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# **Rethinking the Externality Issue for Dryland Salinity in Western Australia**

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# **Rethinking the Externality Issue for Dryland Salinity in Western Australia**

## **Abstract**

Dryland salinity has been conceived of as a problem involving massive off-site impacts and therefore requiring coordinated action to ensure that land managers reduce those off-site impacts. In economic terms, salinity is seen as a problem of market failure due to externalities, including external costs from one farmer to another and from the farm sector to the non-farm sector. In this paper, we argue that, at least in Western Australia (WA), externalities are much less important as a cause of market failure than has been widely believed. If all externalities from salinity in WA were to be internalised, the impact of this on farm management would be small. There are a number of factors contributing to this conclusion, both hydrological and socioeconomic. Together, they mean that, relative to common belief, the true physical severity of externalities is diminished, and the economic significance of the remaining externalities is further diminished. This does not mean, however, that salinity is amenable to resolution in a free market, as there are other major causes of market failure, specifically public-good issues in research and development, and a range of problems related to farmer adoption of salinity treatments. Existing policies are not adequately addressing these market failures. Current misconceptions about the importance of externalities from salinity are themselves hindering progress in a number of ways.

## Introduction

“The fundamental underlying cause of dryland salinity is that the full impact of changed water balance is generally not experienced by those responsible for the imbalance and the resulting recharge of groundwater.” (Hayes, 1997, p. 10).

Hayes’ comment reflects a widespread belief about why dryland salinity has developed to such an extent in Australia and why farmers are still not adopting farming practices that would prevent its ongoing spread. One farmer’s management (or non-management) of salinity has impacts on others through movements of saline groundwater and/or saline discharge into waterways. Economists use the term “externalities” to describe these impacts of one economic agent on others. The impacts may be on neighbouring farms, natural ecosystems, rural towns, water resources, roads and other infrastructure. If farmers whose farms are the sources of salinity were to properly factor in these broader impacts, it is believed that they would act to prevent salinity to a substantially greater extent than they currently do.

The message of this paper is that externalities have been greatly over-emphasised in the shaping of salinity policy and extension in Western Australia, and that this has had some important negative consequences. This argument is advanced on several fronts. It is based on current hydrogeological knowledge, empirical evidence about the impacts of salinity treatments, socio-economic trends and some standard economic theory.

The paper is forward looking. We are not claiming that past land clearing and farming practices have not resulted in off-site impacts from salinity in Western Australia. We are claiming that (a) farmers can, in many circumstances, act to prevent salinity within their own farms without requiring cooperation from neighbours, and (b) an approach relying solely on “internalisation” of externalities will not substantially reduce the level of salinity occurring in

future. (To “internalise” an externality from salinity would mean providing an increased incentive to adopt preventative treatments, with the level of the increased incentive matching the external benefits that will result.)

## **The Issues**

### *1. Local aquifers*

The first issue is a simple and direct argument against the prominence given to farm-to-farm externalities; for a large proportion of the landscape, little groundwater moves across farm boundaries. Groundwater aquifers vary widely in size, shape and geological structure. Some, which are loosely termed “regional aquifers”, extend over large areas (tens of kilometres) and include multiple farms. On the other hand, “local aquifers” are structured such that the water that recharges<sup>1</sup> within the catchment will discharge within the same farm (say, one to three kilometres between recharge and discharge). Having discharged, the water normally enters watercourses which are generally water-gaining<sup>2</sup> streams and is of no further consequence for salinisation of land. Local aquifers tend to occur in relatively undulating landscapes where there are many discharge sites separating the areas of recharge. There is also an “intermediate aquifer” category (three to ten kilometres), in which groundwater is likely to cross a single farm boundary before discharging.

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<sup>1</sup> “Recharge” means that water infiltrates, moves down the soil profile and enters the water table. “Discharge” means that the water table meets the soil surface, such that water is lost from the water table and flows over the saturated soil surface.

<sup>2</sup> “Water-gaining” streams do not lose their waters into the ground.

