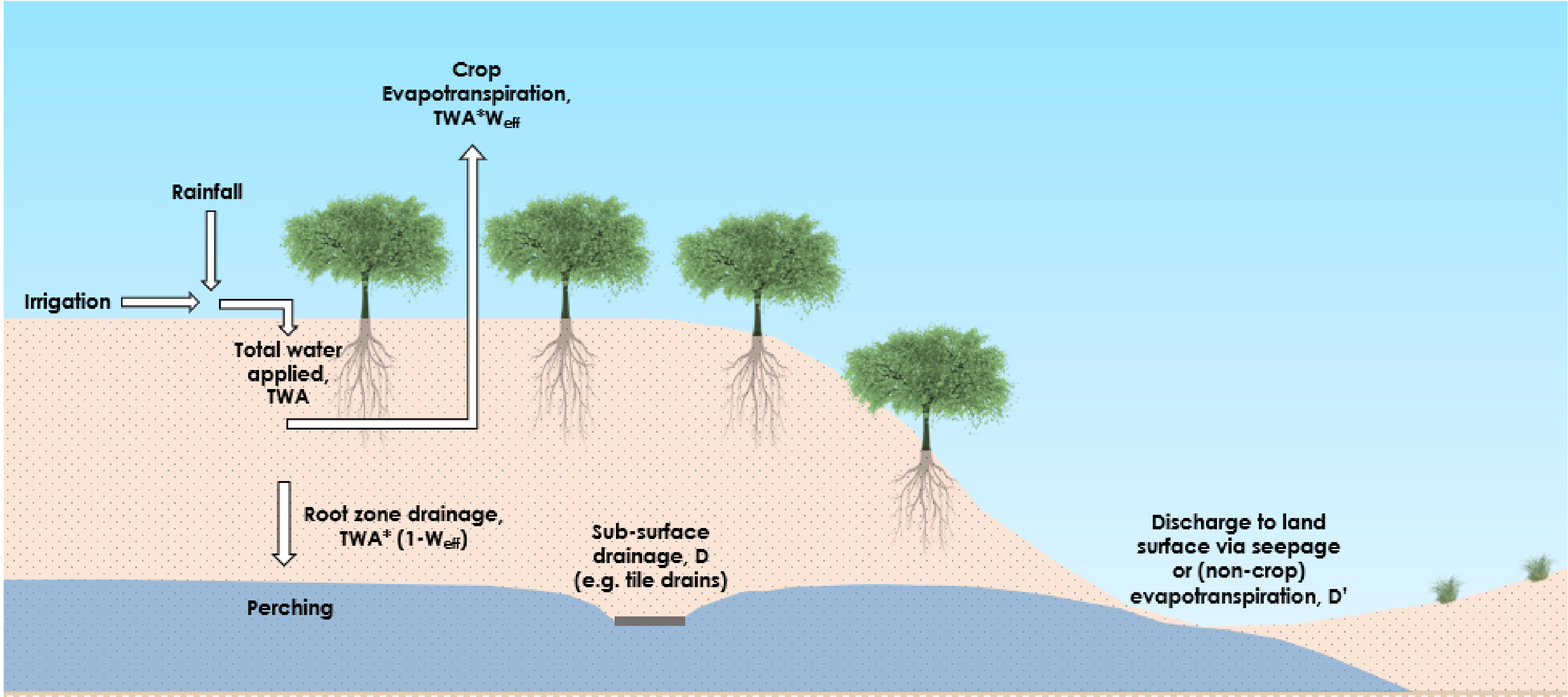
Walker, G.R.; Currie, D.; Smith, T., Middlemis, H. 2018. Development of a transfer function to model irrigation recharge. Report prepared for the Murray-Darling Basin Authority. MDBA: Canberra, Australia.

Loxton-Bookpurnong pilot trial, 2023

- Revision of Type 3 models, treating drainage as an output rather than an input
- Benchmarking against FEFLOW
- Software refinement / bug testing of transfer function
- Partial testing of hybrid (JC) modelling method with linked transfer function
- 2020: journal publications
- 2021-22: software refinement, release and user manual for Type 1 & 3 models

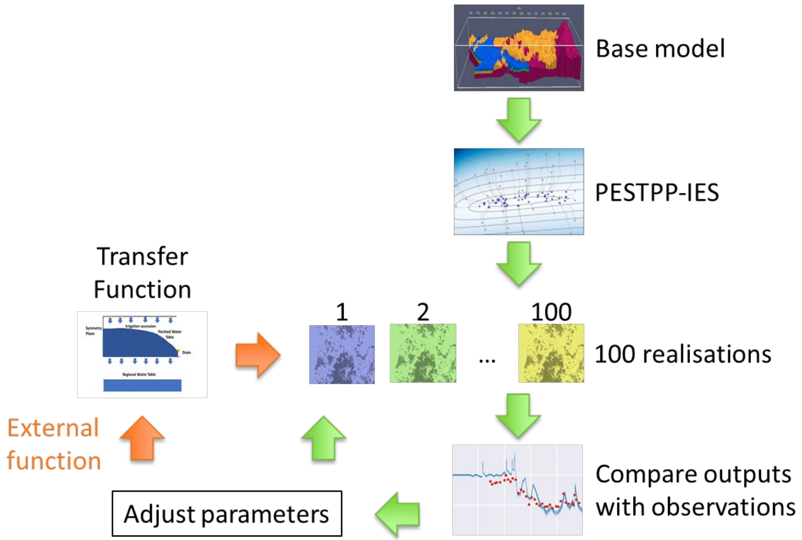


Sunraysia pilot trial, 2023



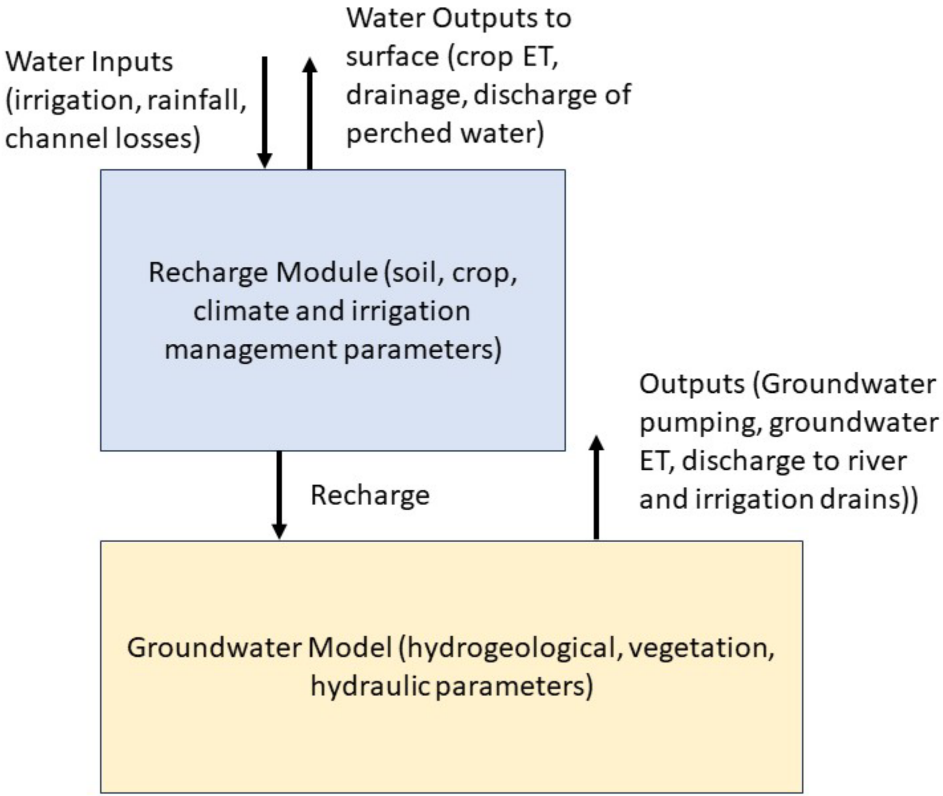
Sunraysia pilot trial, 2023

- Existing approach unsuitable due to conceptualisation of drainage being misaligned with observed trends
- Development of lumped recharge model to replace existing TF approach
  - Based on water balance of a perched system
  - Uses drainage data as primary input
  - Accounts for other forms of surface discharge
- Successful integration of lumped recharge model within hybrid / JC modelling framework
- Trial highlighted importance of robust datasets
- Transfer function works summarised in Guidance for Modelling Irrigation Recharge



