The Effect of Management on the Extent, Timing and Severity of Salinisation; and the Economics of Dryland Salinity in Western Australia

The Impact of the Salinity Action Plan 2

A Report to the State Salinity Council by the Salinity Council Research and Development Technical Committee

16th June 1999

The Salinity Council's Research and Development Technical Committee

The R&D Technical Committee is a standing committee of the State Salinity Council reporting to the Salinity Council's Research and Development Steering Committee. This latter Committee was formed in early 1998 to anticipate future funding opportunities coming from the second phase of the National Dryland Salinity Program (NDSP), the rewriting of the Salinity Action Plan and the National Land and Water Resources Audit (NLWRA). The Committee's role was to oversee a review of salinity research and development needs for the state and to promote a cross-agency approach to seeking funding for priority areas.

To further this role the Research and Development Technical Committee was formed with representatives from Agriculture Western Australia (Don McFarlane – Chair, Bob Nulsen, Richard George, Ed Barrett-Lennard, Mike Ewing, David Tennant and Alan Lymbery), the Department of Conservation and Land Management (John Bartle, Ken Wallace, Greg Keighery and Richard Harper), the Water and Rivers Commission (Geoff Mauger, Viv Read, John Sutton and John Ruprecht), the University of Western Australia (Keith Smettem, David Pannell, Ted Lefroy and Sally Marsh - Executive Officer), Murdoch University (Christopher Clarke, Sue Moore) and CSIRO (Tom Hatton).

The R&D Technical Committee has produced a *Review of Salinity Research and Development in Western Australia* and meets on a regular basis to facilitate the coordination of salinity research across discipline areas and institutions. The *Review* is available on the AGWEST web site - www.agric.wa.gov.au/programs/srd/south_coast/salinity.

Members of the Research and Development Technical Committee are involved in a more detailed evaluation of the costs and benefits of intervention to reduce salinisation in the Great Southern. Results from this project (Salt Scenarios 2020) will be available in about March 2000. These results will be used to update the current estimates in this report and in a revised Situation Statement which will be produced when the Land Monitor Project is completed in December 2000.

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Executive Summary

As part of revision of the Western Australian Salinity Action Plan 2, the Salinity Council requested an analysis of various levels of management intervention on the ultimate extent and timing of salinisation. Additionally, it was requested that comment be made on the estimated costs of salinity as used in the Salinity Action Plan. The Salinity Council's Research and Development Technical Committee was commissioned to undertake and report on this project by June 16, 1999. Scientists from the CSIRO, Murdoch University and Agriculture Western Australia undertook the work on behalf of the Technical Committee.

The terms of reference for the study were as follows:
1. Estimate the impact of the current Salinity Action Plan on the eventual area of salt-affected land and delays in its development as compared with a do-nothing case.
2. Estimate the effects of different reductions in recharge on the area likely to be affected and delays in its development. Note what methods would be required to achieve each reduction.
3. Estimate the different severity categories of salt-affected land through time.
4. Examine the current estimates of salinity costs that appear in the Draft Update, and ensure that they are reasonable.

The results of the analyses undertaken by the R&D Technical Committee to address these terms of reference are reported in this document under the following headings.

1. The effect of recharge management on the extent and timing of dryland salinity in the wheatbelt of Western Australia

The future development and extent of groundwater discharge (equivalent to surface salinity) was estimated for a number of catchments and hillslopes across the wheatbelt through application of a simple groundwater model. This model used the best available hydrogeological, hydrological and topographic data. The assumptions of the model are robust and documented.

The results of the modelling show that except for the steepest or uppermost portions of our landscape, it appears that the original Salinity Action Plan 2 underestimated the general level of salinity at its ultimate extent. Much of our landscape is extremely vulnerable to salinisation at present rates of recharge.

More specifically, the ultimate extent of salinity is generally insensitive to marked reductions in recharge. For the majority of our landscape, reductions in the order of 50% are necessary to reduce the potential area salinised. Management interventions as described in Salinity Action Plan 2 may not be sufficient to reduce recharge by 50%. We equate this level of intervention with only the most optimistic levels of revegetation with perennials and probably associated engineering solutions.

There is some indication that we can characterise the relative responsiveness of catchments to treatments in terms of their shape, for indeed some portions of the wheatbelt appear to respond more favourably to recharge control. Nevertheless, we emphasise that only a widespread and rapid adoption of treatments will return substantial benefits in the ultimate extent of salinity.

Perhaps more optimistically, reductions in recharge rate will buy time. Generally speaking, a 50% reduction in recharge may buy 20 to 60 years before the ultimate extent of salinity is realised. At the upper end of this range, this may be enough time to either adjust to, or otherwise mitigate, the impacts. At the lower end of this range, the time required to implement such dramatic changes in management may be of the same order as the time potentially bought by that intervention.

2. Assessment of areas of saltland suitable for productive use in the wheatbelt of Western Australia

There have been no previous studies of the capability of saltland in WA. Such an understanding is essential if we are to avoid situations where farmers invest in revegetation, only to have this work eventually fail. We are of the view that saltland should be divided into three general capability classes; that of 'low', 'moderate' or 'high' productive potential.

Salt-affected lands that are clays, shallow duplexes, shallow sands and loams are likely to have 'low' productive potential. Planting and other interventions on these sites are likely to be uneconomic. Land of 'moderate' or 'high' productive potential will be deep sandy duplexes, deep sands and sandy and loamy earths. On this basis, we have assessed areas of future saltland suitable for economic productive use. Land of 'moderate' productive potential is highly suited to the growth of saltland pastures, and land of 'high' productive potential will grow a range of moderately salt and waterlogging tolerant trees and so be suited to 'dryland horticulture'.

Estimates of the distribution of future saltland has been done in two ways. Firstly, by using soil-landscape mapping and assuming all valley floor systems will become saline (a scenario in which about 22% of cleared agricultural land becomes saltland). Secondly, by using soil-landscape system mapping and digital elevation modelling to 'guesstimate' the boundaries of saltland at 15% and 30% of the landscape affected for a sample catchment (the Upper Blackwood).

Data from the first analysis suggest that the proportion of saltland with either 'moderate' or 'high' productive potential will be close to 50%. Thus of WA's present 1.8 Mha of saltland, about 0.9 Mha will be capable of some profitable productive use. Data from the second analysis suggest that the proportion of saltland with either 'moderate' or 'high' productive potential will be close to 40%. This analysis also shows that areas of saltland with greatest 'moderate/high' productive potential are localised in particular regions rather than being in a mosaic across the landscape. Maps of saltland productive potential could be of benefit in targeting saltland revegetation extension messages to communities where they will be of greatest benefit.

3. Economics of dryland salinity in Western Australia

The current Salinity Action Plan emphasises the costs of dryland salinity to farmers due to production losses. There are, however, many types of costs that arise from dryland salinity and this report estimates that off-farm costs are likely to be approximately as large as currently estimated on-farm costs.

The current Salinity Action Plan included no estimates of the economic benefits that are expected to flow from the Plan. Preliminary estimates of likely benefits from the Salinity Action Plan as currently configured suggest that they are of a similar order of magnitude to envisaged expenditure. Although the environmental costs of salinity are estimated to be very large, the environmental benefits from the Salinity Action Plan are predicted to be comparatively small. It should be noted that the error ranges associated with these estimates are large.