Local aquifers are not rare or exceptional. Figure 1 illustrates the distribution of local catchments (lightly shaded), regional catchments (darkly shaded) and intermediate catchments within the Upper Pallinup Catchment (including part of the North Stirling Basin) of Western Australia, as identified by one of us (Ferdowsian). Even within the North Stirling Basin (in the lower-left section of the map), which is dominated by a regional groundwater system, there are pockets of local and intermediate systems.

(Figure 1 near here)

This result is not peculiar to the catchment and basin mapped in Figure 1. Table 1 shows estimates of the areas of the three aquifer types for around 2 million hectares of the southern part of Western Australia. Over half is classified as “local”.

(Table 1 near here)

The South Stirling area is an interesting example. It is flat and underlain by Eocene sediments but over a quarter of groundwater systems discharge into local lakes and creeks. This proportion will increase as further saline discharges develop and groundwater flow lines are diverted to these points.

Further, across the entire agricultural region of Western Australia, the proportion of the land surface that is located above local aquifers is substantial, with estimates ranging from 30 percent (Richard George, pers. comm., 1999) to 50 percent or more.

An important consequence of recognising that an aquifer is local rather than intermediate or regional is that it removes some disincentives for farmers to implement salinity treatments. The disincentives may include concern that a treatment will be ineffective because of the actions (or inaction) of neighbours, and concern that the benefits of a locally implemented

treatment will be captured by a neighbour rather than the investing farmer. Of course, removal of these disincentives does not guarantee that farmers will decide to implement treatments as this decision depends on many additional issues.

## *2. Low transmissivity*

Even in regional aquifers, it is possible for treatments to be effective locally, at least temporarily. Typically, soils in the large wheatbelt valleys of Western Australia, which are archetype regional aquifers, have low “transmissivity”, meaning low potential for water to pass through them. This, combined with the very low slopes typical of these large valley systems, means that lateral water movement is very slow indeed.

To illustrate, it is estimated that it would take 3000 years for groundwater to move from the top of the Merredin catchment to Merredin town (Matta, 1999). Clearly, the only land that has contributed groundwater directly to Merredin town site in the 100 years since the region was developed is land in or close to the town site. It is true that water pressure can be more readily transmitted over long distances, even without physical water movement, but in most cases, the more important issue is local increase in recharge due to removal of native perennial vegetation in and around the town site. Thus, on short time scales, salinity in these large regional aquifers is effectively a one-dimensional problem, with changes in groundwater levels depending primarily on recharge at that site. Indeed, hydrologists recommend that the most important and effective treatment for preventing salinity damage within town sites is reducing recharge within the town site (Ferdowsian and Ryder, 1997, 1998), and/or enhancing discharge in and around the town by engineering treatments, such as pumping (Matta, 1999). It is believed that, in most cases, benefits from revegetation of surrounding farm land will be insufficient and/or too slow to prevent major damage to town infrastructure.

For towns such as Merredin, which have fresh water piped to them for domestic use, the problem is exacerbated by release of this imported water into the ground from garden irrigation systems or septic tanks. For some towns in Western Australia (e.g. Cranbrook, Tambellup), imported water and runoff from roofs and roads accounts for a substantial part of the groundwater rise within the town.

Low water movement in broad regional aquifers also has implications for the protection of agricultural land. Treatments implemented in the broad valleys have the potential to be locally effective. Although the protection should be considered temporary in most cases, the time scale over which it will remain effective can often be long on the time scale of farm business planning.

This positive aspect of low transmissivity is matched by a negative; the distance that positive effects may extend away from land on which treatments are implemented is also likely to be very small. A recently published review of field measurements of impacts of trees concluded that measurable impacts at a distance of greater than a few tens of metres away from the trees were very rare (George et al., 1999). Similarly, deep open drains that have been installed by some farmers to enhance discharge have been found to reduce groundwater levels within only a few metres of the drain on high-clay soils and rarely more than 40 metres on the most favourable soils (George, 1985; George and Nulsen, 1985; Speed and Simons, 1992; Ferdowsian et al. 1997). To put this in perspective, the dimensions of farms in the wheatbelt of WA are measured in kilometres.