Refined conceptualisation of problem

- Through the work program we have found that:
  - A single set of transfer functions that is applicable to all settings is unfortunately not feasible
  - Agronomic (surface water balance) and unsaturated zone (transfer function) processes are closely linked and therefore require integration within a broader recharge model
  - Joint calibration of recharge and groundwater models is the recommended way forward



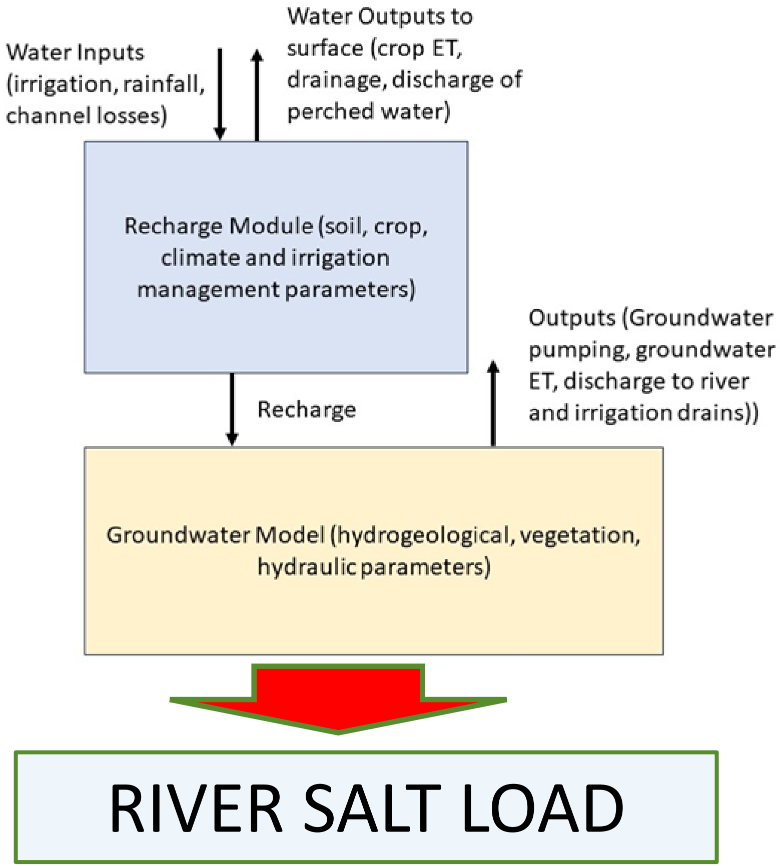
Summary of project outputs

Project reports	Journal Publications	Software released (to SA model database)
> Walker, G.R.; Currie, D.; Smith, T., Middlemis, H. 2018. Development of a transfer function to model irrigation recharge. Report prepared for the Murray-Darling Basin Authority. MDBA: Canberra, Australia. > Walker G.R., Currie D., Laattoe T., Smith A. and Woods J. 2019. Pilot trial of a transfer function for salinity modelling. Report to the MDBA. 20 December 2019. > Walker G. and Currie D. 2021. Transfer functions for modelling irrigation recharge: theory, description and user manual. Draft report prepared by CDM Smith for the MDBA. 16 June 2021. > Walker G., Li C. and Currie D. 2023. Development and application of transfer function to simulate irrigation recharge: Sunraysia pilot trial. Draft report prepared by CDM Smith for the MDBA. 23 May 2023 > Walker G. and Currie D. 2023. Guidance for modelling irrigation recharge in the Mallee region. Draft report prepared by CDM Smith for the MDBA. 23 November 2023	> Walker, G.R.; Currie, D.; Smith, T. 2020. Modelling recharge from irrigation developments with a perched water table and deep unsaturated zone. Water 2020, 12, 944; doi:10.3390/w12040944 > Walker, G.R.; Currie, D.; Smith, T. 2020. Modelling the Effect of Efficiency Measures and Increased Irrigation Development on Groundwater Recharge through a Deep Vadose Zone. Water 2020, 12, 936; doi:10.3390/w12040936 > Currie D. Laattoe T., Walker G., Woods J. and Bushaway K. 2020. Modelling groundwater returns to streams from irrigation areas with perched water tables. Water 2020, 12, 956; doi:10.3390/w12040956	> Type 1 transfer function models (supersedes SIMRAT) > Type 3 transfer function models

Description of transfer functions and application in models

Transfer Functions

1. Transfer functions provide a relationship between inputs (e.g. irrigation diversions, rainfall) to outputs (recharge).
2. In recharge, transfer functions have been used to describe conceptual models that can be calibrated based on individual recharge events
3. For the Mallee, SIMPACT/SIMRAT was originally used to describe time lags through unsaturated zone. Not suitable for irrigation areas with perched water
4. Several agronomic water balance models with applied irrigation efficiency factors used to estimate irrigation accession across Mallee that becomes recharge. Not useful for deep water tables. Requires historical values for efficiency



Transfer Functions

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Recharge modules should be developed for all irrigation districts with appropriate resolution for the purpose, to provide input to groundwater models on both magnitude of recharge and, where important, time lags through the unsaturated zone.

3.