Successful development of profitable enterprises for saline land appears to be the aspect of the current Salinity Action Plan that is economically most important for agriculture. Generating benefits for the environment would depend more upon revegetation of agricultural land. This needs research and development to identify, breed and test potential economic species that could protect land from salinity, and to develop industries based around them. The Salinity Action Plan does include investment in this area, but its share of the effort seems small relative to its importance.

Assessing areas of saltland suitable for productive use in the wheatbelt of WA: a preliminary assessment for the State Salinity Council

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Summary

This report suggests a methodology for determining the productive capacity of saltland, provides an estimate of the area of productive saltland in the State and suggests a program of further research, development and extension to substantiate the methodology.

Western Australia currently has 1.8 Mha of saltland; this area is expected to increase substantially over the next generation. It must be stressed that this land is not necessarily without productive value. However until now the State has not had a means of assessing saltland capability.

This report argues that saltland capability may be assessed on the basis of soil texture. This methodology has been used to estimate the potential value of the valley floors of the agricultural area (4.3 Mha). Assuming that all of these were to become saline, it is estimated that about half of this area would be of 'low' productivity (not suitable for agriculture), with half being of 'moderate' or 'high' productivity (capable of growing saltland pastures and tree crops respectively).

An attempt was made to map saltland capability in the Upper Blackwood Catchment using digital elevation modelling (to estimate areas of land at risk of salinity) and the soils information in the AGWEST soils-landscape database. These maps showed that soils of 'moderate' or 'high' productivity appeared to be located in certain regions rather than being dispersed in a mosaic across the landscape. This observation suggests that it may be possible to use land capability mapping to target revegetation advice to parts of the landscape where revegetation intervention is most profitable.

Further activities are suggested to confirm the methodology for land capability assessment, and demonstrate the value of the technique through the implementation of a pilot extension program.

1. Background

Western Australia currently has a substantial area of salt affected land (1.8 Mha) (Ferdowsian *et al.*, 1996). Since 1996, four WA Government Agencies have coordinated their activities under the Salinity Action Plan to lessen the impact of salinity. Despite efforts under the Plan, it has become increasingly clear that salinity in agricultural land is going to continue to expand.

At a meeting of the Senior Officers Group on 16 April 1999 it was agreed that the key parameters of concern with respect to salinity projections are: (a) reductions in the eventual extent of land salinisation, and (b) delays in the expression of salinity. The Senior Officers Group requested a group of hydrological modellers to estimate the likely impact of recharge reduction on these two parameters. At the same meeting (16 April), Dr Barrett-Lennard was asked to coordinate a group to prepare estimates of the scale of productive use that might be possible from saltland, and to reconsider the R,D&E agenda for the State in the light of this information.

2. Rationale

2.1. Previous land capability surveys of saltland

There have been no previous studies of the capability *of saltland* in WA. An understanding of the capability of saltland is essential if we are to avoid situations where farmers invest in revegetation, only to have this work eventually fail.

2.2. Stresses

Mature saltland sites often show clear ecological zonation (Malcolm 1994). Plant survival on saltland is primarily affected by changes in three conditions.[1] These are:

- Inundation. Inundation covers plant shoots with water, preventing the exchange of gases between leaves and the air. Although there are few well-documented examples, it appears that even short periods of inundation (a few days) can decrease the survival of all but the most tolerant plant species.[2]
- Waterlogging. Waterlogging displaces air from soil pores, causing a condition of oxygen deficiency in roots. This has direct effects on root survival and growth, and

[1] Although these stresses account for most ecological zonation on saltland, there may also be effects of soil nutrient status, the penetrability of the soil to roots (due to pans) and soil acidity (Barrett-Lennard 1993; Malcolm and Swaan 1989).

[2] The susceptibility of plants to damage from inundation varies with species. Some plants like rice are not at all adversely affected by inundation. One example of adverse effects of inundation on the survival of a saltland species comes from a trial with river saltbush (*Atriplex amnicola*) on the flood-plain of the Kabul River in Pakistan (see p. 107, Qureshi and Barrett-Lennard, 1998). In this experiment the plants were measured for height after 7 months growth. Two months later there was a severe flooding event. When the plants were subsequently scored for survival, it was found that survival was related to the height of the shoot. With plants that were less than 0.6 m high, only 36% of plants survived. However for plants that were greater than 1.0 m high, 97% of plants survived.

also causes a failure of the salt excluding mechanisms in roots.[3] Waterlogging under saline conditions can be expected to cause a cessation in root growth (evident within 1-2 days), increased senescence of shoots (evident within 1-2 weeks), and adverse effects on survival (evident within 1-2 months).[4] Waterlogging may affect different proportions of the root-zone: damage increases with the proportion of the root-zone affected.

- Salinity. For most plants growing on saltland, salinity changes over the upper 2-3 meters of the soil appear to be quite slow and occur primarily as a result of salt accumulation in the root-zone. We are of the view that salt accumulation in the root-zone is most likely to be damaging to plants grown in clay soils. In these soils, leaching processes are likely to be inefficient and plant death from the combination of salt accumulation and waterlogging is likely. In contrast, in sandy soils, salt leaching processes can be quite efficient and plant survival is expected in the long-term.[5]

2.3. Saltland capability classes

Based on the responses of plants to these stresses, we are of the view that saltland should be divided into three general capability classes:

- Land of 'low' productive potential. We expect this category to be dominated by clays of the valley floors (lower rainfall areas) and by shallow duplex soils and clays of the valley floors (higher rainfall areas).[6] In higher rainfall areas, the land will also be subject to severe inundation. In general, the soils in this capability class will be bare where there is severe inundation and will otherwise support self-sown samphire (*Halosarcia* species) or contain a patchy cover of highly salt tolerant annual grasses and forbs. These soils may be planted to halophytic forage shrubs like saltbushes (*Atriplex* species), however their productivity (leaf production) will be low (mostly less than 0.5 tonnes per hectare per annum). We are of the view that planting and other interventions on these sites are unlikely to be economic. These sites should be stabilised by controlling grazing and allowed to regenerate naturally.
- Land of 'moderate' productive potential. We expect this category to be dominated by duplex and 'morrel' soils. Salt accumulation in the root-zone may occur in clayey B-horizons, but not in the more leachable A-horizons. These areas may grow trees for

[3] This subject has been reviewed by Barrett-Lennard (1986) and by Qureshi and Barrett-Lennard (1998).

[4] Evidence of this kind of damage sequence has been found for wheat grown under saline/waterlogged conditions by Barrett-Lennard *et al.* (1999).

[5] Attachment 1 gives a chapter from a book by Barrett-Lennard (in preparation) on the consequences for plant growth of salt accumulation in the root-zone.

[6] Our justification for this assertion is based on three considerations:

(a) sands have a higher hydraulic conductivity than clays; they will therefore drain more easily and be less subject to salt/waterlogging interactions than clays,

(b) the likelihood of leaching of salt accumulated in the root-zone is much lower for clays than loams and sands, and

(c) the transpiration of stands of woody perennials appears to be substantially lower on clays than on sands and loams (for trees see Barrett-Lennard *et al.*, 1998; for saltbushes see Barrett-Lennard, 1999).