Salerian et al. (1989) and Salerian (1991) were the first to highlight the economic importance of the ratio of land area protected from salinity to land treated, and to identify the adverse magnitude of this ratio in the WA wheatbelt. They developed a simple model of profits gained



and profits foregone from changing land-use to an enterprise that reduces the rate of increase of salinisation but has lower direct profits. They concluded that, in many cases, the ratio of recharge area treated to reduced rate of salinisation (ha/year) is several thousand, making it uneconomic to switch to an enterprise that has even slightly lower direct profits than the current land use.

At least in Western Australia, it appears that it is rarely possible to implement treatments that protect much more than the land on which they are situated. This information requires us to fundamentally re-think the nature of the salinity abatement problem.

### *3. Persistence of salinity in waterways*

Regardless of the type of aquifer, discharge of saline waters into streams and rivers clearly does impose external costs on others in the community by (a) damage to ecosystems and biodiversity in these waterways and (b) in some cases, loss of potable water resources (e.g. the Kent River in Western Australia). However, in this case the issue is whether on-farm treatments can provide any significant reduction in the off-farm costs. Unfortunately it appears that at least in Western Australia, river salinity is highly unresponsive to revegetation of the surrounding catchment (e.g. Bari, 1998). Even with levels of revegetation in a catchment sufficient to protect much land that would otherwise be lost, discharge into streams and rivers in the catchment would in many cases continue to be saline. Hatton and Salama (1999) review the issue and conclude that, “Catchment scale remediation via revegetation, even extensive revegetation, will have only minimal effect in reversing salinity trends in the foreseeable future.” Similarly, Hatton and Nulsen (1999, p. 212) conclude that, “the control of salt loads to Australia’s major southern river systems may take hundreds of years to achieve following revegetation.”

This means that even if farmers were to factor in additional benefits from revegetation resulting in protection of waterways, the magnitude of these additional benefits would be very small and therefore unlikely to alter farmers' management. The benefits are small not because the impacts of salinity are small, but because revegetation has little impact on the level of river salinity.

Of course this is a generalisation that will not be true in every instance. For example, the Denmark River in Western Australia was under threat prior to the development of the blue gum industry. Now much of its upper catchment has been planted to blue gums and the long-term salinity threat to the river has been dramatically reduced if not removed (at least while the blue gum industry persists).

Currently the cleared upper part of the Kent Catchment contributes 30 percent of the water but 70 percent of the salt that reaches the lower part of the catchment where a dam is proposed. Current strategies aim to dry out the upper catchment as much as possible so that the fresher water that is contributed by forested high rainfall areas is not compromised.

As with land salinity, local treatments (of an engineering nature) are likely to be more effective against river salinity than remote treatments higher in the catchment. For example, groundwater interception schemes were installed in the 1980s in the lower Murray (South Australia) to intercept brine about to enter the river and put it into evaporation basins. Although expensive, such schemes appear to offer the prospect of some reduction in river salinity (Tom Hatton, pers. com., 1999). Whether the expense is warranted is another question.

A related concern is a predicted increase in the frequency and severity of flooding, as illustrated in 1999 by the occurrence of three floods in the WA town of Moora. Each of the

three floods was of a severity classified as a one in 100 year event. The increased flood risk occurs primarily because of the increased run-off from salinised farm land. No doubt the external costs of this flooding are very high. However, the total expense of treating farm land at a sufficient scale to reduce the flood risks would be so large that we may be better off just putting up with the flood costs, trying to minimise them by engineering works in areas of high value and high risk.

#### *4. Consolidation of farms*

Average farm size has grown steadily over time and continues to do so. In recent decades, the predominant cause has been consolidation of farms. For example, in Western Australia, the number of grain, sheep or beef farmers fell from 13,041 in 1983/84 (Bartlett, 1986) to 10,702 in 1995/96 (Nagle, 1998), without any reduction in area farmed. As this process continues, it is increasingly likely that discharge and recharge sites occur within the same farm. In other words, fewer farmers are suffering from saline discharge that originated outside their own farm.

#### *5. Discounting of distant future benefits*

One interpretation of the findings of George et al. (1999) that measurable benefits of treatments do not extend over large distances is that the processes are slow and that distant benefits may eventually be observed. Even if this (probably optimistic) position is true, the economic significance of these benefits will be relatively low due to the impact of discounting. Discounting is employed by economists to allow valid comparisons of benefits and costs that occur at different times. Discounting means that benefits occurring in the distant future carry little weight in present calculations.