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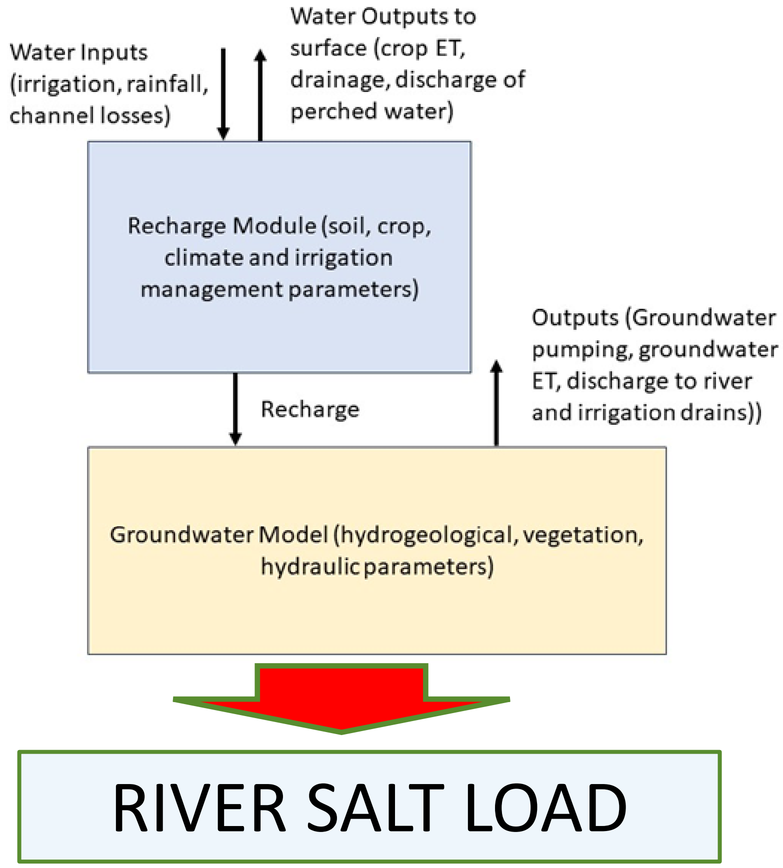
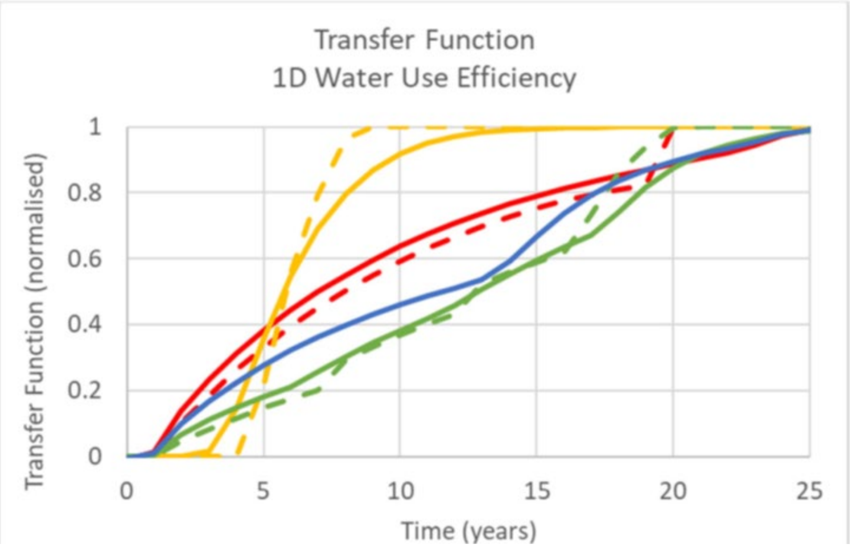
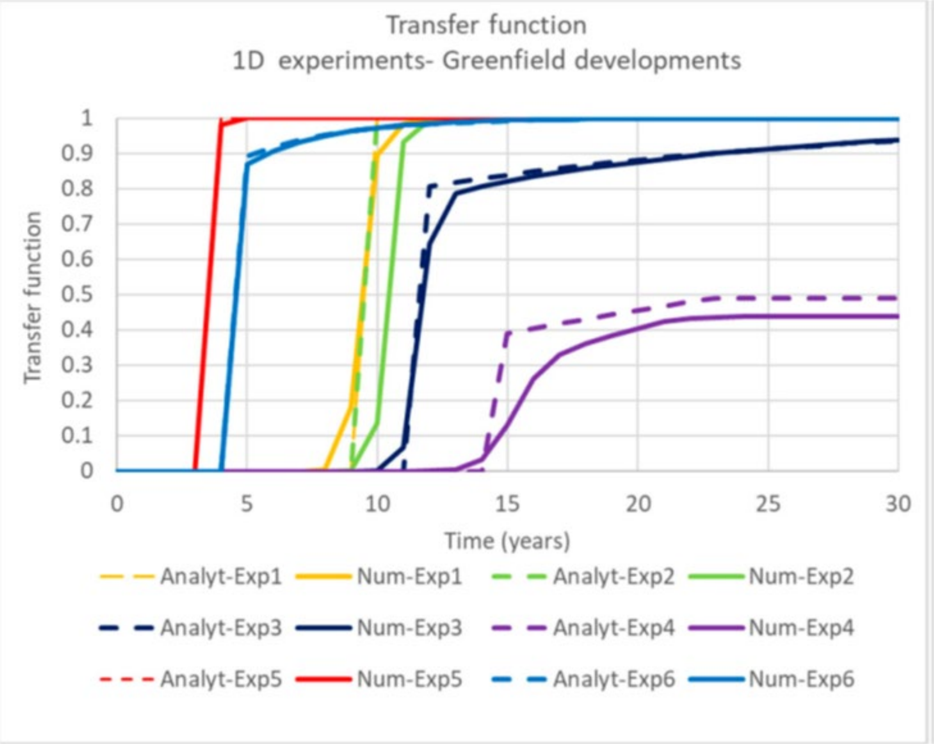
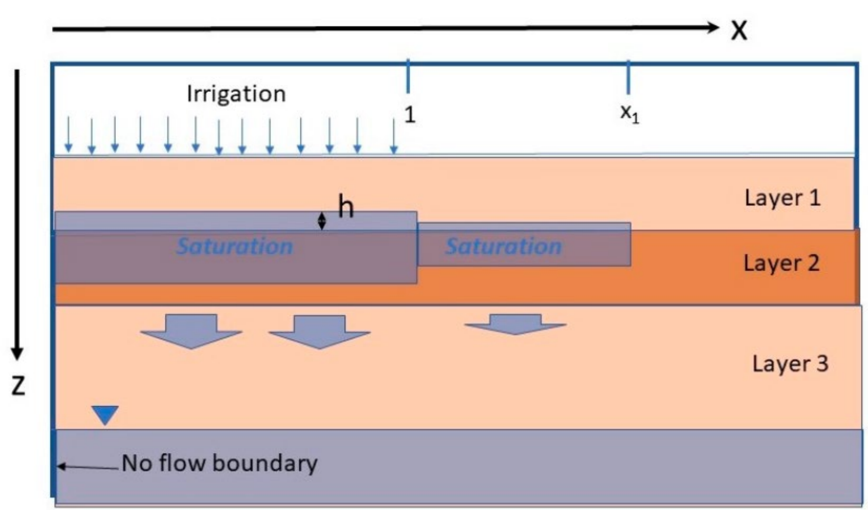