(d)

several years; however we expect that they will probably die in the longer term (say 5-20 years) because of the irreversible accumulation of salt in the deeper root-zones. We regard these sites as highly suited to the growth of saltland pastures. In the 300-400 mm rainfall zone, *Atriplex* species and *Maireana brevifolia* can be established by niche seeding or the planting of nursery raised seedlings. These plants will have value as forages, but more importantly will act as 'water pumps' when grown in partnership with annual mildly salt tolerant legumes like balansa clover. Partnerships on duplex soils are also likely to be profitable in higher rainfall areas (400-500 mm), but the perennial partner plants will probably be *Acacia saligna* and tall wheat grass.

- Land of 'high' productive potential. We expect this category to be dominated by sandplain seeps (areas where deep sands shelve out onto clays). This land is primarily affected by waterlogging. It will grow a range of moderately salt and waterlogging tolerant trees (*eg. Eucalyptus camaldulensis, E. occidentalis, Melaleuca* and *Casuarina* species). We are of the view that many of these areas will be suited to 'dryland horticulture'.

2.4. Salinity prognosis

One dilemma we face in attempting to determine the capability of saltland is that we are not only interested in the productive potential of that land now, but also in the future. If the area of salt-affected land in Western Australia is to increase 3 or 4-fold because of continuing rising water-tables, then the condition of existing saltland may change. Table 1 illustrates this point by considering various combinations of present and future condition.[7] The possibility of site conditions becoming more severe in the future should affect the way in which farmers invest in productive use options. In Table 1, investment in productive use of saltland only appears justified for three of the six scenarios listed.

Table 1. Is investment in productive use of saline land justified? Investment must be based on estimates of both present and future land condition.

Present productive potential	Future productive potential	Justification of investment
Low	Low	Minimise expenditure
Moderate	Moderate	Modest investment justified
Moderate	Low	Minimise expenditure
High	High	Substantial investment justified
High	Moderate	Modest investment justified. Avoid over-optimism
High	Low	Invest for short term profits only.

3. Methods

As noted in Section 2, there have been no studies of land capability of saltland in WA. Surveys conducted by AGWEST's Natural Resource Assessment Group have classified

[7] Note that in considering these combinations of present and future productive potential, we have considered it unlikely that the productive potential of saltland will improve.

saltland in agricultural areas into two soil groups: saline wet soils and salt lake soils.[8] This classification is of no value as an indicator of the capability of saltland soils for productive use.

The rationale outlined in Section 2 suggests that saltland can be broadly divided into at least two categories based on soil texture:

- Land of 'low' productive potential (clays, shallow sands, loams and duplexes).
- Land of 'moderate' or 'high' productive potential (deeper sands and duplexes, and sandy and loamy earths).

On this basis, the identification of areas of future saltland suitable for economic productive use (moderate or high productive potential) should be possible by overlying maps of future salinity (determined from hydrological modelling) on maps of soil texture in a GIS.

Unfortunately, the hydrological modellers were not able to supply us with maps of future salinity in the time available to complete the present task.[9] We have therefore had to estimate typical future salinity scenarios in two other ways:

- By using soil-landscape system mapping for the south-west and assuming that all valley floor systems will become saline (a scenario in which about 22% of cleared agricultural land becomes saltland).
- By using soil-landscape system mapping and digital elevation modelling to 'guesstimate' the boundaries of saltland at 15% and 30% of the landscape affected for a sample catchment (the Upper Blackwood).[10]

4. Results

4.1. Scenario 1: all valley floor soil-landscape systems become saline

Using the AGWEST Natural Resource Assessment Group soils database, the soil-landscape systems of the agricultural area were divided into 'valley floor' or 'other' systems (based on the experience of a senior surveyor). This process identified about 4.2 Mha in the 'valley floor' category.[11] When this land was originally assessed (between the

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[8] Cf. Moore (1998).

[9] We are assured that such maps will be available as part of the Salinity Scenarios 2020 project by mid-year in 2000.

[10] The method used is the 'relative elevation compared with the nearest pixel featuring overland flow' *cf.* Caccetta (1999), Figure 8.

[11] The areas expected to be affected by salinity according to this interpretation were distributed unevenly throughout the south-west of Western Australia. The bulk of the area was in the Central and Eastern Wheatbelt (Zone of Ancient Drainage) where it occupied over a quarter of the land. The Zone of Rejuvenated Drainage and the Salmon Gums-Mallee zone would be less affected. Some small zones were seriously affected (*eg.* the Boorokup Lakes Zone), while areas such as the Darling Range were only slightly affected. These are far from novel findings.

mid 1980s and the mid 1990s) about 21% of it was already saline and/or waterlogged (Table 2). We are not able to comment on the capability of this land as its texture was not reported. Of the remainder, 32% was estimated to be of 'low' productive potential, and 47% was estimated to be of either 'moderate' or 'high' productive potential (Table 2).

Table 2. Classification of the capability of saline valley soils based on their surveyed soil texture.

Category	Area (Mha)	Percent of total
Existing saline/waterlogged soils (no texture information available)	0.88	21
Land of 'low' productive potential • Shallow sandy duplexes* • Shallow loamy duplexes • Shallow sands • Shallow loams • Clays • Other soils (rocky, gravelly etc.)	1.36	32
Land of 'moderate' or 'high' productive potential • Shallow sandy duplexes* • Deep loamy duplexes • Sandy earths • Deep sandy duplexes • Deep sands • Loamy earths	2.01	47
Total	4.25	100

* Shallow sandy duplexes are of 'low' productive potential in higher rainfall areas (zone of rejuvenated drainage) and of 'moderate' productive potential in lower rainfall areas (zone of ancient drainage).

4.2. Scenario 2: estimation of future salinity in a typical wheatbelt catchment based on digital elevation modelling

One problem with the approach outlined in Scenario 1 is that salinity has been forecast to increase to about 6 million hectares;[12] as such, it will certainly extend to many hill-slopes. In the absence of maps based on hydrological models, how can we estimate areas at future risk of salinity? Very approximate boundaries for future saltland can be derived using the 'relative elevation compared with the nearest point featuring overland flow' calculation of Caccetta (1999). If salinity occurs first at points that are closest in

[12] *Cf.* Ferdowsian *et al.* (1996).

elevation to points with overland flow, then this calculation provides us with a simple way of picturing the landscape as 'it gradually fills up with water'.[13]

This calculation was used for a portion of the Upper Blackwood Catchment to generate a spatial model of land salinisation for two levels of 'filling' of the landscape.

- The 'valley floor region' (representing 15% of the landscape). This fills parts of the trunk valleys plus flow accumulation zones within the interfluves (Figure 1).
- The 'valley floor region' plus 20% of pixels above the valley floors (or 32% of the landscape). This fills most of the trunk valleys with some increase in the width of the interfluve flow zones (Figure 2).

We intersected these models of land salinisation with the medium scale soil-landscape mapping of the Katanning (Percy) and Corrigin (Verboom and Galloway) Land Resource Surveys. The surveyors defined major soils to each polygon in this soil-landscape mapping. We assigned each of these soils to one of three capability classes in the event of their becoming affected by salinisation/waterlogging. From the spatial intersection and these data, we were able to estimate the areas of land in the catchment that would have the different capabilities of 'existing wet or saline', 'low productive potential' or 'moderate/high' productive potential (*cf.* Table 3 with Figures 1 and 2).

The results show that for this part of the Upper Blackwood, about 16-21% of the 'saltland' identified by the modelling had been originally assessed (between the mid 1980s and the mid 1990s) as being already saline and/or waterlogged.[14] No texture information was available for this land and it was therefore not further classifiable in terms of relative suitability for productive uses.

