REVIEW OF ENGINEERING AND SAFE DISPOSAL OPTIONS

WATER AND RIVERS COMMISSION REPORT
SLUI 20
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SALINITY AND LAND USE IMPACTS

Water and Rivers Commission

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SALINITY AND LAND USE IMPACTS SERIES
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This report was compiled by Dr Shawan Dogramaci and Dr Brad Degens (Water and Rivers Commission) from the following reviews:

Dogramaci, S (2003), *Review of groundwater pumping to manage salinity in Western Australia,* Water and Rivers Commission, Perth, in prep.

Salama, R, Rutherford, J, Pollock, D, Ali, R & Baker V (2002), *Review of relief wells and siphons to reduce groundwater pressures and water levels in discharge areas to mange salinity*, CSIRO, in prep.

Chandler, KL & Coles, NA (2003), *Review of deep drains to manage salinity in Western Australia*, Department of Agriculture Western Australia, in prep.

Meney, K, Coleman, M & Carey, M (2003)), *Review of safe disposal in salinity management for engineering options*, Syrinx Environmental Pty Ltd in Prep

Farmer, DL, Chandler, K, Coles, N, Stanton, D & Cattlin T (2003), *Review of surface water management to manage salinity in Western Australia*, Department of Agriculture, In Prep.

These reports are available upon request from the Engineering Evaluation Initiative at the Water and Rivers Commission (Phone 9278 0300; email: eei@wrc.wa.gov.au)

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Drains in Belka Valley by

Tim Sparks

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1 Introduction

1.1 Purpose

Engineering options such as deep drainage and groundwater pumping are increasingly being seen by many farmers and catchment groups as viable options to manage salinity. There are now over 11,000 kilometres of drains and banks installed and a significant number of groundwater pumping and siphon bore schemes established, with considerable interest in expanding the use of these across the Western Australian Wheatbelt.

There are widely differing opinions about the scale at which engineering should be implemented. Some consider that all water should be retained 'on-farm' while others suggest substantial arterial drainage schemes that include canals, feeder drains or groundwater pumping can be used to transport water to alternative disposal sites, including ocean discharge.

The Engineering Evaluation Initiative (EEI) being undertaken by the WA Government will encompass a range of on-ground projects to examine the performance of specific engineering options (Deep drains, groundwater pumping, siphon and relief, and surface water management), identify safe disposal options and plan for regional drainage.

This report presents a compilation of technical reviews and workshop discussion of current knowledge about salinity engineering and safe disposal options to determine the main technical problems in using these in WA. This report includes the outcomes of discussion at the Salinity Engineering seminar on the 4 March 2003 and the subsequent workshop with major interest groups on the 5 March 2003. The problems and technical gaps identified at these meetings will be used to determine priorities for investment by the EEI in on-ground works and form the basis for calls for expressions of interest in undertaking engineering evaluation projects.

1.2 Background

The use of engineering to manage salinity is limited by difficulties in choosing an approach that will work, siting the construction and dealing with the water that is produced. The assessment of major drainage schemes or other engineering options at catchment scales is complicated by landscape changes due to the delayed impacts of initial land clearing. These changes appear to be inevitable and any assessment of engineering options needs to take into account these longer-term impacts which may not be fully apparent for at least 20 to 50 years.

The drive for increased engineering has been matched by increasing concern about the potential downstream impacts and resulting social conflict. In particular, there is uncertainty about the cumulative impacts of the many existing and planned local-scale drainage schemes, in terms of discharged water quality, increased flooding and the effects of regional drainage on estuaries, such as the Swan-Canning and South Coast Estuaries.

It is within this context that more information is required to both assist farmers and catchment groups to plan and design engineering solutions and take account of environmental and social concerns. The early stage of many engineering schemes and the timing of the Engineering Evaluation Initiative presents the ideal opportunity to influence and encourage the appropriate use of engineering through better information about siting, performance criteria and selecting disposal options that limit downstream risks. The initiative also provides a forum to address the needs for more understanding and leadership on the complex issue of regional drainage.

In July 2002 the Minister for Environment and Heritage established the following Steering Committee to set the direction for the Engineering Evaluation Initiative:

- John Ruprecht (engineering and hydrology)
- Garry English (farming, State and Local implementation of salinity management)
- Gordon Davidson (farming, local government)
- Kevin Lyon (drainage)
- Neil Coles (agricultural water management)
- Tom Hatton (water and ecology)
- Greg Keighery (biodiversity and nature conservation)
- David Pannell (resource economist)

In addition, Dr Richard George (Department of Agriculture) participated with the Steering Committee in developing the program for the Engineering Evaluation Initiative as chair of the Catchment Demonstration Initiative Steering Committee.

1.3 Scope of the EEI

This project is focused on improving the appropriate use of engineering options to manage dryland salinity for economic, social and environmental benefit through the following work areas:

- improved siting and design of engineering options to maximise performance at farm scale
- safe disposal of discharge waters
- implementation of options within a planned regional drainage context.