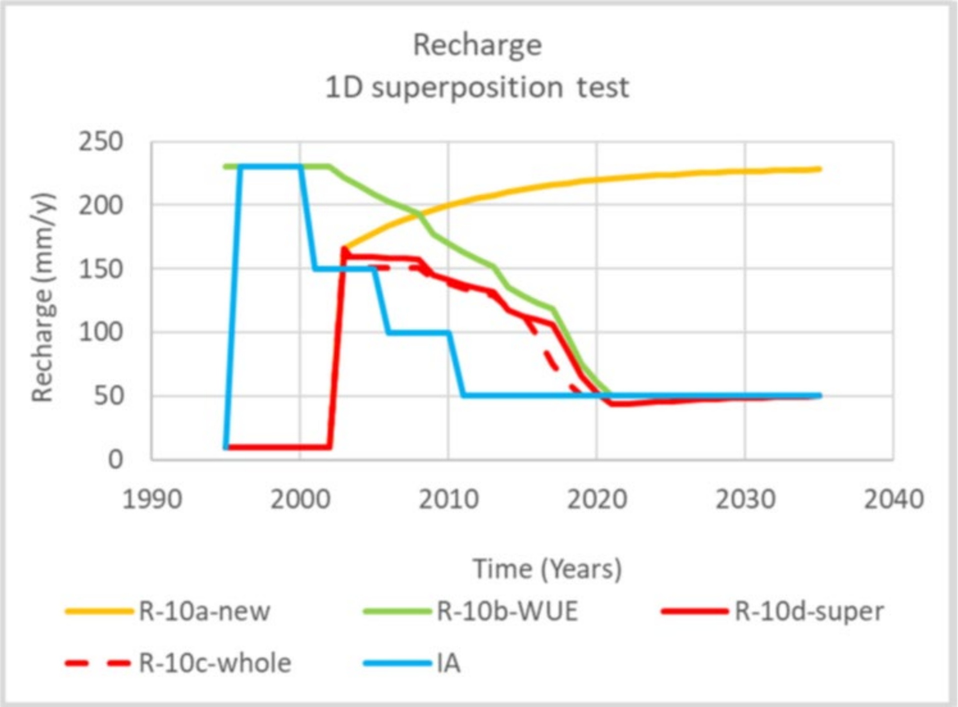
Semi-analytical models

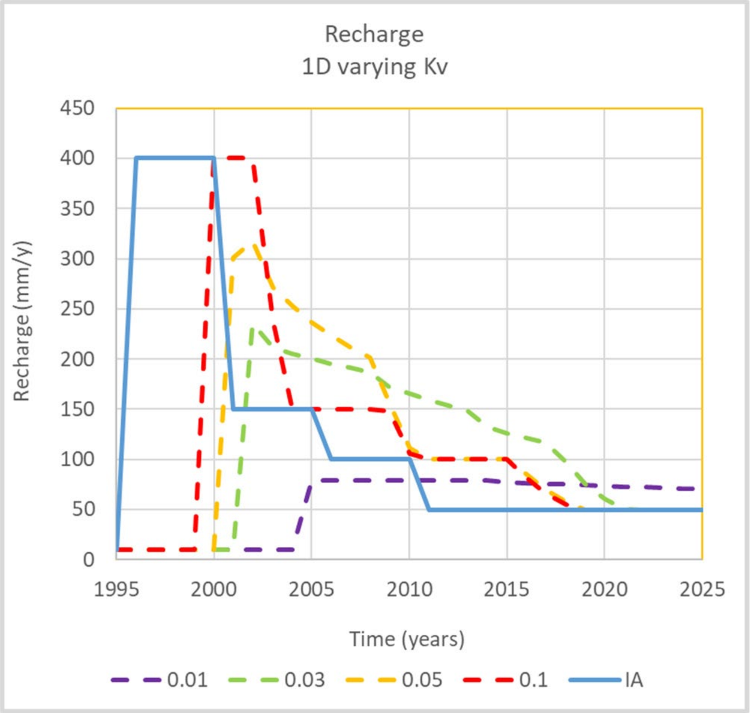






Superposition and life cycle of irrigation districts





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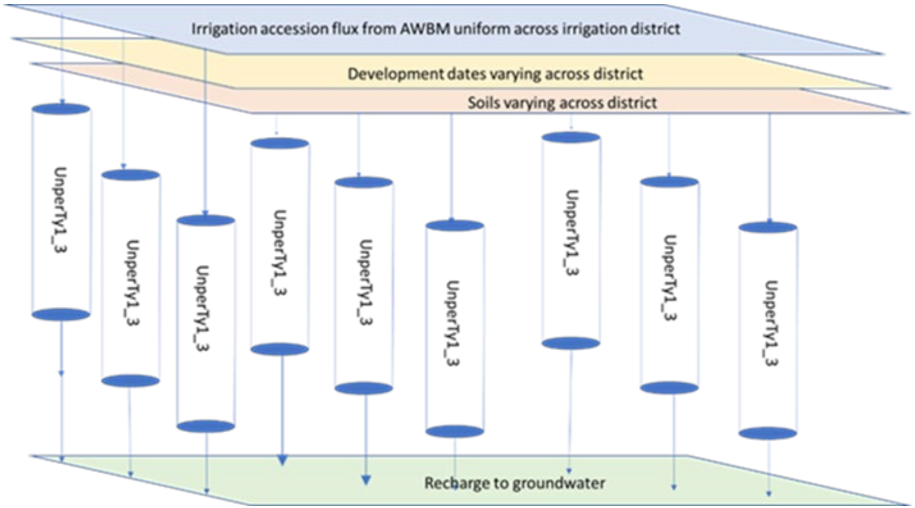
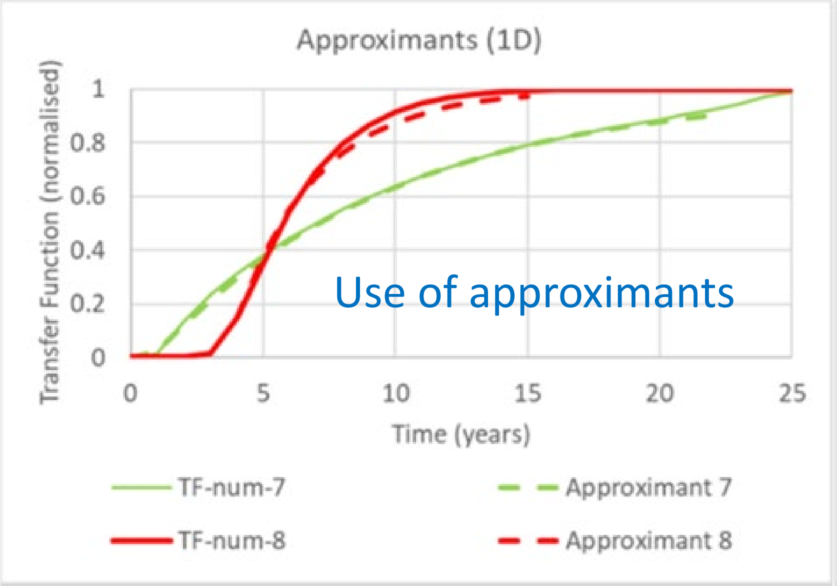
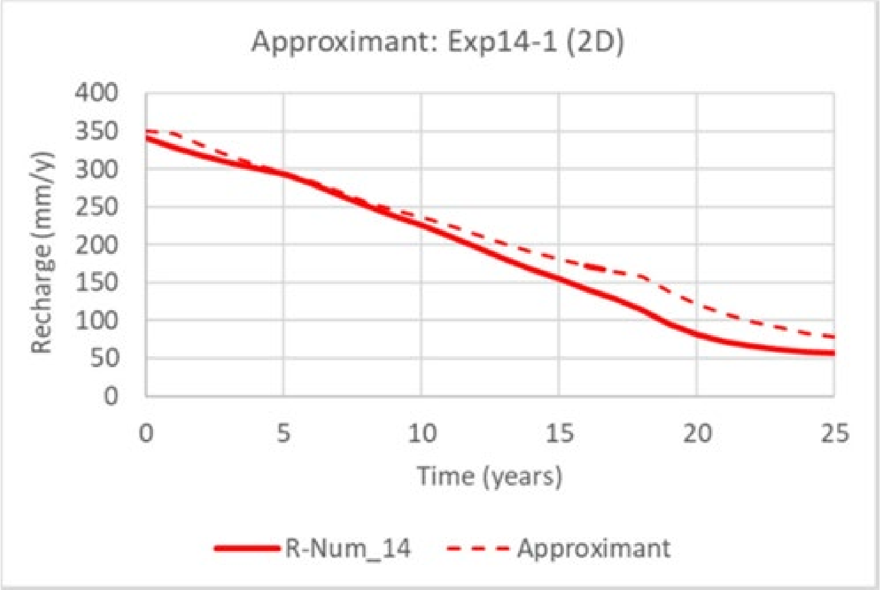
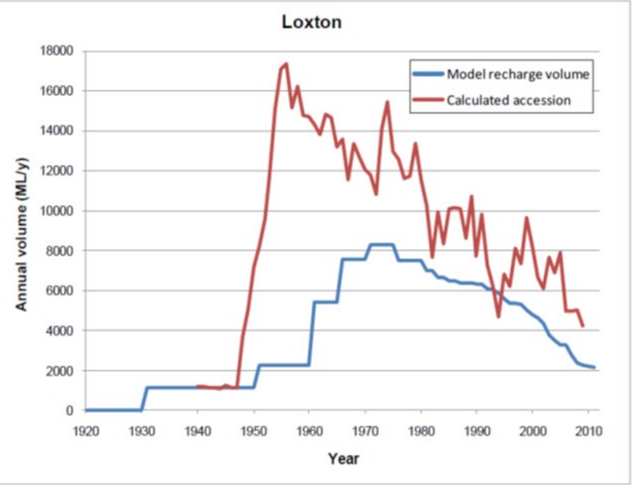


Use of approximants



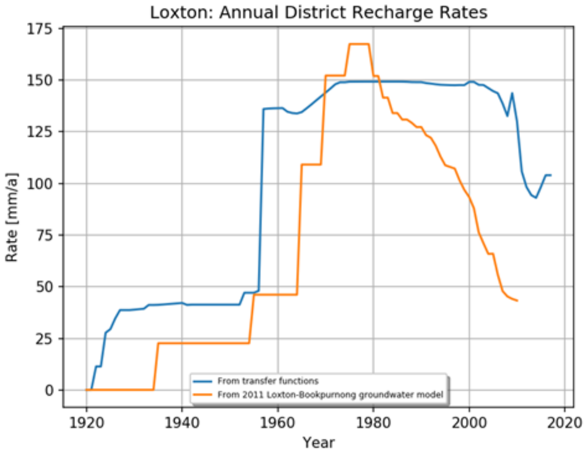


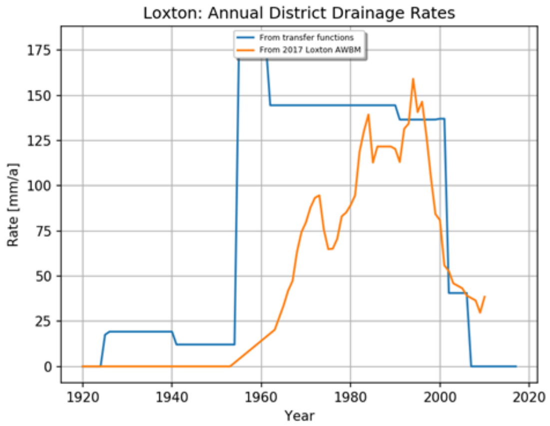
Loxton-Bookpurnong modelling

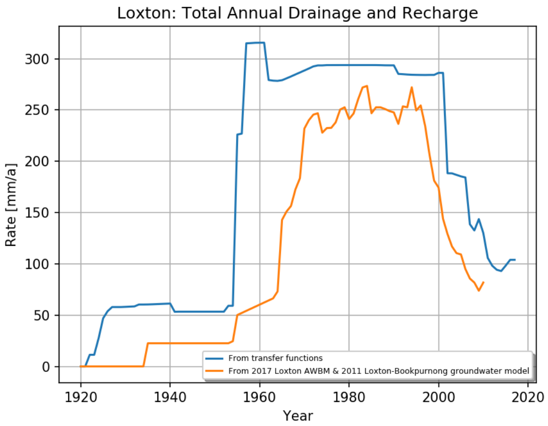


LB 2011 used an inverse approach to estimating recharge. This was compared to water balance modelling (shown left) and unsaturated zone modelling.