Of the remaining 'saltland', 53% was estimated to be of 'low' productive potential, and 26-31% was estimated to be of either 'moderate' or 'high' productive potential (Table 3).

[13] The validity of this technique as a way of locating areas of saltland is presently being investigated by Ms Caroline Anderson, an Honours student working with Drs Ed Barrett-Lennard and Norm Campbell. In this work, the valley floors and hill-slopes of the Upper Pallinup Catchment were defined by calculating the relative elevation of each pixel in the landscape compared with the nearest pixel featuring overland flow. It was found that 48% of landscape salinity occurred in the 11% of pixels with lowest relative elevation, and 65% of landscape salinity occurred in the 23% of pixels with lowest relative elevation.

[14] The increase in the area of this class of land (comparing the 15% with the 32% model) is more an indication that the 'valley floor regions' miss a significant proportion of land identified as saline by the surveyors – perhaps saline and non-saline seeps in more elevated parts of the landscape).

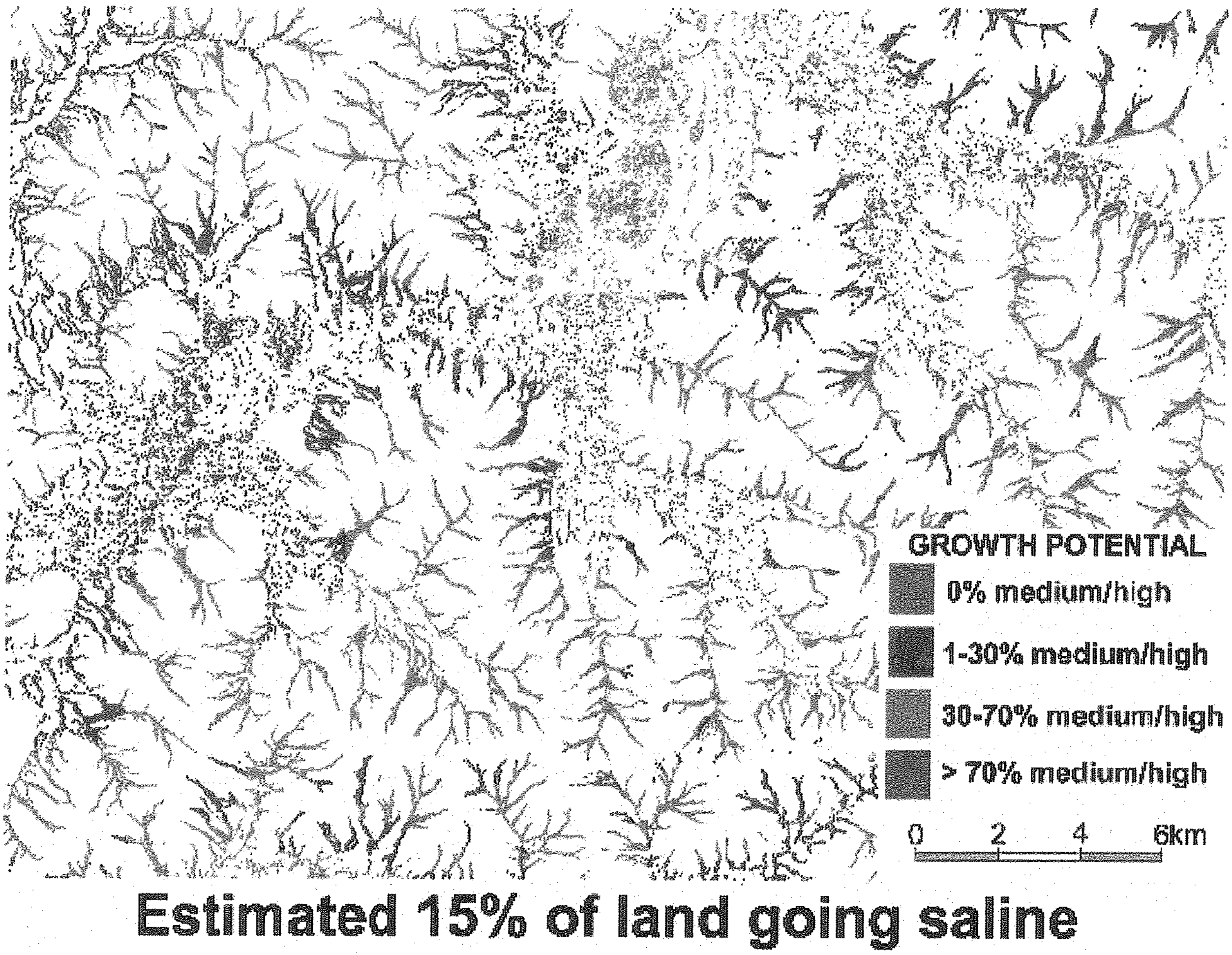

Figure 1. Percent of land with moderate or high productive potential in a portion of the Upper Blackwood catchment (based on the use of digital elevation modelling to predict 15% of the catchment becoming saline).

