Drainage options and their use in Wheatbelt landscapes in WA

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DRAINAGE OPTIONS AND THEIR USE IN WHEATBELT LANDSCAPES IN WA

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ABSTRACT

Effective management of waterlogging and soil salinity is one of the biggest challenges faced by the farming community in the dryland agricultural areas (known as the Wheatbelt) of Western Australia (WA). Many individual farmers, as well as State and local government agencies, have trialled and adopted various drainage methods in an effort to manage salinity. However, only a few large-scale systems have been evaluated on a formal scientific basis for different locations and landscapes in the Wheatbelt. The lack of formal evaluation of engineering options at variable scales has generated intense discussions and at times conflicting interpretation regarding effectiveness of engineering solutions for salinity management.

Evaluation of drainage options at catchment and regional scales is required to assess the economic, social and environmental impacts of using such options in managing salinity in the Wheatbelt. A number of research studies currently underway in the Wheatbelt address some of these issues. The design, construction and maintenance criteria need to be addressed to ensure that appropriate decisions are made regarding planning and implementation of such schemes. Actual drain design evaluations are required which may help minimise silt deposition and maintenance costs and enhance efficiency. The level of effectiveness required for the economic viability of a particular option is a real determinant for making implementation decisions. The adverse or positive impacts of drainage on downstream farmers, wetlands, waterways and natural reserves need to be addressed. Only after thorough assessment is it possible to draft meaningful guidelines, regulations and other related legislation. Without effective guidelines that have been scientifically, economically and environmentally assessed, it is unlikely that the real benefits offered by the appropriate use of drainage will be realised.

INTRODUCTION

The natural water balance of agricultural catchments in the Wheatbelt of WA has changed due to the clearing of native vegetation to allow the development of broadacre farming. Most of the State's commercial broadacre farms are located in the dryland agricultural region of WA, which is defined as farmland that receives less than 600 mm average annual rainfall (Coles *et al.* 2000). Reduced evapotranspiration and increased contributions to shallow and deep groundwater occurred as a direct consequence of clearing (Allison and Hughes 1983). The replacement of deep-rooted native vegetation with predominately shallow-rooted annual crops and pastures has exacerbated the impact of clearing on relatively fragile landscapes of the Wheatbelt.

The remobilisation of salts, stored within the regolith as a result of rising water tables and the development of localised perched systems, has resulted in extensive areas of the wheatbelt being affected by seasonal waterlogging and secondary salinity (McFarlane *et al*. 1992). The scale of this problem has grown each year after clearing, which began with the initial colonisation of WA. By 1996, nearly 90% of the dryland agricultural landscape was cleared. The subtle changes this brought about were first noticed and documented by Wood (1924) in his seminal paper on salt discharge increase following clearing. To date some 1.8 Mha has since been impacted in the Wheatbelt by primary or secondary salinity (Ferdowsian *et al.* 1997).

Management of salinity and other soil degradation issues is a complex problem with almost two-thirds of the agricultural land in this region comprised of duplex soils, the remainder being a mixture of deep sands (i.e. sand plain) and heavy clays. Thus salinity and soil management in this region is one of the

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biggest challenges faced by farmers. Already many relatively small-scale farm enterprises in the Wheatbelt are finding it difficult to remain viable under the impacts of salinity, associated land degradation problems and commodity prices, and are on the verge of collapse. Amalgamation of farm properties is likely to increase, reducing the viability of rural communities as families leave the district. The problem of soil salinity and waterlogging threatens both the productive agricultural land and the rural infrastructure (rural towns, roads, rail etc.) that supports it.