There is controversy over the rate of discounting that should be applied to long term benefits, although there is apparently near-consensus among leading economists that some positive rate, low but greater than zero, should be used (e.g. Portney and Weyant, 1999). Even low discount rates will mean that future benefits are reduced relative to current costs, and thus will reduce the significance of any external benefits from treatments that are implemented. Although this does not eliminate externalities from the equation, it combines with the other factors discussed here to reduce their significance.

## *6. Balancing costs and benefits of salinity treatments*

The basis for blaming externalities for the development and persistence of dryland salinity is the idea that individual farmers acting in their own self interest are not likely to properly weigh up the impacts of their actions on others. If they were to do so, the argument goes, they would do more to prevent off-site salinity impacts originating on their farms. It does not necessarily follow that all salinity would be prevented, but it would mean that a balance would be struck between the costs and benefits of salinity prevention, and this balance would reflect both individual and broader community interests. The optimal balance would result from internalising any externalities (assuming there are no other causes of market failure – see later).

Potential policy approaches to achieving such a balance include (a) systems of taxes and/or subsidies instituted by government in order to provide farmers with appropriate incentives, and (b) an approach based on defining and enforcing property rights, so that winners and losers can negotiate a mutually acceptable outcome (e.g. a tradable pollution permits systems). Using mechanisms such as these, externalities would probably not be eliminated, but would be reduced in severity to the extent warranted by the benefits and costs (both

private and public<sup>3</sup>) of their removal.

A problem with approach (b) is that, given the long time scales involved in salinity and the irreversibility of much of the damage, some of the losers are not able to be parties to the negotiations – their losses are in the distant future, and the individuals in question may not even have been born yet.

With both approaches, given current technologies, the optimal balance between the costs and benefits of salinity prevention may involve very little prevention or abatement of salinity.

This can readily be seen from the following summary of the issues:

- (a). The primary method available to farmers for prevention of salinity off-farm is the establishment of perennial vegetation.
- (b). Perennial vegetation in most situations mainly protects the land on which it is located, with little benefit for surrounding land.
- (c). Establishment of perennial vegetation is expensive.
- (d). In addition to establishment costs, farmers bear an opportunity cost of income foregone on the land converted to perennials.
- (e). In combination, (a) to (d) imply that in most cases, for establishment of perennials to be *socially* optimal (i.e. even considering broader off-site impacts), the perennials need to generate a direct benefit, such as from a harvestable product.

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<sup>3</sup> Transaction costs of monitoring and enforcing such systems impose an additional complexity that may compromise their ability to achieve this ideal result.

(f). Current perennial options available for most agro-climatic zones are, at best, marginally unprofitable and at worst highly unprofitable. Their degrees of unprofitability vary widely between regions and between soil types in each region.

When this set of issues is considered, it becomes clear that the main problem preventing reductions in salinity is not the existence of externalities, but rather the non-existence of sufficiently profitable perennial plants. On land types where there exist perennial plant options that are more profitable than current landuses (e.g. Tasmanian blue gums, *Eucalyptus globulus*, on suitable soils near the south coast of Western Australia) no further government intervention for salinity prevention is necessary.

The point is that internalisation of externalities would provide farmers with an additional incentive to abate salinity, but that this incentive is just one of the incentives that they face. Whether or not the additional incentive is enough to change farm management depends on the private benefits and costs involved in the change. For example, if a salinity abatement practice is already profitable to the individual farmer, internalising externalities may make little difference to adoption of the practice, apart from speeding the adoption process somewhat. Conversely if a practice is highly unprofitable (e.g. non-commercial trees in the wheatbelt), internalising externalities will not increase adoption unless the reduction in external costs that can result from the farmer's treatment is sufficiently high. The information presented here indicates that the likely reduction in external costs is small in most cases.

We have seen that there are three distinct hydrology-related reasons why the reductions in external costs that can result from Western Australian farmer's treatment of salinity are often not high:

(a). The land is in a local catchment, so that there are no externalities from salinisation of

other land,

- (b). The physical distances over which treatments are effective are usually a very small proportion of typical farm dimensions, even in large regional catchments, and
- (c). On-farm treatments seem to have little potential to prevent river salinity.