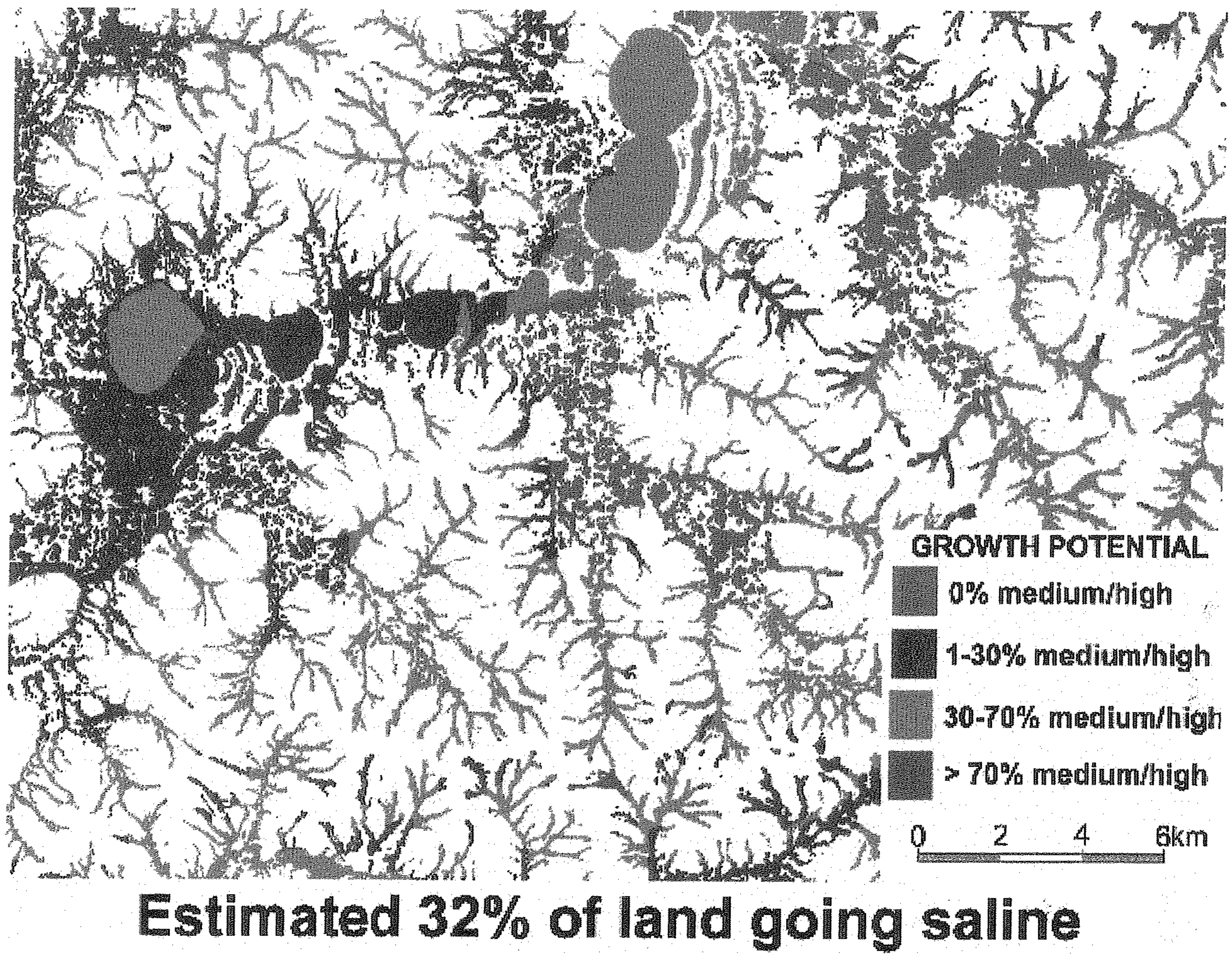

Figure 2. Percent of land with moderate or high productive potential in a portion of the Upper Blackwood catchment (based on the use of digital elevation modelling to predict 32% of the catchment becoming saline).

Table 3. Classification of the capability of saltland in the Upper Blackwood (based on their surveyed texture) assuming that salinity accounts for 15% and 32% of the landscape. The areas of land with salinity were estimated using the calculation of 'relative elevation compared with the nearest point with overland flow' (see text above).

Category	15% of landscape saline		32% of landscape saline	
	Area (ha)	Percent of 'saltland' in class	Area (ha)	Percent of 'saltland' in class
Existing saline/waterlogged soils (no texture information available)	1,536	16.3	4,229	21.0
Land of 'low' productive potential • Shallow loamy duplexes • Shallow sandy duplexes • Shallow sands • Shallow loams • Clays • Other soils (rocky, gravelly *etc.*)	4,949	52.6	10,612	52.7
Land of 'moderate' or 'high' productive potential • Deep loamy duplexes • Sandy earths • Deep sandy duplexes • Deep sands • Loamy earths	2,924	31.1	5,276	26.2
Total	9,409	100	20,118	100

4. Discussion

4.1. Proportion of salt affected land capable of profitable use

Based on the data in Table 2, we are of the view that the proportion of saltland with either 'moderate' or 'high' productive potential will be at least 50% of the total affected.[15] Thus of WA's present 1.8 Mha of saltland, at least 0.9 Mha will be capable of some profitable productive use.

4.2. Need for better basic information to develop maps of saltland capability

The maps in Figures 1 and 2 imply that areas of saltland with greatest 'moderate/high' productive potential are localised in particular regions. Clearly maps of saltland

[15] In making this estimate, we assume that the saltland in the 'existing saline/waterlogged soil' category will be 50% 'low' productivity and 50% 'moderate/high productivity (*cf.* Table 2).

productive potential could be of benefit in targeting saltland revegetation extension messages to communities where they will be of greatest benefit. However, several qualifying comments need to be made regarding the development of such maps.

1. *Maps of present and future salinity will need to be based on more sophisticated salinity predictions than those available to us in digital elevation modelling.* For the present study, in the absence of any better technique digital elevation modelling was used to estimate the areas of land that would be affected by salinity in the Upper Blackwood. However, there is no question that more reliable estimation techniques would be required in any project in which maps were to be used as part of an extension campaign to farmers.

2. *Our methodology for saltland capability assessment needs to be confirmed.* The analysis presented in this report is our best first attempt at predicting saltland capability class against soil types. The legitimacy of this methodology needs to be confirmed based on observations in the field.

3. *Maps of local saltland capability will require higher resolution soil texture information.* The majority of AGWEST's soil-landscape mapping has been of regional or reconnaissance scale. It is strong in identifying the main soils within a polygon but is weak at defining the precise location of those soils. This does not matter for regional interpretations, but has limitations at the local level. In contrast, remotely sensed data are typically collected at the scale required for local investigation. We are intrigued by the possibilities of deriving soil texture information using combinations of airborne gamma ray spectrophotometry[16] and the 'Expector' technique[17] as a means of combining remotely sensed data with the expert systems of soil-landscape mapping.

5. Concluding comments - consequences for research, development and extension[18]

The prognosis for landscape salinisation in the drier parts of the WA Wheatbelt is not promising. At present about 30% of the landscape is at risk. Given a lack of profitable perennial plants, it is probable that much of the predicted salinity will eventuate. However, given appropriate management this saline land could be covered with adapted vegetation. Furthermore, on about half of this land, the vegetation could be of a form profitable to agriculture.

[16] Airborne gamma ray spectrophotometry has some limitations in predicting soil types: the major issues are field validation of remotely sensed signals and the intra-pixel variation in soil characteristics (Verboom 1998).

[17] 'Expector' is a probabilistic predictive modelling technique which uses a variety of evidence layers combined with an expert model. Its ability in being able to incorporate a range of evidence layers makes it ideal for this purpose.

[18] These comments on the Research, Development and Extension agenda for productive use of saline land

One of the keys to encouraging saltland revegetation will be to develop robust criteria for the classification of saltland based on its potential productivity. There are many examples where farmers have attempted to revegetate their saltland only to have the work fail because the plants were inappropriate to the site. Unfortunately, these failures discredit the whole idea of saltland revegetation in the eyes of the community.

We are strongly of the view that Western Australia needs a pilot project to: (a) confirm a methodology for saltland capability assessment, and (b) demonstrate how this capability can be used to assist communities in the implementation of appropriate revegetation strategies. This work should be done in an area where there is access to a motivated community and a number of data sets, including:

- Soils information (AGWEST)
- Radiometrics (World Geoscience)
- Digital elevation model
- Present and future salinity boundaries (SS 2020 project)
- Landsat information on historic vegetation productivity (Land Monitor Project)

These data sets will be used to generate maps of key soil properties at a scale appropriate to the delivery of saltland revegetation advice at the local level. In addition, there will be field validation of predictions from radiometrics data and computer modelling.

<u>Confirmation of methodology for land capability assessment</u>
The methodology for land capability assessment would be studied using a combination of field experiments and satellite imagery.

- <u>Field experiments</u> will examine the annual growth of saltland plants on neighboring pairs of duplex soils and clays. Measurements would be made of annual productivity, salinity, depth to water-table and inundation, and other soil parameters such as pH, nutritional status and the presence of barriers to root penetration such as pans. Plant growth would be related to soil conditions.
- <u>Satellite imagery</u> would test our hypotheses on a larger scale. In this work growth on large areas of land could be assessed over a number of years by comparing reflectance in the near infrared (as an index of leaf area) in areas of saltland with a variety of soil properties. Plant growth over a number of years would be correlated with soil texture (determined from the AGWEST soils database and radiometrics). It might also be possible to relate growth to the risk of waterlogging and/or inundation (determined from digital terrain modelling).