Over the past 25 years, most of the research has been focused on quantifying the problem and finding agronomic and biophysical solutions for the remediation and management of salinity. The adoption rates of these recommendations within the dryland agricultural areas has been limited and has not been of sufficient scale to significantly impact upon the hydrology of catchments. There is a limited amount of literature on engineering approaches generally, and deep drainage specifically, as an approach to manage dryland salinity. The thrust of the research, on a global scale, has been aimed at irrigated drainage or wetlands drainage and associated salinity issues as opposed to the large-scale drainage of dryland agricultural areas affected by rising shallow saline groundwater tables. The drainage management techniques have been developed and applied extensively only for irrigated agriculture where there has generally been a high return on investment.

Revegetation strategies have been successful only at limited locations in the Wheatbelt. Farmers are now starting to employ engineering options as part of the on-farm soil and water management system (Coles *et al.* 1999) and revisit the designs and methods adopted in the past. The relatively rapid spread of salinity or saline affected lands in the last 20 years has refocused attention on the use of large-scale deep drainage to manage rising saline groundwater and perched aquifer systems. In recent years farmers in the Wheatbelt have started to re-evaluate the use of engineering options implemented during the late 1970's and early 1980's for the management of salinity and other water related degradation problems. This includes the use of earthworks (banks, surface drains etc.), deep drainage and groundwater pumping (including relief wells and siphons). The main aim of this paper is to assess drainage of valley floors in the Wheatbelt as a tool to manage salinity, highlight possible directions for further research into drainage and other integrated catchment management options.

HISTORY

Three main strategies are used in the wheatbelt for the management of saline groundwater. These include deep drains, pumping and relief wells. Other engineering options such as grade banks or interceptor drains are used at site-specific locations to manage surface or subsurface water. Large-scale deep drainage was initiated in the late 1970's in the Moora district (Coles *et al.* 1999) and was responsible for the popularisation of this method for salinity management. This led to the widespread construction of deep drains across the Wheatbelt with up to 29 sites being monitored and assessed in the localities near West Wubin-Watheroo region in the north, Narrogin-Wickpin area in the central region and near Esperance on the south coast. The initial results of these trials were reviewed by Nulsen (1983), who concluded that: "*theoretical studies followed by field verification should be undertaken to clarify the role of both underground and surface drainage*". This statement remains valid today with only limited projects being instigated to apply drainage theory and to assess the results of the implementation of large field trials at catchment scales.

Drains now exist in almost every catchment in the Wheatbelt and total some hundreds of kilometres in length, but are generally scattered, isolated and without extensive regional linkages. More farmers now see drainage as a viable alternative to re-vegetation strategies and the availability of information on the effectiveness, placement and design of drains is becoming critical. With the increased level of drainage, adequately designed and maintained regional drainage is likely to become necessary in order for drainage, and thus water management strategies, to be more effective.

PERFORMANCE

Many engineering options including deep open drains have been adopted in the wheatbelt of WA in the past decades. Some form of evaluation has been carried out on a few of them. In most cases individual farmers have carried out the performance evaluation by monitoring some parameters of their interest. State and local government agencies have also been increasingly involved in the evaluation of engineering options, particularly deep drainage and pumping. However, as is often the case, each evaluator may have a different scale for measuring the effectiveness of a particular drainage system and a different system for measuring success. For example, if after constructing a drain, an individual farmer is able to grow a crop in otherwise unworkable lands, he would conclude that the drain is working effectively. However, another measure of success could be the effective lowering of the water table irrespective of whether or not a crop is able to survive.

According to Speed & Simons (1992), a drain is termed ineffective if it does not lower the water table significantly and at a notable distance from that drain. Anecdotal evidence from various sites in the wheatbelt suggest that many drains in the wheatbelt valleys did not impact on the water table (*per se*) but had significant impacts on the period for which the areas were waterlogged and rate at which surface runoff was removed (Coles *et al.* 1999). A drainage option may be termed as effective if it enables the land to economically grow crops on a sustainable basis (irrespective of its impacts on the water table). Deep drainage is often not seen as a preferred tool to manage salinity, as it does not address the root cause, i.e. recharge. It is expensive, not always effective and has high risk factors associated with on-site and downstream impacts (Drainage Taskforce 2000). However, as recent studies have suggested, re-vegetation strategies are likely to have only localised impacts in the near future (George *et al.* 1999) with long term benefits for areas affected by regional groundwater systems to accrue over 100 years or more (Hatton & Nulsen 1999; Pannell 2001), drainage is more often than not seen as the 'quick fix' to the immediate salinity problem.