Given these physical realities, there is only one situation in which internalisation of externalities can make a difference to optimal decisions about a salinity treatment. It would be where on-farm treatment profitability is slightly negative before the externalities are considered. In that case, internalisation of the externalities would convert the salinity treatment from being slightly unprofitable to slightly profitable. This clearly would apply only in a small minority of cases.

## **Exceptions**

One of the general messages of the paper so far is that farmers internalisation of externalities from dryland salinity would make little difference to the farm management decisions of most farmers in Western Australia. There will clearly be exceptions to this generalisation. We have already noted that for at least some rivers, revegetation of the catchment can be effective at salinity prevention in the long term. If such rivers have sufficiently high value (e.g. ecological or for human water consumption) then the incentives provided by internalisation of these values into the farmers' decision making may be sufficient to prompt radical changes in farm management. Similarly high-value public or environmental assets on threatened land may, in some circumstances, clear the necessary double hurdle: sufficiently high value of the assets under threat, and sufficiently high impacts of on-farm treatments on off-site assets.

The possibility of clearing these hurdles may be enhanced if impacts of environmental damage on future generations are weighted sufficiently highly in current calculations. As noted earlier, the normal practice in economic evaluations is to discount benefits and costs to an increasing extent further into the future. Although discounting at commercial rates is a sound and logical practice in the short to medium term, there is concern and uncertainty about discounting for the very long term (Portney and Weyant, 1999). If an approach based on rights of future generations or on the precautionary principle is adopted, future benefits would be weighted more highly than implied by standard discount rates, and it may be considered worthwhile revegetating farms despite the issues raised here. However this possibility raises the following points:

- (a). Such an approach is rather different to the way that salinity is currently widely perceived as an externality problem involving different members of the current generation.
- (b). It would require current generations to be willing to provide to farmers sufficiently strong incentives to act in ways that promote the interests of future generations.
- (c). Even in the very long term, the hydrogeological evidence and modelling seems to indicate that on-site engineering works are often more cost-effective methods of protecting public assets from salinity than large-scale revegetation of farm-land.

Finally, one of the reasons for discounting the importance of externalities is the hydrological reality that on-farm treatments are often of very limited value in protecting off-farm assets. However, there may be externalities from degradation of farm land, even if the physical effects are strictly constrained within the farm boundary. Reasons include:

- Many members of the community (both agricultural and non-agricultural) subscribe to a



land conservation ethic, over-riding mere financial considerations. They grieve at the prospect of millions of hectares of land being more or less permanently lost to salinity and would be willing to see public funds spent to prevent this, even if strictly financial calculations did not support it. Underlying reasons may include attitudes that productive agricultural land is in some sense fundamentally important, or concerns about the aesthetic appearance of salinised land.

- Further declines in rural prosperity due to salinisation of agricultural land will have negative consequences for the social fabric of rural WA. Consequences for mental and physical health, welfare, employment and rural infrastructure (both social and physical) can easily be anticipated.

It is unclear whether the external benefits from reducing these non-physical impacts would be sufficient to justify more positive decisions about on-farm treatments. In some cases, it may be, but we judge that in most threatened areas in WA, the very adverse profitability of current perennial plant options is likely to pose too great an impediment.

### **If Externalities Are Not Important, What is the Problem?**

If it is accepted that a proper balance between the costs and benefits of salinity treatments reflecting both individual and broader community interests would not greatly alter current land management practices, one may ask whether there is any need for government intervention to address dryland salinity. (In economic parlance, where is the market failure that would be necessary to justify government involvement?)

There are two aspects of the salinity issue for which there is a *prima facie* case for an

interventionist government policy to overcome market failures.

(a). *The public good nature of research and development.* The non-excludable nature of results from R&D is well recognised as an argument for government involvement in the conduct or facilitation of R&D. Because private R&D organisations are unable to capture enough of the benefits that result from their work, they do not have sufficient incentive to conduct all the R&D that would be desirable from a broad social perspective. The disincentive is compounded in the case of salinity because of the high risks and very long time scales involved in the R&D. These would interact with differences in discount rate between private firms and a community concerned with “sustainability” to mean that private R&D firms would under-invest in salinity. In particular it appears that they have under-invested in development of perennial plant types for profitable on-farm production, and that Australian governments have also failed to adequately resource this need.