<u>Demonstration of use of land capability assessment to assist communities in the implementation of appropriate saltland revegetation</u>
The aim here would be to use land capability assessment procedures to map the capability of saltland in a similar manner to Figures 1 and 2. These maps would be used to identify areas where saltland revegetation would be of greatest profitability to the local community. An extension campaign with the following elements would then be focused in these areas: (a) extension of existing revegetation information to the affected community, (b) demonstration of appropriate revegetation technology, (c) farmer training, and (d) promotion of farmer investment in land of similar capability.

6. Acknowledgments

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Economics of Dryland Salinity In Western Australia

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Key Points

- There are many types of costs that arise from dryland salinity in WA.
- Off-farm costs are likely to be approximately as large as on-farm costs.
- Estimated benefits from the SAP as currently configured are of a similar order of magnitude to expenditure envisaged under the SAP.
- Successful development of profitable enterprises for saline land appears to be the aspect of the current SAP that is economically most important for agriculture.
- Although environmental costs from salinity are very large, environmental benefits are a small proportion of the estimated benefits of the SAP.
- Achieving greater than predicted benefits to agriculture and the environment seems to depend on R&D and industry development for new perennial species.

1. Introduction

This paper has been prepared to provide advice to the Western Australian Salinity Council. It arises from a request from Alex Campbell to evaluate the economic information contained in the state's Salinity Action Plan (SAP). Our advice is that the economic information in the current SAP is not adequate. There are several reasons for this, including that it contains only a small sub-set of the information that would be needed to properly inform public decision making. This paper is an attempt to provide a more comprehensive set of information, although we emphasise that it has been compiled at extremely short notice and in the absence of quality data on many aspects. Therefore, the numbers presented here are indicative but speculative.

2. Costs of Dryland Salinity in Western Australia

The current SAP emphasises the costs of dryland salinity to farmers due to production losses. Table 1 shows that this is only one of a range of types of costs.

Table 1. Examples of different types of costs caused by dryland salinity in WA

Type of salinity cost	On-farm	Off-farm				
		Domestic	Commercial	Local govt.	Govt agncs/ public utils	Environ't
Preventative action	Planting trees	Minor	Minor	Drains for towns	Rescue town program	Strategic tree planting
Repairs, maintenance and replacement	Buildings, dams	Houses in rural towns	Commercial buildings in rural towns	Buildings, roads, etc.	Infrastructure, water resources	Drainage to repair a reserve
Direct losses	Agricultural production	Minor	Indirect	Indirect	Indirect	Extinctions, lost reserves

Key Point: There are many types of costs that arise from dryland salinity in WA.

* We thank Laura McCann and Steven Schilizzi of UWA for helpful comments.

Note that costs of preventative action and the other categories are not necessarily additive. For them to be validly added, costs in the other categories should be appropriate for the level of preventative expenditure indicated. This recognises that the preventative action will generally not be fully effective and that as preventative action is increased, the costs resulting from salinity will fall.

Table 2 shows our estimates for Western Australia of the levels of each of the cost categories. Information about the bases for these cost estimates is shown in Appendix A. The cost estimates shown are those estimated to occur **without the SAP**. It is assumed that in the absence of the SAP, there would still be government expenditure to repair, maintain and replace assets damaged by salinity, but that strategic, preventative actions (such as R&D) would not be undertaken.

Table 2. Costs of salinity per annum **with no SAP** (equivalent annual cost for 2000-2050)

Type of salinity cost	On-farm	Off-farm				
		Domestic	Commercial	Local govt.	Govt agncs/ public utils	Environ't
Preventative action	$10m	Minor	Minor	$1m	0*	0*
Repairs, maintenance and replacement	$5m	$18m	$9m	$20m	$19m**	$26m**
Direct losses	$102m	Minor	Indirect	Indirect	Indirect	$29m
Total	$117m	$18m	$9m	$21m	$19m	$55m
Total	$117m	$122m				

* Zero by definition, as this table relates to a "no SAP" scenario

** Non-strategic (i.e. reactive and unavoidable) costs of repairs, maintenance and replacement of man-made and natural assets are included. Some of these are included as expenditures within the current SAP. Water resources for human use are included in the "Public utilities" category.

Key Point: Off-farm costs are likely to be approximately as large as on-farm costs.

3. Benefits of the Salinity Action Plan

The benefits of the SAP are not equivalent to the total costs of salinity, because the SAP will not result in zero salinity. The current SAP includes no estimates of the economic benefits that are expected to flow from the plan. This is an important omission, given the very large government investment being undertaken and earmarked in the SAP (in the order of $50m annually for the next decade). This section presents very preliminary estimates of likely benefits.

For consistency with the cost estimates in Table 1, it is assumed that in the absence of the SAP, there would still be government expenditure to repair, maintain and replace assets damaged by salinity, but that strategic, preventative actions would not be undertaken. The benefits reported below are the benefits of these strategic, preventative actions. Underlying these benefit estimations is a set of assumptions that is outlined in Appendix B. Key assumptions are:

- 7.5% of the land that would have gone saline is maintained in traditional agriculture.
- 40% of the potentially saline land benefits from the development of new enterprises for saline land.
- Costs of salinity for off-farm man-made assets are reduced by 50%.

- Costs to the environment are reduced by 7.5%.

If the assumptions are correct, benefits of the SAP will be as shown below (in annual equivalent terms over 50 years, 2000-2050). The error ranges around these estimates are large.

On farm	\$25m	per annum
Off farm man-made assets	\$34m	per annum
Environmental assets	\$2m	per annum
Total	\$61m	per annum.

Key Point: Estimated benefits from the SAP as currently configured are of a similar order of magnitude to expenditure envisaged under the SAP.

The estimated on-farm benefits of \$25m consist of \$5m per annum from preventing agricultural land from going saline, \$18m per annum from developing profitable enterprises for saline land and \$3m from "quasi-option value", meaning the value of preserving land in a productive state to exploit as-yet-unforeseen production opportunities. The smallness of the first type of benefit reflects the relatively small area of agricultural land that is predicted to be protected. The second category of benefit is larger because it is relevant to the large area of saline land that is predicted to occur despite the efforts of the SAP.

Key Point: Successful development of profitable enterprises for saline land appears to be the aspect of the current SAP that is economically most important for agriculture.

Key Point: Although environmental costs from salinity are very large, environmental benefits are a small proportion of the estimated benefits of the SAP.

The reason why environmental benefits from the SAP are small relative to agricultural benefits is that the environment has no equivalent of "profitable enterprises for saline land", which give benefits on the land that goes saline. Increasing the benefits to the environment will depend very much on the success of the SAP in developing a wider range of perennial options giving economic returns. Greater success in this area will:

(a) increase the likely level of farmer/industry investment,
(b) increase the leverage from any future government subsidies,
(c) decrease the total level of subsidies needed for any given outcome, and
(d) increase impacts of extension activities by providing better options to promote.

This is also an area with great potential to increase agricultural benefits. For example, if an additional 10% of potentially saline agricultural land could be protected, benefits to agriculture would increase by the equivalent of \$9m per year. Generating these extra benefits for agriculture and the environment would require a greater emphasis in the SAP on R&D to identify, breed and test potential species and to develop industries based around them. The SAP does include investment in this area, but its share of the effort seems small relative to its importance.

Key Point: Achieving greater than predicted benefits to agriculture and the environment seems to depend on R&D and industry development for new perennial species.