1.4 Objectives

The following are the objectives for each work area.

Specific farm-scale engineering options

- Identify the limitations to siting and design of engineering options for optimal performance.
- Undertake on-ground evaluations for information that will overcome these limitations.

- Develop decision support system (DSS) tools to select what and where engineering options will perform best.
- Provide guidelines and best management practices for groundwater pumping, deep drainage, relief bores, siphons, and surface water management.

Safe disposal options

- Review options for the safe disposal of drainage water including the productive uses of saline waters.
- Evaluate the characteristics of discharge waters from specific engineering options, analyse the likely effect of these for disposal options and develop risk-based approaches to assess suitable disposal options.

Regional drainage planning

- Evaluate the implications of rising groundwater trends and Land Monitor predictions of increased land areas with shallow watertables on agriculture, infrastructure, lakes systems and riverine environments.
- Develop the tools to evaluate the net cost/benefits of broad-scale integrated engineering proposals for the WA Wheatbelt.

1.5 Target outcomes

The Engineering Evaluation Initiative Steering Committee has identified the main outcomes as:

- Improved application of engineering options to manage dryland salinity to provide benefits for landholders, communities and the environment.
- Farmer, contractor, community and agency consensus on the best sites where deep drains, groundwater pumping, surface water management or siphons/relief wells can be used to manage salinity.
- Widespread use of guidelines for a range of landscape forms. The stakeholders will be involved in the evaluations and production of the guidelines.
- Greater efficiency in evaluating potential options for the disposal of saline discharge waters. These options include natural basins, constructed evaporation basins and productive uses of saline water.
- Greater confidence in identifying safe disposal sites, including the development of tools to select safe options for disposal and provide a framework for the continuous incorporation of new information.
- Regional drainage plans developed with the commitment of the regional NRM group, community groups, farmers, state agencies and downstream interest groups.
- Understanding of the conceptual design, economic viability, funding mechanisms, and management responsibilities of major drainage schemes.

1.6 Setting priorities for investment

Reviews of the four engineering options commissioned by the EEI to identify technical gaps in understanding siting, installation and maintenance of the engineering work to provide greatest benefits. A review of options for safe disposal was also commissioned to highlight the gaps in understanding of how to identify safe natural sites or to construct engineered evaporation basins to deal with the discharge water.

The results of these reviews and case studies were presented to an audience of farmers, land managers, scientists, other stakeholders and interested community members (about 160 people altogether) at a public seminar held at the Burswood-on-Swan reception centre on 4 March 2003. These presentations will be available on the web at www.wrc.wa.gov.au/salinity /EEI.

On the following day a workshop was held to discuss and recommend priorities for the on-ground investment of funds. About 50 key stakeholders participated in the workshop representing a broad cross-section of farmers, drainage proponents, community members, land-care representatives, conservation organisations (WWF), regional NRM group representatives, local government and state agencies involved in NRM (Department of Conservation and Land Management, Department of Agriculture and Water and Rivers Commission).

This document summarises the results of the technical reviews presented at the workshop and incorporates additional recommendations and agreed priorities identified during the workshop.

2 Review of groundwater pumping

2.1 Introduction

Groundwater pumping is an effective method for lowering watertables in some areas within the Wheatbelt of WA. The response of groundwater to pumping is primarily dependent on the hydraulic properties of the water-bearing formations.

2.2 Current understanding

1. The effectiveness of pumping in lowering the watertable and recovering saline land depends on the degree of salinisation, soil and aquifer type. Detailed specific investigations will be needed to improve bore siting (rather than developing guidance maps) as the spatial variability of these properties makes it difficult to use current information at a farm-scale.

2. Pumping from high yielding palaeochannels will be effective if the overlying layer is pervious and not confining. The response time for groundwater to fall depends on the degree of connectivity between the surficial sediments and palaeochannel sediments.

3. Leaching salts from surface soils and the restoration of surface and subsoil structure and fertility are critical to the recovery of land after the watertable is lowered. In WA, draining soils can result in increased sodicity and associated problems for soil structure and drainage. Considerable intervention to restore agricultural productivity may be needed to deal with changes in subsoil chemistry and structure caused by draining the saline soil profiles.

4. The accumulation of iron (iron fouling) and related deposits in groundwater pumping systems is the common factor limiting the efficiency of pumping in recovering saline areas. This widespread problem leads to decreased pump performance and increased maintenance costs. Chemical shock treatment is considered the most effective treatment.

5. Groundwater pumping is a viable management option to lower the watertable but the costs of pumping exceeded the financial benefits. This was the main conclusion of cost-benefit analyses of pumping for six rural towns in the Wheatbelt (Brookton, Corrigin, Cranbrook, Katanning, Merredin and Morawa) conducted by Dames & Moore (2001).

6. On the other hand, the economic study of regional-scale salinity management options in the Collie River catchment suggests that groundwater pumping may be more economical than other engineering options when high value assets such as the water resources in the Wellington Dam are at risk.