Past Research on Drainage

The research-based assessment of deep drainage in WA was instigated in the late seventies. Deep drainage, as a method for treating salt land, was assessed by Bettenay (1978) at farm scale level at the Yalanbee research station and by George (1985; 1991) in the Moora district. These investigations concluded that severely degraded land will take many years to reclaim - if at all - and that marginal or recently degraded land should be targeted for drainage. Three issues were identified as being critical to the success of drainage: (1) an assessment of the most likely impacts of a drain on the shallow and deeper groundwater table; (2) the disposal of drainage water, which may be highly saline; and (3) cost/benefit including construction, maintenance and return on investment. The first two are site specific whilst the third is likely to depend on personal choice and perceived net benefit. Despite problems such as relatively flat landscapes in the wheatbelt, deep drains are increasingly seen as a viable option in this region (Luke 2000).

Cox & McFarlane (1995) evaluated inverse seepage interceptor and other shallow drains in a number of sub-catchments at Mt Barker and Narrogin. The spacing of these drains varied between 70 and 140 m. They concluded that the drains helped in reducing waterlogging immediately downslope in 18 of the 21 transects in which the problem of waterlogging was present. There were similar reductions in waterlogging at both Narrogin and Mt Barker during wet years. Another drainage study at Bulyee (Berhane 1999) assessed that the shallow drains (less than 1.8 m), constructed on the lower slope and in valley near the break of slope in heavy clay soils, had no measured effects on salinity and a limited impact on waterlogging. Some leaching occurred in the upper perched system (20-40 cm bgl) but it was difficult to determine if salts were being removed from the deeper profiles. It was difficult to attribute the apparent changes in soil salinity and salt distribution to the construction of drain. These drains did not have any appreciable impacts on shallow water table and it was concluded that water in the drain was derived from surface runoff and subsurface flow from the perched aquifer system or via preferential pathways (Berhane 1999).

Coles *et al.* (1999) reviewed the efficacy of deep open drains in the wheatbelt. Their appraisal was based mainly on existing hydrological investigations and interpretations and anecdotal evidence from landholders. This review suggested that deep drains might reduce waterlogging and improve leaching and plant survival at distances greater than those predicted by drainage theory. They were of the view that improvements in the yields (recounted by farmers at some sites) were due to amelioration of waterlogging, the management of surface runoff and changes in the behaviour of water storage in the unsaturated zones. The location of the drains was considered an important factor, with drains constructed at the break of slope appearing to have a greater impact because of their location at the point of stronger upward flow. They concluded that a careful evaluation of the feasibility of drainage is required for each location and placement in the landscape was as critical a factor as design in determining the effectiveness of a particular drain.

Only limited in-depth scientific studies have been completed on drainage of dryland areas of WA. Large-scale drainage designs need to be evaluated at the catchment scale to ensure that the effectiveness and impacts of these systems are fully understood. Current studies on drainage address some of these issues. Guidelines, drafted after proper design evaluations, will help minimise sedimentation, erosion, maintenance costs and increase drain efficiency. Similarly positive or adverse impacts of drains on downstream farmers, wetlands, streams, and environment need to be addressed. However, the integration of surface water management strategies with other management options (e.g. trees, alternate-farming systems) are viewed as a vital part of the catchment planning process to reduce episodic and localised recharge and to manage catchment discharge.