The LB trial for using 'transfer functions' to simulate time lag and to predict drainage to observed targets. Recharge rejection rom shallow water tables which was not included in transfer functions or in groundwater model appears to have led to discrepancies.

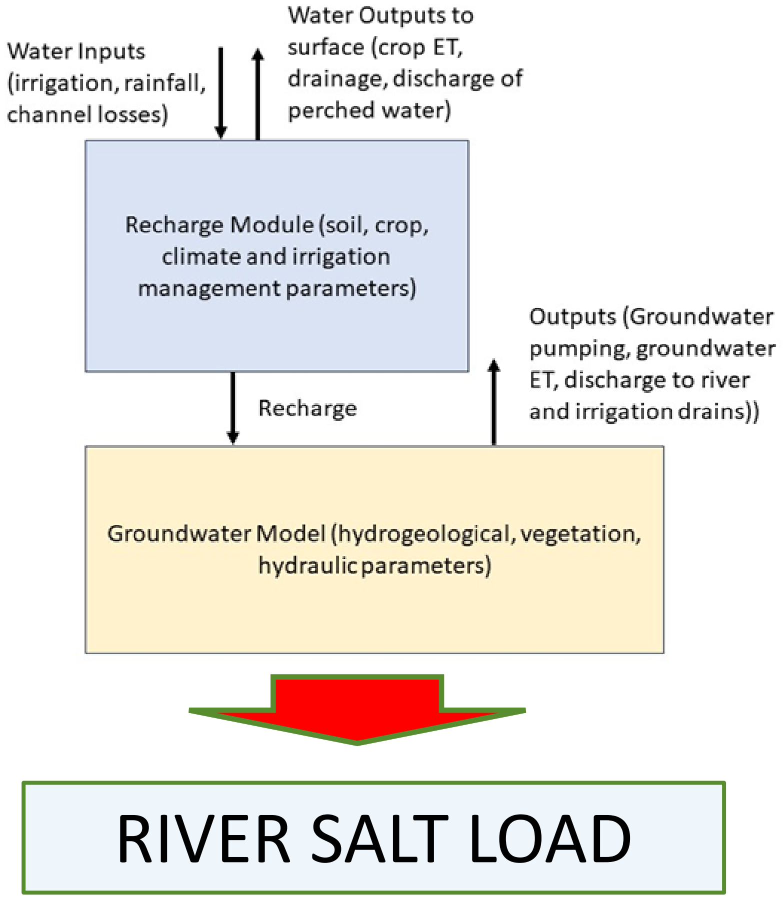






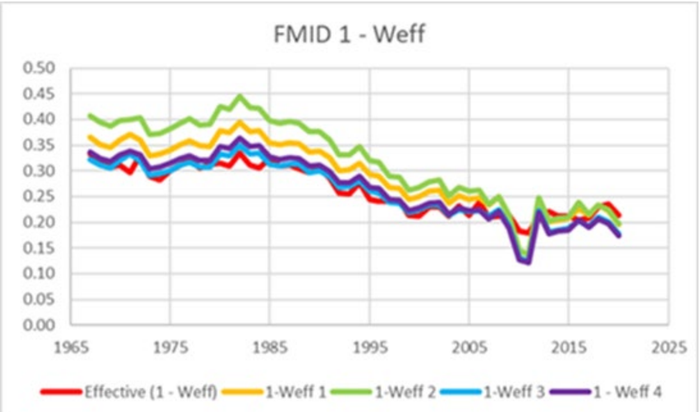
Joint calibration

1. A high-level objective of project is to develop a Joint Calibration (JC) of recharge and groundwater models (previously ‘hybrid’ cf Forward (FM) and Inverse (IM) approach) to manage risks associated with non-uniqueness
2. Rationale for this had been given in guidelines in literature review on non-uniqueness:
   - Voss on FM
   - Knowling and Werner
   - Requires recharge module
   - Qualitative iterations
   - Flux-based observations include salt load and SIS

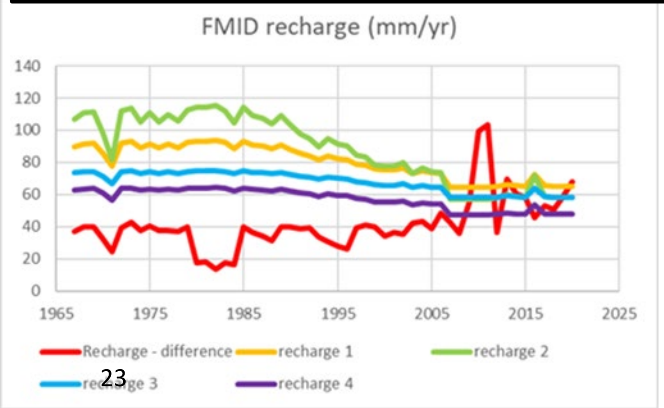


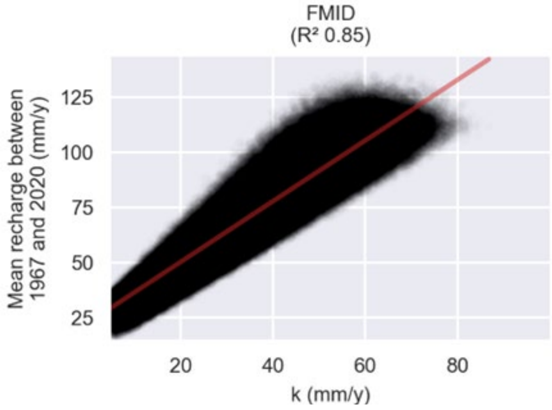
EM modelling experiment #1

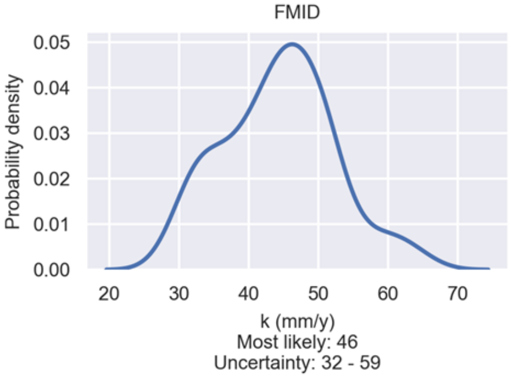
***a priori* setting of W_{eff} can lead to bias in recharge.**



When compared to outputs from different sets of parameters, small differences in W_{eff} lead to significant recharge variations