2.3 Recommended further work

1. Select groundwater pumping sites that represent diverse landforms and aquifer types. Implement monitoring programs to enhance the current projects and effectively monitor the impact of lowering the watertable on assets at risk. These sites should include rural towns, agricultural land, and important public assets such as roads, water supplies and biodiversity conservation areas.

2. Establish a long-term pumping and monitoring project to evaluate the effectiveness of de-pressurising the deep aquifers in reducing soil salinity for various types of soils in the Wheatbelt. Many existing sites have appropriate bores that could be use to address this gap in current knowledge. This project is important because there is limited data and literature on leaching salt from soil profiles and restoring soils.

3. Undertake comprehensive cost-benefit analyses on using groundwater pumping to protect a range of public and private assets at catchment- to small-scale systems encompassing social and environmental impacts.

4. Use the Rural Land Value Spreadsheet, prepared by the Department of Agriculture, to carry out the simple cost-benefit analysis of groundwater pumping for reclaiming agricultural land. Increase the reliability of this simple assessment approach by including the time taken for recovery.

5. Evaluate and compare the efficiency and cost effectiveness of siphons, solar, wind and electric powered pumps.

6. Investigate preventative measures to avoid the clogging of pipes and pumps with iron oxides.

7. Monitor and analyse the effectiveness of the bore layouts of current projects (private and government projects, such as those in place in rural towns, and Maxon Farm, East Collie) over the next four years.

3 Review of siphon and relief bores

3.1 Introduction

A siphon bore is essentially a passive vacuum pump. The siphon bore is a closed pipe or conduit which conveys water from a point of higher hydraulic head to one of lower head after raising it to a higher intermediate elevation which is under negative pressure. Siphons have a maximum theoretical lift of 10.2 m (equivalent to atmospheric pressure) but a maximum practical lift of 8.3 m (the decreased lift is due to the vapour pressure of water and friction head loss).

Pressure relief bores, called artesian bores continuously discharge at or near the soil surface. The groundwater pressure enables water to passively discharge to the soil surface.

3.2 Current understanding

Siphon bores

1. Additional and regional projects to characterise the different hydrogeological provinces in terms of the effectiveness of siphon bores in managing salinity at farm scale will not substitute for the detailed site-specific studies and will only be a waste of resources.

2. The effectiveness of siphon bores in lowering the watertable depends primarily on the difference in elevation between the watertable and the discharge point. This means that siphon bores function on hillsides, but not on broad valley flats.

3. While the technology and expertise for constructing groundwater bores that can be used as siphon or relief bores are well known and applied by farmers in all parts of the Wheatbelt, the bore effectiveness has only been assessed in the Great Southern.

4. All successful constructed siphon and relief bore sites are located in natural discharge areas. Relatively high yielding borefields are mainly due to more transmissive aquifers and the gradient of the landscape and perhaps the enhanced recharge from dams and banks upstream of the bores.

5. Siphons can be very effective in discharging low to moderate volumes of groundwater in suitable hydrogeological conditions and with proper bore design. However, crop productivity will not improve unless the reduced water levels are accompanied by the leaching of accumulated salts.

6. Although there are regional maps of terrain, soils, geology, geomorphology and, in some areas, detailed hydrogeology, the spatial variability of these properties in WA makes it difficult to use the available information on the paddock scale to site bores successfully.

7. Failure in siphon operation is mainly caused by poor design (air leak) of the discharge pipeline.

8. Most of the siphon bores investigated in the Great Southern have been effective in lowering groundwater locally.

Relief bores

9. Relief bores can reduce pressure head in discharge areas. They are not, as such, effective in recovering saline land as they do not lower the water level below the surface at the discharge area (unless constructed with a sub-surface outlet). However they can halt salinity spread in the catchment if they are designed to remove the additional recharge and may reduce the severity of the salinity.

10. Relief bores can successfully be used to relieve hydrostatic pressure and to halt saline seepage from farm dams.

11. Relief bores are always constructed in the lower areas of the landscape which are the natural actual or potential groundwater discharge zones. Salt export to these sites will continue until all the mobile salt in the catchment is depleted. This can take from a few hundred to a few thousand years.

12. Relief bores may be more effective when installed at the base of a deep drain.

3.3 Recommended further work

1. Evaluate and communicate the results of the current investigation in the Great Southern to allow farmers to assess the suitability elsewhere.

2. Investigate the off-site impacts of siphon and relief bores in terms of chemistry, hydro-period, salinity other environmental effects compared with 'do nothing' option.

3. Systematic analysis of cost and benefits for relief and siphon bores has not been carried out, but there are several studies associated with groundwater pumping for mitigation of salinity that might be relevant to cost-benefit analysis of siphon and relief bores.

4. Conduct a trial of combined relief and siphon bores.

4 Review of deep drainage

4.1 Introduction

Deep drains collect and transport groundwater and, at times, surface water across the landscape.