Drainage Research in WA

Apart from some unpublished studies in the Moora District, most - if not all - of the evaluations of deep open drains, carried out in the wheatbelt in the past, were short-term, informal (occasional/unplanned), and based on monitoring of minimal parameters. Whereas to scientifically evaluate the impact of drains on crops, hydrology, soil root zone salinity etc. at farm, sub-catchment and catchment scale levels, long-term monitoring is required. Several large-scale drainage studies that address some of these issues are underway in the Wheatbelt (Narembeen, Jibberding, Beacon River and Dumbleyung). At Narembeen and Dumbleyung, similar parameters are being monitored to evaluate the performance of deep drains at farm and sub-catchment scale levels. Whereas a feasibility study of regional drainage is underway at Beacon River. A brief outline of the parameters being monitored and some of the initial results will be presented here from the Narembeen research project. The main aim of the Narembeen research project is to evaluate the impact of drains on crop productivity and environment at farm and sub-catchment scale level (Figure 1).

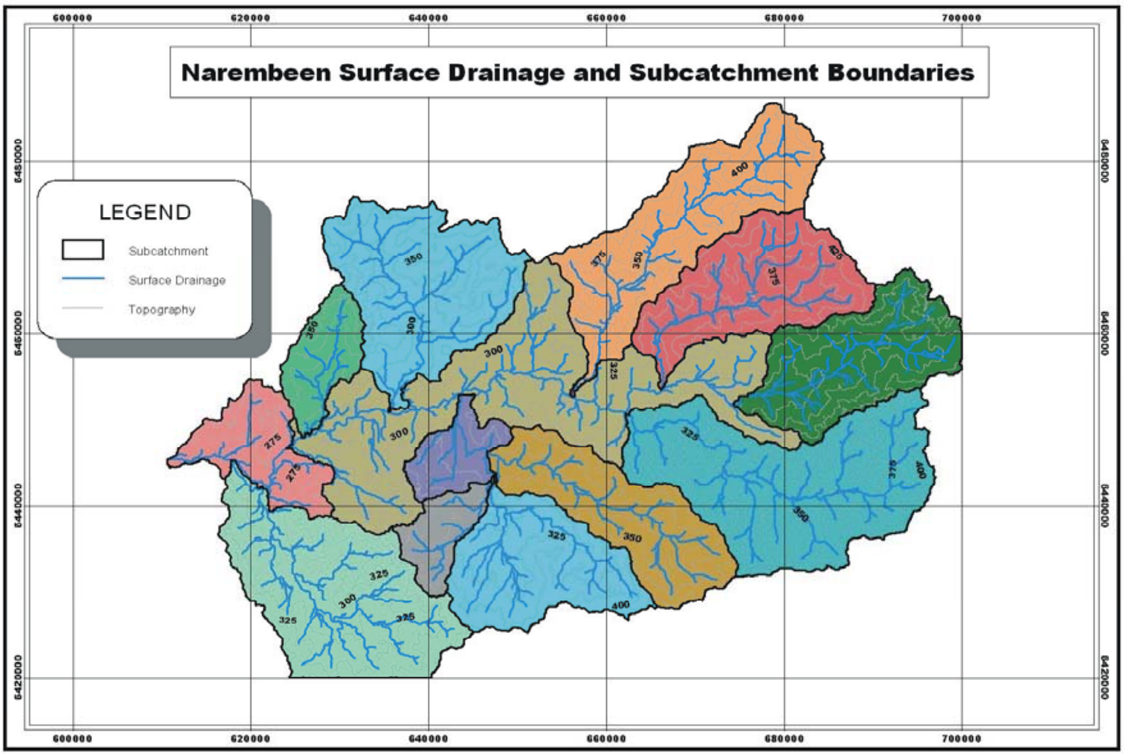

Figure 1: Wakeman sub-catchment and surface drainage boundaries (Narembeen)

Several sites that reflect the major representative landscapes evident at the sub-catchment level in the Wheatbelt were chosen. Drains with various design types and drain ages were selected and instrumented last year to evaluate the impact of drains on crops, shallow and deep groundwater, soil root zone salinity, regional hydrology and the environment. Similarly several sites were selected and instrumented in areas where the drains will be constructed in the near future. The monitoring of instrumented sites started last year and will continue for the duration of the project (approximately five years) in order to collate a long-term comprehensive suite of data on drainage performance. At this relatively early stage in the project only preliminary data and limited evaluation are available; however, trends in shallow and deep piezometers at various transects and sites, quality of water flowing in various drains, and water and salt outflow rate from the sub-catchment will be discussed.