(b). *The adoption problem.* In cases where viable treatments for salinity problems exist, there can still be formidable problems achieving high levels of adoption of the treatments. The market failure here arises from the existence of uncertainty and misinformation. Pannell (1999c) argued that the adoption problem for salinity treatments is more difficult than for other types of agricultural innovations. Speed of adoption is affected by social (Vanclay, 1997), informational (Marsh et al., 1999; Pannell, 1999a) and economic (Lindner, 1987) factors, and each of these aspects seems to be unusually adverse to rapid adoption of salinity treatments. Kington and Pannell (1999) provide evidence on farmer perceptions about each of these aspects for farmers in a particular catchment in Western Australia. These issues point to extension as a potential means of reducing the degree of market failure.

## Implications for Policy

It seems that we need to recast the salinity problem from a policy perspective, at least for Western Australia. Externalities appear to have contributed to development of the problem, but internalising the externalities at this point will make relatively little contribution to reducing the extent of off-site salinity impacts in future. Consider in this light the broad approaches to salinity policy that have been used in the past or that are canvassed in current policy discussions.

(a). *Landcare*. The National Landcare Program has been widely criticised for failing to deliver substantial improvements to dryland salinity (e.g. Lockie and Vanclay 1997). Given the technical and economic nature of the salinity problem in Western Australia, its failure in this regard is not at all surprising in that state. Criticism should be directed not at those implementing the program, but at those who conceived that a program based mainly on extension and social processes could make significant impacts on salinity in WA. Recognition of externalities seems to have played some part in choosing this approach, but this now seems misguided.

(b). *Integrated catchment management*. The concept that most (or even all) farmers must collaborate and coordinate their actions to defeat salinity has gained a strong hold on the collective conscience of many farmers and of most professionals working in agriculture-related areas in Western Australia. The strength and common-ness of this belief is astonishing given the proportion of land for which it is actually untrue (in terms of managing groundwaters as distinct from managing surface waters and nature corridors which do require a collaborative approach). To the extent that it is falsely held by farmers, the belief potentially has an important negative consequence. Given the difficulty of

achieving a collaborative and coordinated approach in practice, the belief that it is necessary to do so provides a disincentive for farmers to act individually to address salinity on their own farms. This disincentive may arise even though in most situations on-site treatments are by far the most effective option and may often be the *only* potentially effective option. The mistaken belief has also constrained thinking about policy measures that can be effective against salinity, apparently deflecting attention away from approaches designed to be effective on an individual farm basis. This does not mean that catchment groups are unhelpful for other purposes, such as coordination of surface water management, or sharing information and experience. They will also be useful for groundwater management in catchments with significant intermediate and regional aquifers, subject to there being potential in these catchments for treatments to be effective at a distance in a relatively short time.

(c). *Institutional arrangements*. The search for an effective weapon against salinity has recently turned attention towards options that could broadly be grouped under the heading of institutional arrangements (using the term in the very broad sense adopted by economists to mean not just organisational structures, but also the full range of laws, regulations, taxes and subsidies). There may be inflated expectations about the potential effectiveness of this group of options, as we have seen for other policy approaches in the past. If the concept is that changes in institutional arrangements will help by internalising externalities (as envisaged, for example, by the Industry Commission, 1997), then the approach seems destined to have very limited success in Western Australia. It appears that in most situations, with current technologies, the extra incentives that would need to be provided to farmers to achieve widespread adoption exceed the external benefits that would result.

(d). *Research*. There has been an emphasis in past research on understanding processes of salinisation. R&D to develop profitable new farming options based on perennial species has been under-resourced given its obvious importance. We now have a good understanding of salinity processes, but are a long way from having profitable perennials for all the farming situations where they are needed. Recent funding has started to rectify this situation.

This review points to the need for two important policy initiatives.

(a). Greater investment in development of profitable agricultural systems based on perennial plants.

(b). Extension to dispel myths and misunderstanding about the physical nature of the salinity problem and to inform farmers which of their land is underlain by local, regional or intermediate aquifers. It is likely that many will have land in more than one category. Farmers need to be made aware (where it is true) that they can act unilaterally without fear that their efforts will be thwarted by an influx of groundwater and salt from off the farm.