Deep drains are typically used where the natural drainage system is inadequate to remove the inflow of water and salts in rainfall and irrigation water. In these areas, accumulated water and salts in the soil profile decrease land capability such as agricultural production. An artificial or man-made drainage system increases discharge by removing water. Draining saline agricultural land can significantly improve crop production because it prevents waterlogging and may lower the soil salinity in mid to long term.

The main types of deep drainage include:

- Deep open drains
- Deep closed (leveed) drains
- French drains
- Pipe drains
- Mole drains

French, pipe and mole drains can be classified as deep subsurface drains.

Deep surface drains (open and leveed) remove land from production; restrict the use of machines and movement of livestock; may require bridges and culverts; have a higher risk of slumping and transmission losses; and require more maintenance. The area of cultivable land lost and the maintenance requirements may be less with subsurface drainage systems (French, pipe, mole) but the installation costs may be higher due to the materials, equipment and skilled manpower involved. In general, deep surface drains are most suitable for larger-scale drainage, while deep subsurface drains are most suitable for smaller, more intensive drainage systems.

4.2 Current understanding

1. The preliminary results from the only two comprehensive investigations (Dumbleyung and Narembeen) indicate that 2 m deep drains are effective in lowering the watertable up to 0.5 m for approximately 150 m from the drain. The lateral extent of the drain's influence of the watertable depends mainly on soil characteristics.

Causes of variability with drain performance

2. Transmission losses (the reduction in downstream flow of a deep drain) can be significant, particularly in large-scale drainage networks which may traverse a wide range of soil and landscape types. The exact extent and impacts of transmission losses are not well understood as they have not been formally studied in WA.

3. It is difficult to transfer results from studied drains to other areas because the Wheatbelt soils and landforms are so varied. There have also been large variations in maintenance problems with drains that can greatly influence the functional life and impacts of drains on down-stream farms/environments.

Chemistry of drainage waters

4. The geochemical processes occurring in deep drains in the southwest are poorly understood. The presence of iron oxides, other indurates and low pH drainage waters in many deep drains in WA has been noted but their significance for drain function is not yet well understood. There is conflicting evidence concerning the drainage of sodic soils. While sodic soils require pre-drainage treatment, this is rarely adequately done, if done at all. If sodic soils are to be treated, then the types of pre- and post-drainage treatments available and application rates to avoid loss of soil structure and land capability must be determined. Furthermore, the rehabilitation time for sodic soils using drainage and treatments is unclear. It is also necessary to alter the design of deep drains constructed in sodic soils to ensure stability. Shallower batters are suggested, but this has not been quantified.

Financial aspects

5. A generic economic evaluation concluded that to break even it would be necessary to reclaim/protect a strip extending between 25 and 90 metres on either side of a drain (depending on assumptions as to the frequency of drain maintenance and the applicable gross margins). The two most recent studies, Narembeen and Dumbleyung, exceed this criterion. A critical limitation of this analysis is the availability of crop yield responses that can be attributed to the impact of drainage.

4.3 Recommended further work

Priority

1. Develop an appropriate site test to assist with effective drain planning and design. The site test can be used to estimate the permeability of soil at a site, and possibly to detect the presence and connectivity of preferred pathway flow.

2. Construct a series of deep drains in different soil and landscape types, with pre-drainage watertable data. Conduct a thorough site investigation, including permeability estimates via auger hole method at each site and design the drain accordingly. Measure the flow and watertable drop at the site, and compare with those predicted using standard drainage theory with estimated soil permeability. Monitor the decay of the drainage structure and determine whether the auger hole method was an adequate predictor of soil strength for stability. Use existing drains if relevant or new to develop tests and principles.

3. Collate all crop productivity data and analyse whether it is likely to be a realistic measure of drainage performance, given seasonal variability and lack of pre-drainage data. If it has potential to be an effective measure, determine the number of years of data is required to estimate increased production. Examine whether soil salinity, soil moisture content and depth to watertable are more accurate measures.

4. From the existing and future data, develop a list of standard methods that should be used to monitor deep drains and determine the minimum necessary controls for WA conditions. Develop simple monitoring techniques (for example, the extent of sedimentation and the quality of drainage water) for landholders to use to improve the success and maintenance of their deep drains.

5. Quantify transmission losses along the constructed drains compared to evaporation loss, and their impacts downstream.

6. Improve the prediction of potential drainage discharge quality from pre-construction measurements of water chemistry, pH and EC. Investigate pH and EC of existing deep drains in the Wheatbelt, determine whether there is a spatial relationship, and whether it can be used as an indicator of drainage performance or potential discharge quality problems.

7. Develop and promote field tools for determining the level of sodicity of soil and required treatment.

8. Investigate the process of acid water generation in drains, impacts on sub-soils and drainage function and solutions to neutralise acid waters (capacity for soils to neutralise water in drains, downstream or with addition of amendments to drains).

Financial aspects

9. Evaluate costs and benefits of drainage systems. This must include intangible (non-market) factors, such as social and environmental costs, as well as opportunity costs. Compare case studies using standardised units, such as $/km or $/ha.