Economics of Dryland Salinity in Western Australia: Appendices

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APPENDIX A: Assumptions for Estimation of Total Costs of Salinity

Current salinity = 1.8 million ha (Situation statement). Without SAP, salinity in 2050: 6.1 m ha (Situation statement). Linear trend in saline area between 2000 and 2050.

Year	Saline area without SAP
2000	1.8
2020	3.5
2050	6.1

Assumed discount rate = 5% real.

The costs below are all intended to relate to the "no SAP" scenario. They represent the likely **future** costs of worsening salinity. We assume that in the absence of the SAP, there would still be government expenditure to repair, maintain and replace assets damaged by salinity, but that strategic, preventative actions would not be undertaken.

On-Farm Costs

Assume 90% of saline area is agricultural land.

Preventative action: 5000 farmers each take modest levels of preventative action that costs them directly and/or indirectly the equivalent of $2000/year = $10m/year.

Repairs, maintenance and replacement: 5000 farmers at $1000/year = $5m/year.

Lost income – production losses: Saline agricultural area suffers production losses worth either $40/ha/yr or a lower amount of $20/ha/yr (due to lower severity of salinity or availability of salt-tolerant enterprises). In absence of SAP, 80% of saline agricultural land suffers the higher level of loss.

Infrastructure

Assume 12 towns of 3000 people with $200,000 worth of infrastructure per person. 25% of this is lost over the 50 year period, with losses distributed evenly over time = $36m/year.

Domestic

Repairs, maintenance and replacement: 50% of infrastructure costs calculated above = $18m/yr

Commercial

Repairs, maintenance and replacement: 25% of infrastructure costs calculated above = 9 m/yr

Local Government

Preventative action: We conservatively estimate aggregate annual expenditure by local governments of $1m/year on drains, revegetation, etc. for prevention of damage to towns.

Repairs, maintenance and replacement: 25% of infrastructure costs calculated above = 9 m/yr.
Roads, based on ABARE study of Loddon and Campaspe catchments x 5 (due to much greater expected severity in WA) = $0.375m/shire/year x 30 shires = $11.25m/yr. Total = 20.25

Government Agencies/Public Utilities

Salinity Situation Statement indicates past government expenditure on protection of water resources of $90m and suggests future expenditure of $115m over an unspecified time period. We assume that over 50 years, without the SAP actual expenditure will be the current equivalent of $150m, either due to additional water storage infrastructure construction, revegetation, or desalinisation plants. For main roads, we assume that the present value of expenditure over 50 years = $200m (based on main roads estimate of $100m needed in short to medium term).

Total present value = $350m. Annual equivalent cost over 50 years = $19.2m

Environment, Repairs, Maintenance and Replacement

We assume that without the SAP, there would still be government expenditure to repair, maintain and replace environmental assets damaged by salinity. The level of costs is taken from SAP 1.

SAP 1 indicates existing funds for environmental repair, maintenance and replacement:

CALM	$2.5m + $0.3m = $2.8m
AgWA	$0.9m
DEP	$0.35m+$0.15m = $0.5m
Total	$4.2m

SAP 1 indicates that new money is required as follows:

Land conservation and biodiversity plantings	$13.5m
Remnant vegetation	$2.3m
Recovery catchments, wetland natural diversity	$6.0m
Total	$21.8m

Assumption: This total annual expenditure of $26m represents the annual cost of repairs, maintenance and replacement associated with salinity for the whole state for the next 50 years.

Appendix C shows the background to our estimation of $55m for total environmental costs from salinity. Part of this cost (ie $26m) is incurred through expenditure on repair and maintenance work. This cost is assumed to prevent environmental damage of an equivalent value. The other component of total costs (i.e. $29m) is the direct cost which is incured from environmental damage despite the repair, maintenance, and replacement work.

APPENDIX B: Assumptions for Estimation of Benefits from the Salinity Action Plan

As noted earlier, the benefits of the SAP are not equivalent to the total costs of salinity, because the SAP will not avert all of those costs. The estimation of benefits of the SAP thus depends on the effectiveness of the SAP at averting those costs.

The estimation of benefits from the SAP is based on the following considerations.

- The plan relies on farmers/industry for the majority of the needed investment.
- Farmers/industry will not make this investment on the very large scale needed to address salinity unless they consider it economically worthwhile.
- For low to moderate rainfall areas, currently available options are not economically worthwhile for most farming situations.
- It is hard to predict the success of current projects to develop new industries based on perennial plant species, but it would seem overly optimistic to expect them to lead to areas of revegetation in excess of 10-15% of the agricultural region.
- Based on latest hydrological modelling results presented at the Salinity R&D Technical Committee on 8 June 1999, reducing recharge by 10-15% would reduce the area of saline agricultural land at equilibrium by no more than 5-10%.
- It is difficult to reconcile what area of the revegetated land would have gone saline, and what area of the "saved" land would remain in production of annual species. For the purposes of these calculations, it is assumed (perhaps optimistically) that revegetated land suffers no net economic loss (opportunity cost) and that the assumed 12.5% revegetation results in maintenance of an additional 7.5% of land in traditional agriculture.
- In the absence of the SAP, it is assumed that 80% of saline land suffers high income losses, with the other 20% either being low productivity land, or high productivity land with profitable saline agriculture established. The impact of the SAP is assumed to be a reduction in the area of high losses from 80% to 40%. (The assumption that saltland enterprises can halve the area suffering high losses is loosely based on an estimate by Ed Barrett-Lennard for valley floor soils, presented at salinity R&D technical group meeting, 8/6/99). This reduction from 80% to 40% is assumed to occur linearly over the 10 years from 2000 to 2010.
- Quasi option value of protecting agricultural land is the value of preserving land in a productive state to exploit as-yet-unforeseen production opportunities. It was set at $20 per ha per year protected = $3m/year for the whole state. Given the relatively small magnitude of this relative to some other benefits, this crude approach based on a hypothetical $/ha value was accepted.
- In calculating benefits of the SAP for off-farm man-made assets, we assume that SAP investment is targeted to protect these assets, such that costs associated with them are reduced by 50%.
- In calculating environmental benefits, we only examine those benefits that are attributable to strategic control measures outlined in the SAP. ie. we do not count the benefits that accrue from repairs, maintenance and replacement work (which is regarded as non-strategic action). This being the case, the environmental benefits of the SAP are governed by the extent to which natural areas are protected. We assumed that 7.5% of natural areas that would otherwise become saline are protected, which leads to the following calculation of benefits: 7.5% x $29m = $2m.

APPENDIX C: Valuation of Environmental Resources at Risk from Salinity

Salinity can disrupt, degrade or destroy a range of "services" that flow from environmental resources such as native bushland, wetlands and waterways. The majority of these services are "public goods", although some accrue to private businesses. Tourism and honey production are two examples of business activities that rely on natural areas.

Examples of environmental services include:

- recreation and tourism,
- apiaries,
- biodiversity,
- aesthetics.
- flood control,
- nutrient filtration,
- carbon sequestration,
- remnant vegetation contributes to salinity control.

This review will principally deal with those services that are "public goods". The values attached to these types of services are often classed as being either "use" or "non-use values". Hence an individual's willingness to pay to prevent environmental degradation may comprise a number of components:

- direct use value (e.g., recreation)
- option value (e.g., the option to recreate at some stage in the future)
- existence value (i.e., the value that stems from knowledge that an environmental resource is in "good health")
- bequest value (i.e., the desire to preserve an environmental resource for future generations)

What Environmental Resources are at Risk in WA?