## **Conclusion**

We emphasise that we are not attempting to claim that saline groundwaters never cross farm boundaries. (Indeed where large faults and shear zones are important groundwater movement can even transcend surface water catchment boundaries – Clarke, 1998). Instead, our objective is to move general perceptions towards a more balanced and realistic view of the importance of externalities from salinity. Externalities are not the essence or the defining characteristic of the salinity problem in Western Australia. To the contrary, for a combination of hydrological and socio-economic reasons, they are of secondary importance in our overall

efforts to reduce the future extent of salinity.

Finally, some assessment of the extent to which these points are relevant in states other than Western Australia would be desirable. Even if they only apply to a minority of areas, it is important that any misconceptions about the universality of externality problems are not allowed to persist. Although we have only made the case for Western Australia, this state contains by far the majority of the existing salinity in Australia, so our arguments are highly relevant to national salinity policy.

## References

- Bari, M. (1998). Reforestation reduces ground water level and stream salt load. In: Nico E. Marcar and A.K.M. Afzal Hossain (eds). *Managing Saltland into the 21st Century: Dollars and Sense from Salt. Proceedings of the 5th National Conference on the Productive Use and Rehabilitation of Saline Land, Tamworth, 9-13 March*. National Committee for the Productive Use and Rehabilitation of Saline Land, Canberra, pp. 38-46.
- Bartlett, W.M. (1986). *Western Australian Year Book No 24 – 1986*, Australian Bureau of Statistics, Western Australian Office, Perth.
- Clarke, C.J. (1998). The Impact of Geology on Dryland Salinity, and the Development of Revegetation Strategies, in the western wheatbelt of Western Australia. PhD Thesis, Murdoch University.
- Ferdowsian, R. and Ryder, A.T. (1997). *The Salinity and Hydrology of Cranbrook*. Resource Management Technical Report 170, Agriculture Western Australia, South Perth.
- Ferdowsian, R., Ryder, A. and Kelly, J. (1997). *Evaluation of Deep Open Drains in the North*

- Stirlings Area*, Resource Management Technical Report 161, April 1997, Agriculture Western Australia, South Perth.
- Ferdowsian, R. and Ryder, A.T. (1998). *Salinity and Hydrology of the Tambellup Townsite and Jam Creek Catchment*. Resource Management Technical Report 172, Agriculture Western Australia, South Perth.
- George, R.J., Nulsen, R.A., Ferdowsian, R. and Raper, G.P. (1999). Interactions between trees and groundwaters in recharge and discharge areas - a survey of Western Australian sites. *Agricultural Water Management* 39: 91-113.
- George, P.R. (1985). Drainage prospects of saline wheatbelt soils, *Journal of Agriculture, Western Australia* 26(4): 109-111.
- George, P.R. and Nulsen, R.A. (1985). Saltland drainage: Case studies, *Journal of Agriculture, Western Australia* 26(4): 109-111.
- Hatton, T.J. and Nulsen, R.A. (1999). Towards achieving functional ecosystem mimicry with respect to water cycling in southern Australian agriculture, *Agroforestry Systems* 445(1-3): 203-214.
- Hatton, T. and Salama, R. (1999). Is it feasible to restore the salinity affected rivers of the Western Australian wheatbelt? In: I. Rutherford and R. Bartley (eds.) *Proceedings of the 2<sup>nd</sup> Australian Stream Management Conference, Adelaide, 8-11 February 1999*, pp. 313-318.
- Hayes, G. (1997). An Assessment of the National Dryland Salinity R, D & E Program, LWRDC Occasional Paper No 16/97, Land and Water Resources Research and Development Corporation, Canberra.
- Kington, E.A. and Pannell, D.J. (1999). Dryland salinity in the upper Kent River catchment of