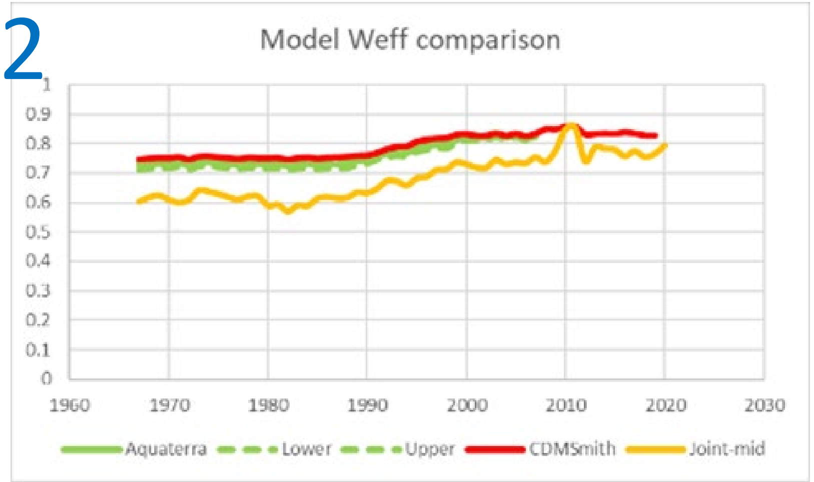


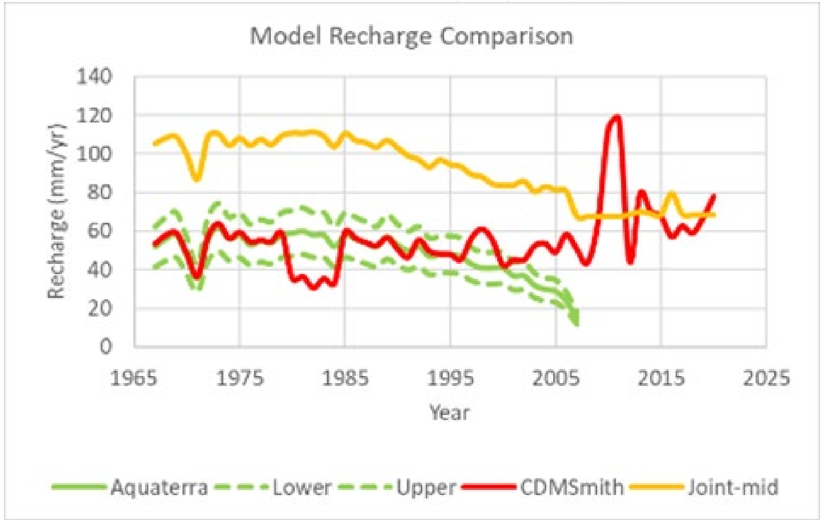
MC analysis of recharge module shows that recharge is most sensitive to K_v. Values of recharge in range 20-50 mm/yr corresponds to K_v of 0-40 mm/yr (<0.1 mm/d)

Joint calibration using ensemble modelling produces a parameter distribution for K_v of 32-59 mm/yr (0.1-0.16 mm/d) with most likely estimate of 46 mm/yr

EM modelling experiment #2

1. Comparison of 4 approaches for FMID
   - Existing model and associated data
   - No cross-checking with local
   - No pre-judgement with respect to model quality
2. Small differences in W_{eff} leads to large changes in R
   - Differences method
   - Implicit assumption of very low conductivity
   - Drainage volumes high: almost no discharge to surface or areas with no perched water tables within model 4
3. Expectations don't align with model 3 outputs





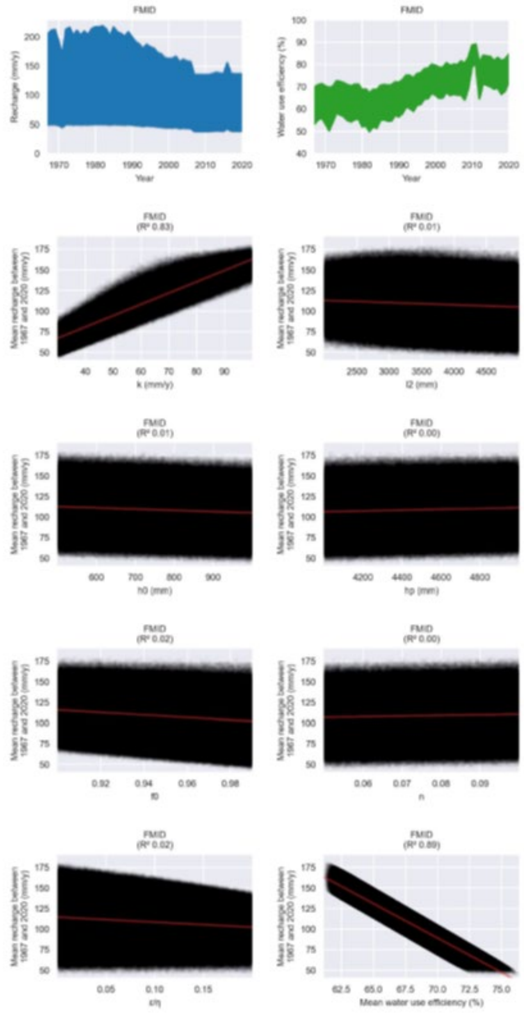


Figure 4 Monte Carlo analysis for FMID

1. Theory that has been developed and tested with respect to perching and time lags;
2. Semi-analytical models for time lags, that have been developed and tested against numerical models and for field situations;
3. Simpler conceptual models, similar to those used internationally, that have been developed for the deeper water tables in the Mallee;
4. Relationships between the magnitude of recharge, water use efficiency and drainage, similar to those that have been successfully used to provide time series for both recharge and water use efficiency in the Eastern Mallee; and
5. Representation of recharge rejection by shallow water tables, for which theory and modules have been developed; and the linkage to groundwater models, through scripting or use of historical data.

3. User experience in applying TFs within a salinity assessment model

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9th May, 2024

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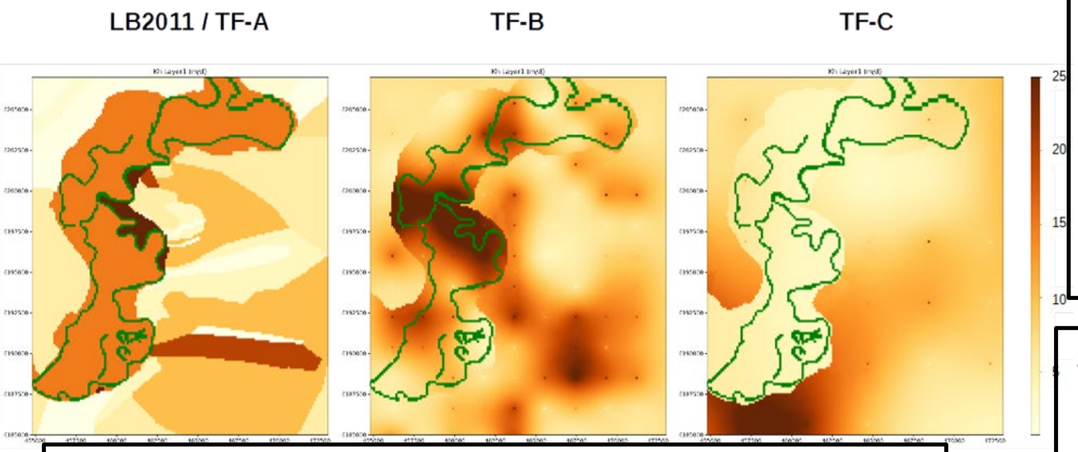
GROUNDED IN WATER

1. Joint Calibration (JC) of recharge and groundwater models should be the preferred modelling approach to manage risks associated with non-uniqueness.

2. Joint calibration requires that data and information are collated at the regional and irrigation district scale that provides sufficient information content to confidently calibrate parameters.
3. Recharge modules should be developed for all irrigation districts, with appropriate resolution for the purpose, to provide input to groundwater models on both magnitude of recharge and, where important, time lags through the unsaturated zone.

Loxton-Bookpurnong District



There were many positive aspects to LB experiment:

- calibration of the aquifer conductivity (left),
- time lags estimates
- calibration of the conductivity of the impeding layer.

Since this experiment, improvements have been made to:

- transfer functions ,
- shallow water table situations and the
- JC approach

that would allow whole approach to be implemented

- No inconsistencies between LB2011 and observations that may be expected with non-uniqueness
- Intensive hydrogeological work associated with SIS and geophysics
- Narrow floodplain and larger role of salt loads with calibration
- High quality water balance and unsaturated zone modelling

Recommendation 1b

Method 4 estimates:

- 18% improvement in water efficiency across the EM region from 1988 to 2000 with 12-28% within individual irrigation areas.
- Reductions in recharge by 28-68% across irrigation districts.
- Consistently higher recharge values than those from *a priori* setting of W_{eff}.

The JC framework requires that the a priori assignment of time series of water use parameters (field water use efficiency, channel loss factors,..) be limited to providing initial estimates. The parameters are then adjusted during the calibration and provide field evidence of the degree of improvement in recharge-relevant water use efficiency achieved.