The Salinity Situation Statement (1996) outlines the extent to which environmental resources are at risk.

Wetlands

Both freshwater and naturally saline wetlands have conservation value in terms of the diversity of species they support. Virtually all wheatbelt wetlands (fresh and saline) have been severely degraded.

Waterbirds: Freshwater wetlands in the south west are known to support up to 40 species of waterbirds. Surveys of salt-affected wetlands have recorded a 50% decline in the number of waterbird species. If the (salinity) process continues, it is predicted that only 16 species will remain.

Wetland invertebrates: Current trends suggest that the original population of aquatic species in agricultural regions, which are thought to number approximately 200, will be reduced to less than 50, leading to extinction of endemic species.

Wetland flora: The flora associated with wetlands in the south west of WA is one of the most diverse Mediterranean floras in the world.

Remnant vegetation

Remnant vegetation is estimated to occupy 2.8 million hectares of privately owned land in the agricultural region of WA (or 13.5%). A further 4.5 million hectares of natural vegetation resides on public lands and occur in relatively large blocks.

It is thought that 80% of susceptible remnants on farms and up to 50% on public land could eventually be lost (note that the area of remnants classed as "susceptible" has not been published in the Salinity Statement).

Eleven species of "declared rare flora" occurring in the agricultural region have at least one population considered to be at threat from salinity.

Waterways and river banks

The beds and banks of 80% of the region's rivers and streams are seriously degraded.

General

Keighery (1999) reports a much bleaker outlook that that which appears in the Salinity Situation Statement (1996). The following are notes from his report:

- Major declines in biodiversity have been observed in freshwater wetlands and stands of remnant vegetation that have become salinised. Biodiversity is also under threat in areas that are naturally saline. In their natural state, these areas are known to support a diverse range of species. Rising watertables are forecast to cause major losses in diversity.
- Flora: The wheatbelt region has an estimated vascular plant flora of 3-4,000 species, of which 60% are endemic to the area. Of these species, over 850 are found only in fresh or naturally saline lowlands, which are directly threatened by rising ground water and salinity. Several other species are found only in woodland sites and will be under threat in the longer term.
- Fauna: Over 500 species of spider have been recorded for the northern and central areas of the wheatbelt. Surveys have shown a major decline in species diversity and numbers with salinisation.

Other questions

A number of other factors are likely to influence the value of environmental resources at risk from salinity. These are:

- Are the natural areas aesthetically pleasing?
- Do they provide a wide range of services or only a limited range?
- Are substitutes available. i.e., how unique is the resource?

Willingness to Pay for the Environment: Some Empirical Evidence

The following table lists some values for environmental resources that have been estimated for other regions.

Table C.1: Summary of value estimates for environmental resources at risk from salinity. All values are means, unless otherwise indicated. Values are expressed in present day Australian dollars.

Study	Description of scenario	Value estimate.
Wetlands		
Bennett, et al. (1997)	Once-off payment to prevent the degradation of 2 large wetlands in South Australia	$40 per h/hold.
Morrison, et al. (1998)	Once-off payment to improve the quality of the Macquarie Marshes, a large wetland area in NSW.	$34 - 103 per h/hold
Gerrans (1994)	Annual payment to preserve the Jandakot wetlands of WA in their current state.	$35 per h/hold *
Stone (1991)	Once-off payment to preserve the Barmah wetlands of Victoria. Respondent presented with trade off between preservation versus draining of the wetlands for agricultural use	$33 per h/hold
Remnant vegetation		
Blamey et al. (1998)	Once-off payment to reduce the proportion of farmland that is allowed to be cleared in the Desert Uplands region of Queensland	$71 - 76 per h/hold
Lockwood and Carberry (1999)	Once-off payment to conserve remnant vegetation on farms in north east Victoria and the Southern Riverina in NSW.	$71 - 98 per h/hold
Lockwood, et al. (1993)	Annual payment to reserve unprotected East Gippsland forest in national parks.	$58 per h/hold
Windle and Cramb (1993).	Annual payment over the next 10 years by local residents to preserve, upgrade and maintain an area of natural bushland in the urban Brisbane.	$36 per h/hold
Endangered species		
Loomis and White (1996).	Once off payment for species preservation. The estimates represent a range of values elicited by numerous studies that sought to value endangered species in the United States.	$29 to 498 per h/hold

* median estimate.

The estimates in Table C.1 were obtained using social-survey techniques, namely choice modelling and contingent valuation. All the studies listed assess the public's willingness to pay to prevent degradation or improve the quality of natural areas. Whilst the form of environmental threat is not necessarily salinity, most of the studies examine a form of degradation that is linked to agricultural activity. The majority of studies were undertaken in Australia.

Transfer of Value Estimates to Western Australia

The transfer of estimates from external studies to sites where environmental assessment is taking place is called "benefit transfer". While this presents a low-cost means of including environmental values in decision making, care must be taken in transferring values. The validity of transferring the estimates contained in Table C.1 to the agricultural region of Western Australia is dependent upon the soundness of the methodology used to transfer them and the similarity of the subject site to the study site. While there are limitations in using benefit transfer to derive a precise dollar value for impacts, it can provide an indication of the likely magnitude of environmental values.

Assuming the values summarised in Table C.1 provide a reasonable indication of the public's willingness to pay for environmental protection (or improvement), an aggregate measure of value can be obtained by multiplying the per household estimates by the total number of households in Western Australia. Table C.2 below summarises the likely ranges of "lump sum" values that result from using the lower and upper bound estimates that appear in Table C.1.

Table C.2: Transfer and aggregation of value estimates to Western Australia

	Perth metropolitan area	Whole of Western Australia
Number of h/holds *	385,000	654,000
Value of wetlands	$13 - 40 m	$22 - 67 m
Value of remnant vegetation	$14 - 38 m	$24 - 64 m
Value of endangered species	$12 - 192 m	$20 - 326 m

* Data from Australian Bureau of Statistics (1996).

A matter still to be resolved is the extent to which the estimates for the three environmental resources in Table C.2 are additive. It is highly likely that some degree of "double counting" will occur if the values are simply added. Furthermore, there is the issue of scope or scale effects. Recall that the estimates listed in Table C.1 were obtained from surveys that asked the respondent to value a particular natural area. One would expect that the values are related to the size or number of natural areas under consideration. The exact nature of this relationship is a matter for further research.

Conclusion

Considering the information from previous studies outlined above, what value should be placed on the environmental assets and environmental services that will be lost if salinity is not controlled? In forming a judgment about this we took account of the following considerations.

- Taken at face value, the above literature implies a present value for Western Australia of up to $450m.
- This literature has considered loss situations of considerably smaller scale than that envisaged for salinity (e.g. a small number or species lost to extinction, whereas losses of the order of 850 species have been predicted due to salinity).
- The regions affected have unique ecological assets and internationally high levels of biodiversity, and so would be significant beyond Western Australia.
- The environmental values reported here are only a sub-set of the different types of values that have been identified for the environment (for instance, carbon sequestration and flood control have not been considered).
- The values in the literature mainly reflect values to the current generation. Values to future generations are captured only partly and indirectly.

Considering all of these issues, we consider that a total present value for environmental losses to dryland salinity in Western Australia would be of the order of $1000m. Annualising this over 50 years using a discount rate of 5% gives an annual value of $55m.

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