10. Compile an up-to-date list of costs for constructing and maintaining deep drains of different designs in different landscapes.

Lower-priority

1. Develop a standardised list of criteria for determining the success of drainage systems. These criteria may include cost recovery, reductions in groundwater levels, salt leaching, land recovered/protected or increased crop productivity. Use these criteria to assess existing and future drainage networks.

2. Investigate the use of watertable levels as a criterion for the success of drainage systems. Experiment to determine the critical depth for different soil types and uses.

3. Investigate innovative approaches such as using passive relief wells in conjunction with deep drains, biopolymer drains (use of a slurry to stabilise banks), and tyre drains. Is it technically and economically feasible, and if so, what are the design principles? Construct a deep drain with passive relief-bore along the base and compare with the performance of a standard deep drain. This may include monitoring the quantity and quality of drainage water (especially acidic) of existing tyre drains and the benefits and limitations of using tyres as filling.

4. Investigate the post-drainage treatment required to assist with crop productivity or asset protection. Refining treatments such as ripping and application of gypsum should be part of this work.

5. Investigate in-drain methods to reduce discharge volumes and treat low quality drainage water to minimise disposal problems.

6. Investigate existing deep drains with stepped batters for benefits and limitations in different soils and landscapes. Determine where stepped batters are most effective and develop preliminary best-practice design and maintenance. Construct a deep drain with stepped batters to test the best-practice guidelines and compare with a drain with straight batters.

7. Investigate existing drains constructed in sodic soils (high in sodium) for suitability of the drainage design and soil type. Develop best practice guidelines for drains constructed in sodic soils and construct a drain to test the design.

8. Develop a tool for contractors and landholders, which calculates design aspects such as drain spacing, width, and batter slope, from inputs such as soil type, permeability, depth, grade, depth to watertable.

9. Investigate the current best-practice design and maintenance of deep drains and see whether there is scope for modifications that reduce the risk of downstream impacts of the drains. The modified best practice would need to be field tested with deep drains constructed and managed in a range of soil landscapes.

5 Review of safe disposal options

5.1 Introduction

There is concern in the WA Wheatbelt regarding how to manage the water discharged from engineered schemes designed to reduce salinity. Large drains that allow saline (up to twice seawater salinity) or acidic (less than pH 5) drainage water to flow downstream onto neighbouring land, natural waterways, wetlands and/or salt lakes have been and are being constructed. There is a lack of specific information on the effects of discharge water on downstream properties, ecology and communities. Preliminary results of engineering schemes indicate that, across the state, there is considerable variation in discharge water quality and quantity, which is likely to have widely varying impacts on receiving sites. High salinity, large volumes, low pH, dissolved heavy metals, nutrients and sediment loading are the main water quality problems that pose significant risks to downstream land productivity and ecological values.

There are currently several options for the disposal of discharge water from engineering schemes:

Natural Disposal Sites

- Direct disposal to natural waterways or wetlands
- Disposal to natural playas and salt lakes

Engineered Disposal/Re-use

- Direct disposal into local constructed evaporation basins
- Disposal to modified playas and salt lakes for controlled release and flood control
- Fodder/aquaculture productive re-use of discharge water (serial biological concentration, artificial saline wetlands) and disposal to evaporation basins
- Industrial or commercial use of saline water (solar ponds, mineral extraction) and disposal of effluent.
- Disposal into an arterial drainage network to the sea

The purpose of the safe disposal review was to evaluate all available literature and data on the safe disposal of drainage waters within the Wheatbelt of WA, and other parts of Australia and the world where applicable.

5.2 Current understanding

There is very little known about what constitutes safe disposal in natural sites. There are two principles to disposal relating to the way in which discharge is dealt with –

- Redistribution — to either natural sites or artificial sites involving management of salt balances and distributions within landscapes (which has been likened to managing the evaporation of water in the landscape and re-internment of the salt rather than attempting to move salt stores)

- Release — via arterial disposal to the sea (although this may also result in local redistribution via leakage from channels *en route*)

Most disposal has consisted of discharge directly to natural waterways, lakes or depressions with little prior assessment of the criteria for safe disposal. This assessment is limited by information on ecosystem responses to saline discharge and the availability of this in a format for use by farmers, community groups and land managers. Where criteria have been set there has been little or no monitoring to verify or refine safe disposal criteria, particularly in comparison with the "do nothing" scenario. Balancing the short-term impacts of intervention against forecast long-term impacts if no intervention occurs remains an unresolved dilemma.

Disposal to constructed basins is a technically sound option, with considerable understanding of design and performance known from their use to dispose of water from groundwater pumping schemes in the Murray-Darling Basin. While the use of disposal basins in WA has been limited by siting problems and construction costs, integrating the basins with productive uses for saline discharge may provide an offset to these problems.

Little is known about the construction and performance of modified natural basins or the benefits/costs of retaining discharge for controlled release during floods. This option presents opportunities for the safe disposal of discharge waters within contained areas for long-periods with periodic flushing and/or release during high flows to rejuvenate the disposal capacity of the site.