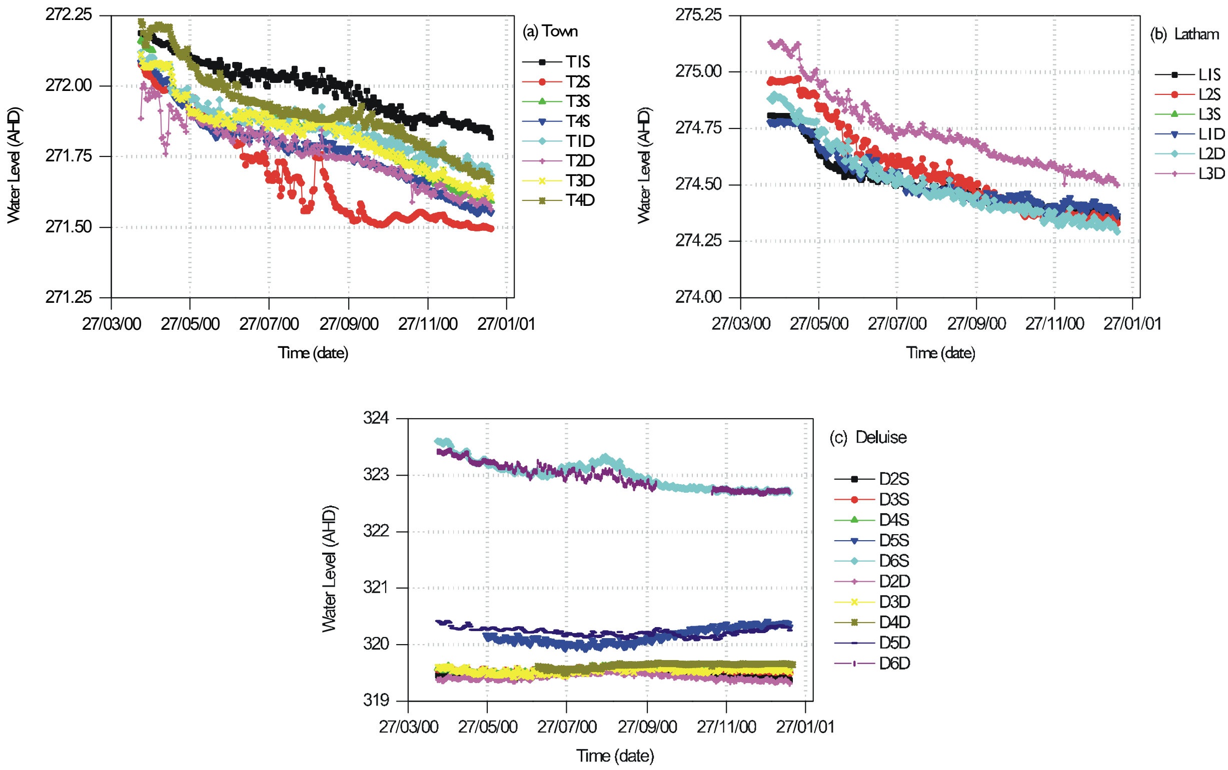

Figure 2: Temporal variation of water levels in shallow and deep piezometers at (a) town, (b) Latham and (c) Deluise sites (Wakeman sub-catchment, Narembeen).