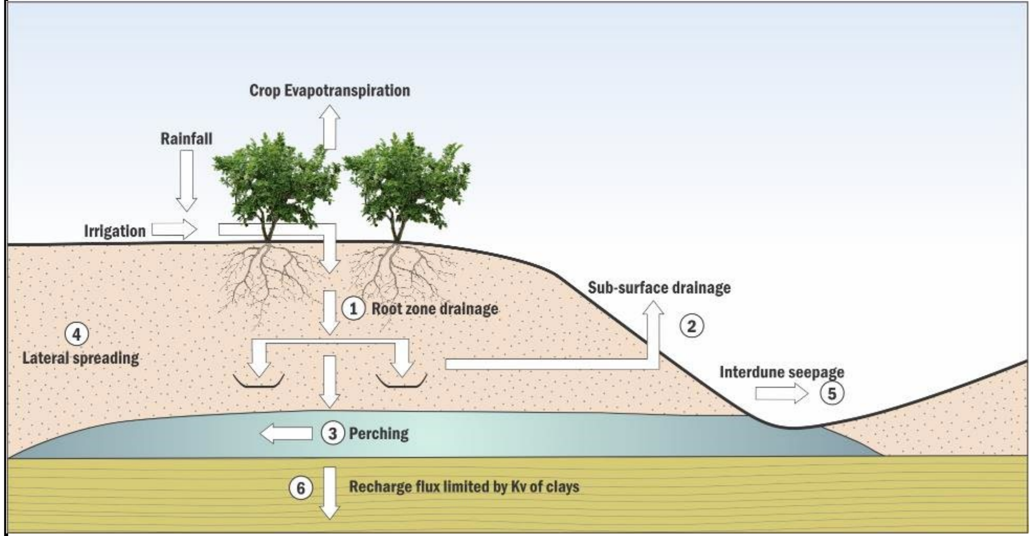
The newly calibrated groundwater model can be used to predict future salt loads to the River Murray under various scenarios, as required under the basin salinity strategies.

For Loxton model, recharge estimates from a priori setting of W_{eff} only used qualitatively by LB2011 model. Integrated modelling TF-C had problems, but calibrated W_{eff} only changed from initial settings for earlier times.

Recommendation 2

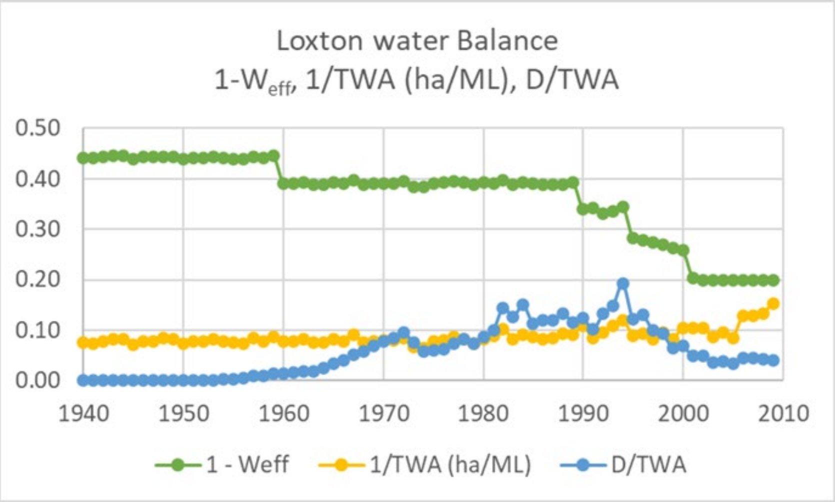
- Recommendation is effectively a statement about predictive modelling.
- Issues are what datasets, their cost, and why are they important. Non-uniqueness for gw models is largely about using piezometric heads.
- Recharge requires data related to the land surface.
- All current models ignore discharge to the land surface
- Current models sensitive to sub-surface drainage volume to central drainage systems or otherwise.

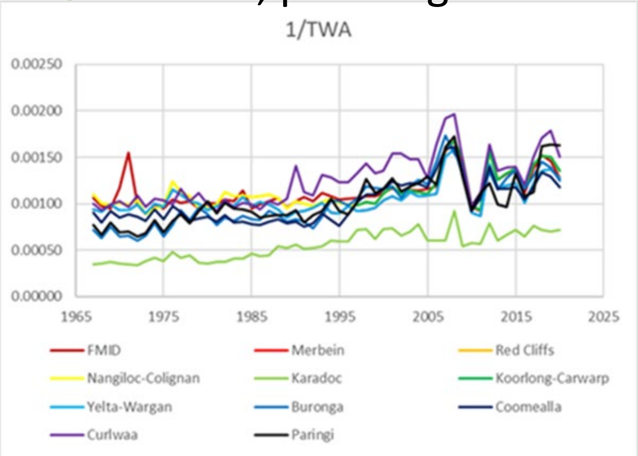
Joint calibration requires that data and information are collated at the regional and irrigation district scale that provides sufficient information content to confidently calibrate parameters.

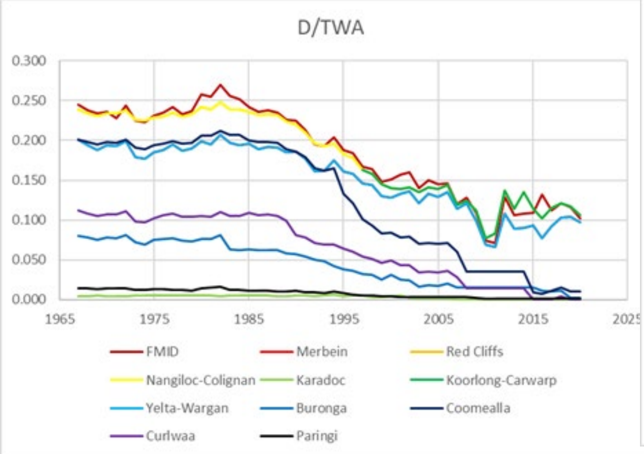


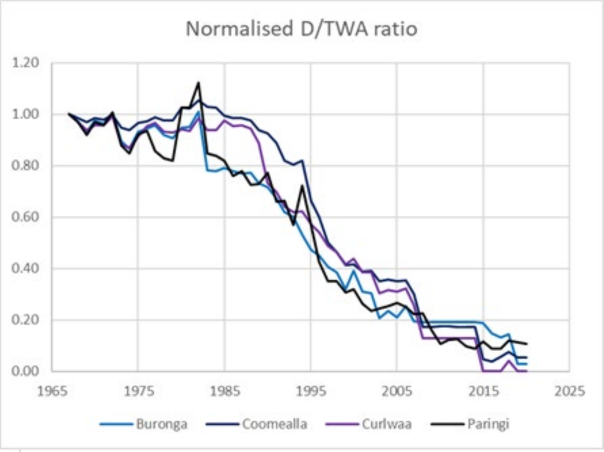
Interrogating regional data

- Examples show utility of interrogating existing regional data relevant to recharge for developing modules
- EM examples shows three different forms of drainage and water availability
- Loxton data shows potential for recharge rejection into drainage system
- Other data related to discharge to land surface , perching volumes









Remotely sensed ET

1. Increasing use of remotely sense ET data for recharge studies in international studies
2. Experience for EM region (right)
3. Readily available CMRSET data
4. Only recent decades
5. Feasibility needs to be established
6. Perching means use will be different to other recharge studies.
7. Need to develop relationships with drainage and percolation.