There is little knowledge of the suitability or opportunities presented by other safe disposal options incorporating serial biological concentration, salt-tolerant fodder production from artificial saline wetlands, solar ponds or mineral extraction. These options present opportunities for farm-scale productive uses of saline water as well as larger scale uses suitable for larger sub-catchment drainage schemes.

5.3 Technical gaps

The technical gaps can be generalized as:

1. *Uncertainty in the current effects of catchment water and salt inputs on remnant native ecosystems*.

- Current baseline information is extremely poor and limiting to formulate the criteria for potential disposal sites. The information is also needed to identify the limits for disposal in numerous sites with "marginal" or uncertain ecological value sites to ensure that disposal does not unnecessarily degrade these sites.
- There is also a paucity of knowledge on scoping where discharge can benefit degraded natural ecosystems by establishment of new salt-land ecosystems.
- The hydro-period (number of days and extent of waterlogging) that remnant ecosystems can tolerate is a critical unknown for many systems.
- There is little known about the impacts of natural discharge from surrounding landscapes and salt loads on remnant ecosystems compared the changes that would occur from engineering discharge.
- The lack of knowledge about the risks of modifying degraded natural sites to use as disposal basins or the opportunities and costs of controlled release from these during flood events. More information is also needed to integrate productive uses of discharge with modified basins.

2. *Poor understanding of the long-term hydrological and geochemical risks of disposal to natural sites:* The long-term on-site and off-site risk associated with sacrificial disposal sites beyond impacts on ecology (lakes, wetlands and drainage lines) is unknown. This gap relates to risks of disposing to sites where protection of the ecology is not an issue (degraded sites).

3. *Impacts of transmission losses from drainage system:* The effect of transmission losses from drainage systems on natural vegetation, particularly the effects on ecosystems where drainage/disposal channels traverse areas where the ground-water is below the channels. These losses need to be considered in relation to evaporative losses that would result in hypersaline recharge.

4. *Impacts of changes in surface water volumes and quality on estuaries.* The impacts of the “do nothing” scenario vs changes in discharge from engineering landscapes on estuaries is not known. Engineering may result in changes in the hydroperiod of the estuaries and interaction with coastal environments (particularly when estuaries open to the sea more often) greater than would occur without engineering.

5. *Uncertain benefits of productive uses of discharge*: Little is known of the suitability of discharge from various engineering schemes for productive uses (particularly on-farm uses) or the cost-benefits of different reuse options.

6. *Poor understanding of the social and economic opportunities and costs of all disposal options*:

   - The social and economic aspects of disposal options (integrated with environmental impacts) are poorly understood. This is needed to support development of an improved decision support system (DSS) process to guide landowners and managers towards making better decisions about disposal options.

   - The costs and benefits of allowing salinity to reach equilibrium (taking no action) compared with intervening with engineering need to be explored. Social and economic assessments need to include equity issues, both within and between generations and public vs private benefits/costs.

5.4 Recommended further work

The table below presents a synopsis of the specific recommendations of the Engineering Evaluation Steering Committee endorsed at the workshop. These were recognised as forming the basis of specific actions that could be taken within the context of the priority recommendations below.

Specific technical recommendations	Relevant engineering options
Clarify risks associated with disposal in natural systems	
Understand effects of constant base flows • compared with periodic flushes from non-engineered saline areas.	Groundwater pumping, siphon/relief bores and drains with constant base-flow

Specific technical recommendations	Relevant engineering options
Determine range of impacts of acidic waters on streams/waterways • How does the impact of discharge from engineering intervention compare with the impacts of acidic saline run-off and discharge from areas in similar sub-catchments with no intervention? • What are the long-term consequences of disposing of acidic groundwater to natural disposal basins? • How does this differ compared with the acidic saline run-off and discharge from areas in similar sub-catchments with no intervention?	Deep drains with acid flows (during base-flow) Groundwater pumping Deep drainage with significant base-flows, groundwater pumping schemes
Investigate impacts of non-acidic water disposal on natural sites • Are the effects of non-acidic discharge to low-value natural disposal basins constrained to the basins? • What are the long-term on-site factors that contribute to off-site problems? • How do these factors compare with drainage from similar saline areas with no engineering intervention?	Deep drainage with constant baseflows, deep drainage with seasonal flows, pumping schemes
Improve decision tools to identify potential safe natural disposal sites • Can a rapid appraisal system be developed to broadly determine the possible suitability of sites for safe disposal? • Can this include a system to classify rivers, wetlands and lakes on the basis of sensitivity to change with further disposal (accounting for the trends in degradation pressures within the catchment)?	All
Trade-offs between discharge volume/load and salt concentration. • Do drains with low flows, high ion concentrations have more localised effects than drains with high flows, low ion concentrations? • Is this constrained to the edges of the disposal sites for low flow drains?	Deep drains with high and low flows
Identify where discharge can be used to renew ecology in degraded systems. • Can drainage be used to improve salinity threatened natural sites (through increased stability in hydroperiod between flood events) and for what discharge quality and flow characteristics does this occur? • Are there potential ecological benefits provided by discharge to already degraded systems (apply principles of ecological restoration to low-value systems)? • Can ecologically stable saline wetland systems be created with discharge (volumes and characteristics where most likely)?	Deep drains, groundwater pumping, siphon & relief bores
Limitations to disposal in constructed basins and productive uses.	
Evaluate integration of on-farm productive uses as disposal options. • Can saline discharge be used to develop farm-scale fodder production systems or artificial saline wetlands with salt tolerant vegetation?	Deep drainage and groundwater pumping
Evaluate the costs vs benefits of constructed basins. • Can <u>constructed</u> disposal basins be used to provide productive uses for salt water? • What are the benefits relative to any short-term costs and long-term impacts? • What opportunities exist for using controlled release from evaporation basins during flood events to expand the working life of these sites?	Deep drainage and groundwater pumping