Figures 2(a), (b) and (c) illustrate the temporal variation of shallow and deep water levels in piezometers at various sites with a water table decline evident at all sites except Deluise. The decline, although significant, may be related to a natural balancing of the system following an extreme episodic recharge event that occurred in January 2000. Continued monitoring over a longer time period will enable the impact of drainage on the system to be evaluated. Preferential flow, through lenses of porous material, was observed at various sites through visual observation and dye tests (Figure 3). This may explain the ability of seemingly low conductivity soils being able to transmit larger quantities of water than theory would suggest as summarised by Nulsen *et al*. (1986) and Berhane (1999) and may have contributed to the lowering of the water tables. There were rising trends in both shallow and deep water levels at the Deluise site (Figure 2(c)).

Figure 3: Lenses of porous material in clayey soil at Deluise site (Narembeen)

The drain at this site is not connected to the local natural creek line and therefore acts as an evaporation ditch. Rising water tables over time are expected under these conditions. The quality of water flowing in the drains declined as it moved towards the downstream end of the sub-catchment. The quality of water flowing in the drain at Pini was relatively fresher as compared to that flowing through the town of Narembeen. This is not an unexpected trend (Figure 4). The deterioration in the drain water quality at the Deluise site was considered to occur as a result of evaporation of water in the drain due to its isolation and role as a containment structure. Water flow and salt loads discharged from the main drain passing through the town of Narembeen varied between 10 and 15 ML/day and between 400 and 600 Tons/day respectively for the period of record (Figure 5). The rate of discharge and salt load changed drastically during and after the occurrence of significant rainfall events. The contributing area surrounding the drain is yet to be determined, and no valid conclusions can be drawn from these initial data as yet.

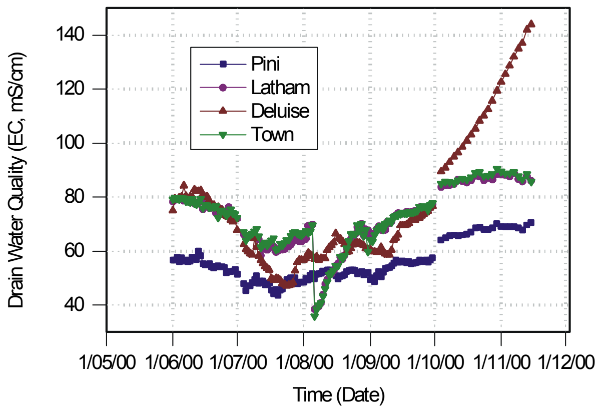

Figure 4: Temporal variation of water quality during 2000 in selected drains (Narembeen)

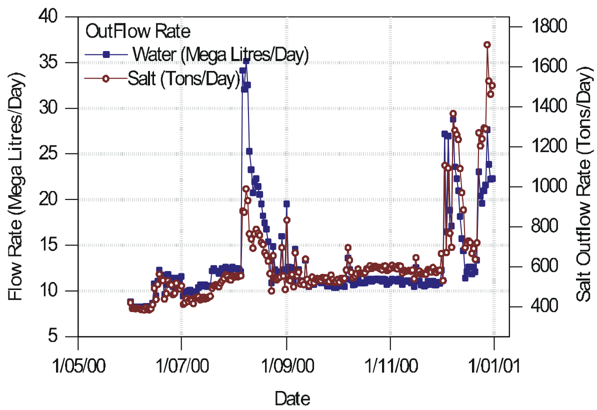

Figure 5: Temporal variation of flow and salt outflow from a main drain in the town of Narembeen (Wakeman sub-catchment)

Drainage Design, Construction and Maintenance

The design, placement and maintenance of drains are critical issues that should be considered in conjunction with environmental impacts. In general, the majority of deep drains constructed in the Wheatbelt are designed on the basis that they do not allow the entry of surface runoff. That is why only base flow is usually considered in the design of these drains. But due to poor protection against its entry, the surface runoff usually enters into these drains as a result of significant rainfall events. Velocities generated within these drains during heavy rains result in the undercutting of the drain slopes and washing of eroded material into the drains. This causes sedimentation and a drastic reduction in their effectiveness. Additionally, at locations where drains cross roads, the culverts are usually required. These are designed on the basis that the drains are for groundwater or baseflow only and, therefore, are incapable of managing excess surface runoff. This often causes extensive damage to both the drain and the road. Spoil bank slumping into the drains is another major cause of sedimentation (Figure 6).