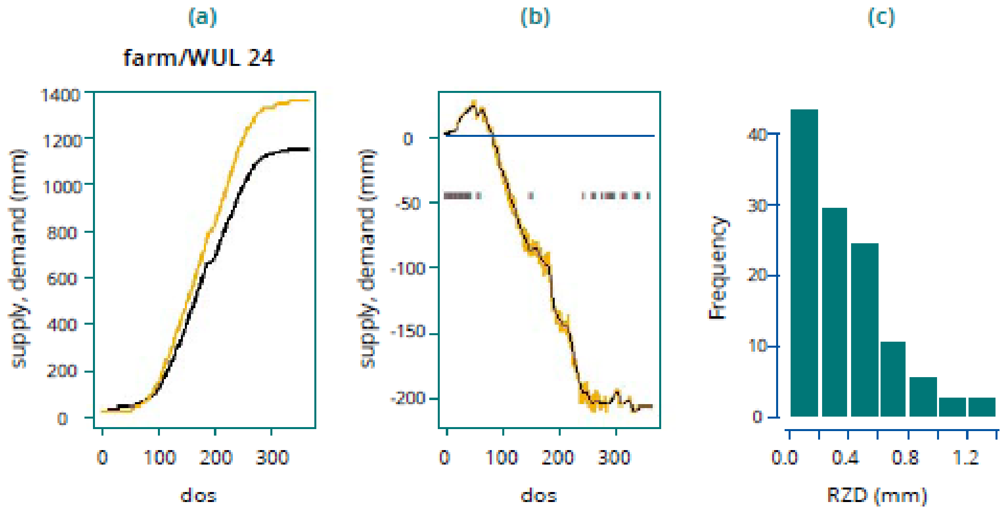
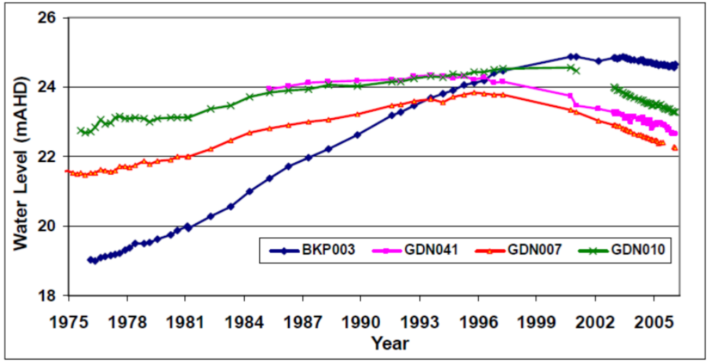
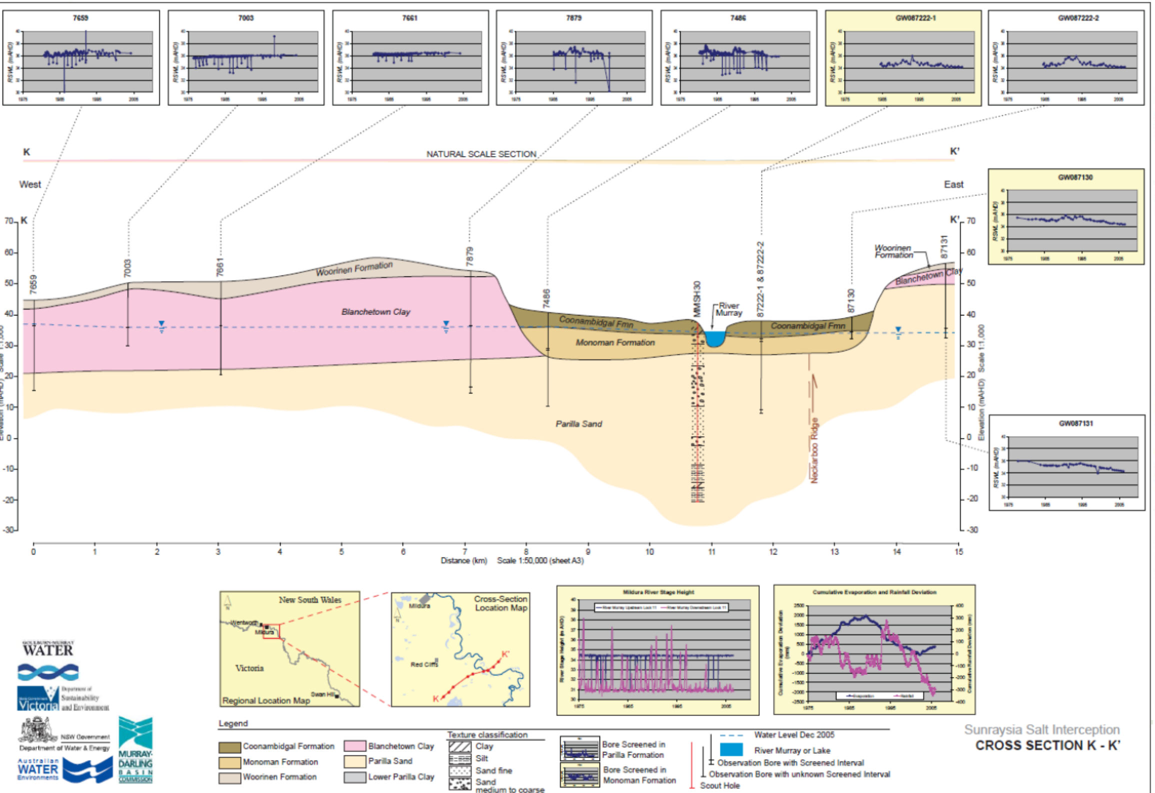


Figure 1: Over-irrigation contributions to RZD on farm/WUL 24:

(a) basic supply (black) and demand hydrographs (yellow) – with supply information sourced from the Victorian Water Register and demand sourced from satellite-based soil water balance methods,
(b) difference (yellow) and smoothed difference (black) calculated from the supply/demand hydrographs in (a), and
(c) magnitude and frequency of RZD events derived from (b)

Shallow water tables

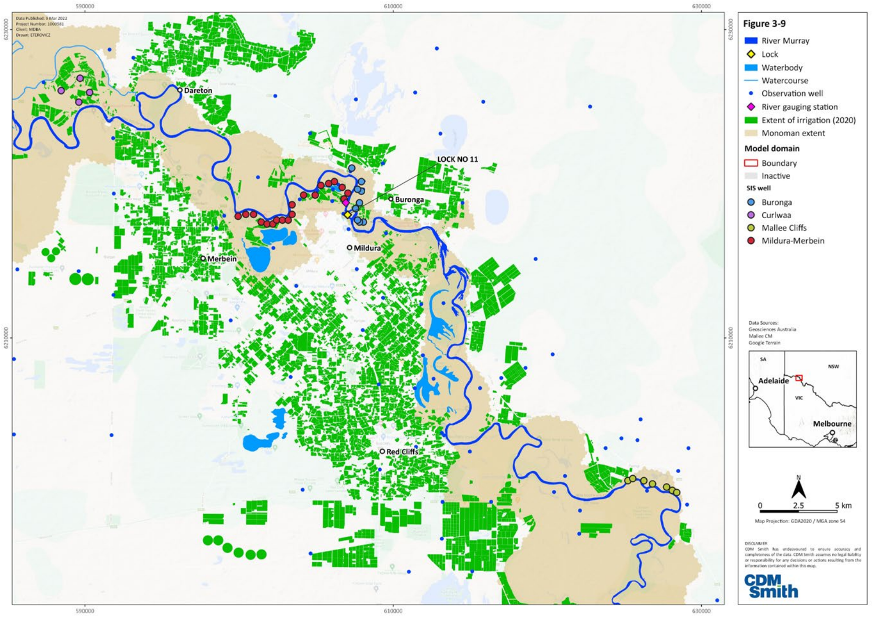




Recommendation 2 Contd

Other datasets include:

- that embedded within current *a priori* W_{eff}
- Local knowledge on discharge to land surface
- Local knowledge on distribution of perching



Information required for JC calibration and the development of recharge modules require collation of data on:

a. Sub-surface drainage for irrigation districts, including centralised drainage systems;
b. Spatial Information on discharge to the land surface, even if qualitative;
c. Areas of shallow water tables, both historical and current; and
d. Readily available regional evapotranspiration datasets, if shown to be feasible.

Recommendations

Recommendations

1. Joint Calibration (JC) of recharge and groundwater models should be the preferred modelling approach to manage risks associated with non-uniqueness.

2. We recommend an evolutionary change, where surface water balance models are still used, and the shift to joint calibration is a variation of the current groundwater models made possible by the development and deployment of recharge models/transfer functions.
3. Given the SA Mallee and EM models are very different not only in the calibration approach, but in the scale, frequency of assessments and underlying data, the changes required for SA Mallee and EM modelling workflows will be different

Recommendations (cont'd)

4. Future salinity assessment in the Eastern Mallee should apply a joint calibration process, in which the water use efficiency and unsaturated zone parameters are adjusted within an uncertainty framework. Before the next assessment, some further work would be required on improving the methodology and supporting data, for one or more irrigation districts.

5. For the South Australian Mallee region, there should be further testing of the simplified transfer function methodology for a South Australian irrigation district within a groundwater model, as a step towards joint calibration into the future.

Recommendations

6. The use of easily accessed remotely sensed data for evapotranspiration for the joint calibration should be explored, to constrain uncertainty and reduce bias.

   Improved collation and interrogation of other irrigation and soil data (e.g. drainage data) should also continue in parallel -- to support surface water balances and the development of transfer functions.

   While this could occur as a regional initiative across the Mallee, it is best embedded in individual modelling assessments as it assists the development of unsaturated zone conceptualisations and in the design of groundwater modelling approaches to robustly simulate irrigation recharge.

Close