- Western Australia: Farmer perceptions and practices, *Journal of Environmental Management* (submitted).
- Lindner, R.K. (1987). Adoption and diffusion of technology: an overview, In: *Technological Change in Postharvest Handling and Transportation of Grains in the Humid Tropics*, B.R. Champ, E. Highley and J.V. Remenyi (eds.), ACIAR Proceedings No. 19, pp. 144-151.
- Marsh, S.P., Burton, M.P. and Pannell, D.J. (1999). Understanding monitoring of "sustainability indicators" by farmers: A case study of groundwater monitoring under threat of dryland salinity, Presented at COMLAND, University of Western Australia, Nedlands, 21-25 September 1999.
- Matta, J. (1999). *The Rural Towns Program, Groundwater Modelling, The Merredin Catchment*, Agriculture Western Australia, unpublished report.
- Nagle, C. (1998). *Western Australian Year Book No 34 – 1998*, Australian Bureau of Statistics, Western Australian Office, Perth.
- Pannell, D.J. (1999a). Uncertainty and Adoption of Sustainable Farming Systems, Paper presented at the 43rd Annual Conference of the Australian Agricultural and Resource Economics Society, Christchurch, New Zealand, January 20-22 1999.
- Pannell, D.J. (1999b). Social and economic challenges in the development of complex farming systems, *Agroforestry Systems* 45(1-3): (in press).
- Pannell, D.J. (1999c). Explaining non-adoption of practices to prevent dryland salinity in Western Australia: implications for policy. Paper presented at COMLAND Conference, University of Western Australia, Nedlands, 21-25 September 1999.
- Portney P.R. and Weyant J.P. (eds) (1999). *Discounting and Intergenerational Equity*,



- Resources for the Future, Washington D.C.
- Rogers, E.M. (1995). *Diffusion of Innovations*, 4<sup>th</sup> edition, Free Press, New York.
- Salerian, J.S. (1991). Economic Analysis of Soil Salinity in a Sub-Catchment in Western Australia, Thesis (Ph.D.), University of Western Australia, Nedlands.
- Salerian, J.S., McFarlane, D.J. and Bathgate, A. (1989). The Economics of Manipulating Recharge by Economic Means, Technote 9/89, Western Australian Department of Agriculture, South Perth.
- Speed, R.J. and Simons, J.A.S. (1992). Deep Drains – A Case Study and Discussion. Division of Resource Management Technical Report 133. Department of Agriculture Western Australia, South Perth, 12 pp.
- Vanclay, F. (1997). The social basis of environmental management in agriculture: A background for understanding Landcare, In: S. Lockie and F. Vanclay (eds.) *Critical Landcare*, Key Papers Series 5, Centre for Rural Social Research, Charles Sturt University, Wagga Wagga, 9-27.

Table 1. Areas ('000 ha) of different aquifer types in southern Western Australia

Region	Type of aquifer			Total
	Local	Intermed- iate	Regional	
Frankland-				
Gordon	282	50	41	374
Upper Kent	51	27	19	97
Western South				
Coast	79	8	34	122
Western				
Fitzgerald				
Biosphere	437	62	58	557
North Stirling	29	28	125	182
South Stirling	161	208	238	608
Total	1039	384	516	1939
	54%	20%	27%	

Source: estimates made by Ferdowsian

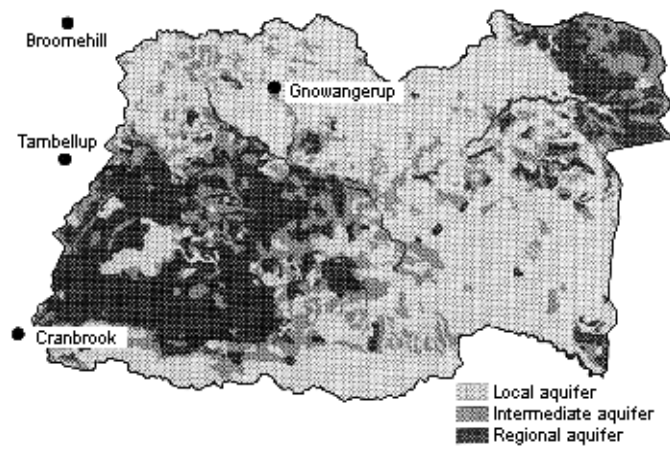


Figure 1: Distribution of local, intermediate and regional aquifers in Upper Pallinup Catchment

(Note: a better quality figure will be provided on acceptance).