Appropriate design and placement of the drain and spoil banks can minimise the amount of runoff entering the drain and reduce erosion. Drain embankments/spoil banks, shape, landscape location, compaction, angle of repose, soil type, gradient, velocity and carrying capacity are some of the factors that must be considered at the planning and design phase. The drain slope is another important design parameter as it determines the drain's stability and is likely to vary according to soil type based on light (sandy) to heavy (clayey) soils and it is considered best practice to determine the natural angle of rest for each location.

FUTURE DIRECTIONS

While there are a myriad of views about drainage and its effectiveness, there remains a limited amount of scientific research directed at the long-term effectiveness of such drains at local and catchment scales. Study sites like those at Narembeen and Dumbleyung are being designed and managed to answer the long-term questions about drainage efficiency; however, it may be some time (5-10 years) before there are adequate data to make informed decisions concerning deep drainage. Optimal management strategies can be recommended and applied only after the impacts of such strategies have been evaluated. However, it is incumbent on the researchers and organisations involved in these projects to ensure that data are passed on to the public, landholders and contractors in a timely manner to ensure that only appropriate practices are adopted and continued.

Figure 6: A main drain silted up due to spoil bank slumping and erosion

Other engineering options should also be considered and evaluated as part of an integrated approach to water management in wheatbelt landscapes. These include surface water control structures and groundwater pumping. For example, windmill/solar pumping may be considered as previous long-term windmill experiments have shown that under the right conditions pumping rates of 15-30 m^3/day can be achieved. In the experimental catchments examined, this resulted in a reduction of water levels by up to 2 m at radial distances of more than 1 km after several years of pumping (Salama *et al*. 1994).

A revised approach to water management, involving the use of earthworks to manage surface and shallow sub-surface water and re-distribute that water more evenly within the catchment, is being considered as a tool for recharge management. The methods proposed deal with managing: (1) surface water from upper and middle catchment into dams or discharge areas in lower catchment; (2) recharge in the upper catchment; and (3) the impact of waterlogging and salinity in broad valley floors. (Coles & Ali 2000). An integrated approach to catchment planning and water management in the landscape that includes re-vegetation options and farming systems is viewed as one of the most important aspects of salinity management.

CONCLUSIONS

Effective management of soil salinity and waterlogging is one of the biggest challenges currently faced by farmers in the Wheatbelt of WA. Agronomic manipulations have had only limited success and require long time frames and large areas to be managed under these systems. Engineering solutions have been increasingly seen as viable for the management of waterlogging and soil salinity in the Wheatbelt. Many farmers have constructed drains at various locations and landscapes in the Wheatbelt. However, there is a lack of formal evaluation of deep drainage which has made it difficult for agencies to provide a formalised set of guidelines for their construction, placement and effectiveness.

Only limited in-depth scientific studies have been completed on drainage of dryland areas of Western Australia. Large-scale drainage designs need to be evaluated at the catchment scale to ensure that the effectiveness and impacts of these systems are fully understood. Current studies on drainage address some of these issues. Guidelines, drafted after proper design evaluations, will help minimise sedimentation, erosion, maintenance costs and increase drain efficiency. Similarly positive or adverse impacts of drains on downstream farmers, wetlands, streams and environment need to be addressed. However, the integration of surface water management strategies with other management options (e.g. trees, alternate-farming systems) are viewed as a vital part of the catchment planning

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