Specific technical recommendations	Relevant engineering options
Determine what sites would be suitable for disposal to modified natural basins and evaluate costs vs benefits. • Can modified natural disposal basins be used to provide productive uses for salt water? • What are the benefits relative to any short-term costs and long-term impacts? • Can discharge be stored and released at opportune times from constructed evaporation basins?	Deep drainage and groundwater pumping
Audit characteristics of discharge water to provide better information on what alternative uses might be suitable for different parts of the wheatbelt.. • Is water produced by deep drainage and ground-water pumping suitable for geoprocessing, aquaculture, solar ponds, plant production uses (serial biological concentration)? • Scale and quantities of discharge required – schemes where this may be suitable?	Deep drainage and groundwater pumping
Investigate options to treat poor quality discharge within drainage systems. • Can poor quality water be treated within drainage or pumping schemes before disposal to minimise disposal problems?	Deep drainage
Improved Information on the Cost and Benefits of All Disposal Options.	
Define the social and economic costs and benefits of all options. • For each disposal option, what social and economic factors need to be considered and in what priority? • What factors influence the social and economic factors?	All
Investigate the social benefits can be achieved through using engineering discharge to improve degraded sites? • Do these benefits extend to local economic benefits? • Compare benefits with the implications of further degradation to sites.	All

In addition, the Salinity Engineering workshop emphasised the need for the following:

1. Identify key changes in hydroperiod and water quality that will have greatest impact on natural systems.
2. Collate and widely distribute existing information, reports and guidelines on setting safe disposal criteria for natural disposal sites.
3. Evaluate the capacity of engineered disposal options to safely deal with discharge from drains, pumping or siphon/relief wells in a range of landscapes.
4. Develop tools to help farmers, catchment groups and communities make decisions about safe disposal and guidance on what information is needed to select most appropriate disposal/reuse options (including WA specific design standards for engineered disposal options).

6 Review of surface water management

6.1 Introduction

Surface water management uses combinations of earthworks, minor structures, detention storage and 'purpose planting' of vegetation to modify the movement of water through the landscape. This is achieved through a variety of methods that interact to collect, slow, divert, store and safely convey excess water before it causes problems through increasing recharge, flooding, erosion or vegetation decline.

6.2 Current understanding

1. Purpose-designed diversion projects at Towerining and Toolibin have demonstrated the ability to manage saline flows.

2. A number of studies using interceptor bank systems and raised bed farming systems have demonstrated production benefits when surface water management options are used to address waterlogging. Monitoring at the Berkshire Valley experimental site demonstrated a reduction in expected peak flows following runoff management using banks.

3. The adoption of effective surface water management structures has been slow, despite more than 60 years of promotion by individual farmers, private organisations (e.g. Keyline, WISALT, Kondinin Group) and government agencies. The reasons for this are not clear, although it is most probably due to the indirect and slow appearance of the benefits of surface water management. It is expected that the encouragement of integrated farm management and water harvesting systems could offer a more direct economic benefit to the farm business.

4. Surface water management is often not considered beyond the role of a basic soil conservation activity (at paddock-scales). The main issue at present seems to be a poor realisation that surface water processes and landscape degradation are linked, particularly in contributing to salinity.

5. The poor understanding of the benefits of surface water management is complicated by the widespread belief that management of salinity should focus on groundwater recharge and discharge aspects and the recent emphasis on vegetation solutions.

6. Surface water management has been under-utilised as a beneficial co-option for many deep drainage sites. There are studies that demonstrate the benefits of integrating deep drainage with surface water management to provide workable packages for managing salinity.

7. Assessment of the benefits to be gained from managing surface water is limited by a lack of knowledge of hydrological processes in Wheatbelt areas and impacts associated with changes in runoff regimes as a result of initial land-clearing. There is a need to better define the interaction between valley watertables and surface water movement, particularly in the eastern Wheatbelt.

8. There are problems with the design and implementation of purpose designed surface water management systems for catchments using simplified methods. Traditional methodology for farm-based management of surface water is based upon rule of thumb and flow assessment methods that are not applicable to catchment-scale systems. In many cases the theory and physical basis that originally lay behind the numbers used in conventional designs have been lost in the act of simplification.

9. The functional basis of various engineering structures to manage water is not clearly established, which presents problems for pre-construction evaluation of designs within integrated management systems.

6.3 Recommended further work

1. *Develop WA specific design guidelines.* Guidelines for a range of scales (10 km^2, 100 km^2 and 1000 km^2) and catchment systems (eg Northern vs Eastern and South Eastern Agricultural Zones). Develop a tool box of approaches with implementation guidelines conforming with principles of Environmental Management Systems.

2. *Conduct detailed economic cost-benefit analyses of existing evaluation sites.* Improve financial justification for implementing surface water management within integrated systems by analysis of water management components and whole systems. Analyse total costs of catchment-scale deep drainage and surface water management systems and off-site impacts of each system.

3. *Evaluate integrated systems at catchment scales.*

   - Evaluate systems in the context of farm practices. Carry out an audit of surface water management systems to provide base information on the long-term costs and benefits. Review and conduct a rudimentary assessment of the original 1950s soil conservation sites (where appropriate), Department of Agriculture sites and data, WISALT sites and of sites of recent work. Establish anecdotal links between surface water management, increases in productivity and reduction in degradation. Link this to recovery at catchment scales.

   - Evaluate integration of water management in isolation and integrated with large-scale deep drainage systems.

   - Improve information on runoff regimes for various landscapes and understanding of changes to these as a result of engineering intervention. This should include the influence of landscape heterogeneity on runoff-run-on characteristics of catchments.

   - Evaluate systems in the context of Environmental Management Systems.

   - Investigate the links between infrastructure protection, waterlogging and salinity. Infrastructure such as roads act as flow impediments that can increase salinity risk. Evaluate options for improving water conveyance through areas where flow impediment risks increased recharge to groundwater.

4. *Improve modelling of catchment responses*

    - Increase predictive power of existing models for at paddock, farm and catchment scales. Improve modelling capability at single bank scale for various slopes, treatments, and characteristic events.

    - Integrate evaluations of surface water management systems to improve modelling of water balance in catchments. Provides capacity to evaluate the benefits of water management at catchment scales to ground-water recharge and salinity.

5. *Develop better economic, education and extension tools to demonstrate the economic benefits of integrated farm management and water harvesting systems.*

6. *Develop approaches to improve the adoption of surface water management systems*

- Accreditation
- Regulation and legislative tools
- Codes of practice
- Increased availability of catchment information to assist in the implementation of surface water management schemes (eg runoff characteristics).

7 Concluding remarks

The reviews and discussions at the seminar and workshop highlighted the following critical points.

Site-specific investigation is needed to make decisions about engineering work and safe disposal sites.

1. It is not considered possible to compile maps to guide implementation of engineering works for use at farm-scales. Additional projects to characterise the different hydrogeological provinces in terms of the effectiveness of engineering work in managing salinity at farm scale will not substitute for the detailed site-specific studies and will only be a waste of resources. This is due to the variability of the hydraulic properties of the soil and the underlying water bearing formations in the Wheatbelt The wide range of values obtained from these studies for the water yield from groundwater via bores or drainage limits the transferability of data from existing sites to other parts of the landscape.

2. As with engineering options, it is not considered possible to compile maps of suitable safe disposal sites for use at farm and sub-catchment scales. Regional characterisation of safe disposal sites in natural rivers, lakes and wetlands is no substitute for detailed site-specific assessments which will be necessary to finalise whether a site can safely handle discharge water from engineering options. This is due to the variability of the eco-hydrological properties of natural systems, with is a consequence of the vegetation composition and the underlying variations in water bearing formations in the Wheatbelt (as highlighted above). The variety of natural ecosystems and current condition of these limits transfer of safe disposal criteria defined for specific sites to other parts of the landscape.

7.1 Beyond the scope of farm-scale engineering options

The following issues raised at the seminar or the workshop were beyond the scope of the reviews and investment planning for farm-scale engineering or safe disposal. In some cases these will be dealt within the regional drainage planning program or are beyond the scope of the Engineering Evaluation Initiative. In the latter case, they are recorded here in the expectation that there will be opportunities to address these in other initiatives.

- Issues relevant to the regional drainage planning program
    - Consequences of flow conveyance and linking of small systems between small systems.
    - Connecting local scale drainage to regional drainage. What are the requirements for doing this?
    - Management/ownership issues/responsibilities for drainage systems (including money for management).
    - Disposal via regional systems.
- Issues beyond the scope of the EEI
    - Disposal via regional systems.
    - Protection for landowner with the salinity problems. Current regulation centres on protection of downstream landowner. Provision for considerations of upstream landowners to deal with these problems

- Put together a full array of criteria for informed choices between engineering and safe disposal options
- Pull together overarching guidelines, information and best management practices
- Investigation of the form and function of rivers.

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