ASSESSMENT OF DRYLAND SALINITY BENEFITS AND OPTIMISATION OF MANAGEMENT ACTION COMBINATIONS

(With reference to application in the Murrumbidgee Region)

Ary van der Lely, DLWC, Wagga Wagga

Introduction

The salinity benefits associated with management actions to combat dryland salinity are threefold:

1. Stream salt load reduction benefits, and
2. Saline land reduction benefits.
3. Infrastructure and assets

The first of these has several components. In the Murrumbidgee Region for instance there is riparian vegetation which may benefit, there is an in-stream component, there are irrigation areas and flood plain districts which may benefit, and there are the water users downstream along the Murray River who may benefit. Each of these components should be considered.

Benefits are achieved by reduction of recharge in the catchment, and by interception of ground water flow before it reaches a stream or a saline discharge area. The end-of valley target involves a reduction in salt load in the upper catchment, without affecting stream flow.

The possible management actions involve recharge reductions, and removal of ground water before it reaches a discharge site. The latter could be called a discharge reduction, except that this is not strictly correct, rather it is a discharge diversion to another sink (which could be an evaporation basin, irrigated land, or the root zone of interception forestry). A reduction in recharge will cause a reduction in discharge compared to a No Plan scenario, whether the ground water system still is in a rising mode or not. In this report it is assumed that recharge reductions lead to an equivalent discharge reduction. However, the latter may be achieved only after a response time lag. This aspect will also be considered based on recent work ([1]).

Based on the above, the economic benefits of applying management actions are a function of:

1. The volume of recharge reduction effected by the option
2. The salinity of the discharging ground water to a saline area or stream
3. Any discharge diversion due to an option.
4. The value of one tonne of salt load reduction upstream of Wagga Wagga
5. The proportion of saline land which potentially may benefit from recharge reductions or discharge diversions.
6. The response time between a reduction in recharge and the full equivalent reduction in discharge.

Algorithms were developed based on catchment biophysical data to assess the size of the benefits, expressed as Present Value using economics discount analysis over 50 years. The method of calculation is described in part A below.

The second issue to be addressed by Catchment Management Boards relates to the choice of options and option combinations, which together will produce the required target for salinity. Catchment plans have been prepared and are being prepared showing areas where benefits for the salinity objective and other objectives may be expected. The total cost of implementation

[1] See: A. van der Lely, 2001. "Response times in dryland salinity", DLWC, Wagga Wagga, NSW.

of all potential actions in all these areas is huge, and may overshoot the targets for the valley by 2010. Part B of this report discusses for the end-of-valley salinity objective a methodology by which choices may be made to achieve the end-of valley target at least net costs, subject to a variety of constraints, which will ensure that other targets may also be addressed.

PART A: ASSESSMENT OF DRYLAND SALINITY BENEFITS

The discussion of the next two sections is cryptic, but the concepts used should become clear by following the logic presented. Sections A01 and A02 do not describe the effect of response times to recharge reduction on economics benefits, this is described at section A03

A.01. Stream Salt Load Reduction Benefits

Present Value Salinity Benefits (PVSB) = Value salt load reduction/tonne (VSLR)
x Discounted cumulative salt load reduction (DCSLR)

VSLR = based on MDBC analysis for Murray River at Euston ([2]), corrected upstream via Balranald to Wagga Wagga by dividing the Euston value by a factor 3. The factor 3 is based on the model data reference period, in which only one tonne of salt reaches Balranald for every three tonnes that passes Wagga (See Salinity Predictions report, MDBC audit, 1998).

DCSLR = EC ground water x 0.6/1000 x Discounted cumulative recharge reduction (DCRR). For the catchment model it was assumed that the median salinity in a tributary stream is a good measure for the salinity of the ground water discharge. This is reasonable, since the median flow is a ground water derived base flow.

DCRR = Cumulative recharge reduction due to option over 50 years, including phase in period and a discount rate of 7% (NSW Treasury). The cumulative recharge reduction is based on the estimated annual recharge reduction due to the option, which may be 20mm for perennial pastures and 50mm for forestry options.

If the stream salt load benefit is due to a discharge diversion management action, a similar calculation may be applied, substituting DCRR for an equivalent, present value, discharge reduction. This would apply to for instance ground water pumping and re-use, provided the pumped salt load after diversion does not become a problem at a later (foreseeable) date.

The VSLR factor above relies on Murray River benefits downstream of Balranald only. The other benefits identified at page 1 have not been evaluated, but are not considered to be significant at present. Firstly, it is assumed that there would be no riparian vegetation or in-stream benefits. That assumption appears reasonable since the Murrumbidgee River EC is in the order of 200-300 EC, well below the quoted thress-hold salinity for aquatic eco-systems (ANZECC). Secondly, it is also assumed that the irrigation areas, etc. would not benefit by a reduction in river salinity due to a reduced salt load. This is based on the notion that the current river salinity will not affect the growth potential of irrigated crops, provided there is some leaching. In that context, a 5 EC reduction as per the end-of valley target would not make a difference. However, many areas have very small leaching potential due to high ground water levels, and without action salt will accumulate a little more quickly in the root zone over time, and this may affect the trend predictions for areas of salt affected land. The

[2] The value of one tonne of added salt at Euston is about $53.40/tonne, representing economic costs downstream of that location. Based on two aspects, firstly, a discharge of 100 t/day all year produces 15 EC costs at Morgan, SA. Secondly, one EC at Morgan costs $130K/year. Reference: Pradeep Sharma, MDBC. Also see: “S&D Strategy – Ten years on”, 1999 and original documentation.

area with salt over 2 dS/m is currently estimated to be about 20% in the MIA, rising to 28% by 2025 (MIA LWMP, 1998). In Coleambally the increase will be similar (CIA LWMP, 1996). It is important that the impact assessment is addressed and the actual benefit assessed. There is no methodology for that at the moment, but it could be developed using models. In the meantime, the assumption of this report that the associated benefit is small only appears reasonable.

A.02. Saline Land Reduction Benefits

Present Value Land Salinity Benefits =
= DCRR x Value/ML of Recharge Reduction by option (VRR)

DCRR = As described above.
VRR = Average value of production loss/ha of saline land (AVPLSL), divided by,
the Volume of Recharge needed in the sub-catchment to increase the area of Saline Land by one hectare (VRhaSL)
AVPLSL = Productive value of land (PVL) x % of production loss,
in which:
PVL = Value of land x 7% (simple assessment).
VRhaSL = Annual volume of Recharge to Ground water Storage over catchment (AVGWS) divided by, the Annual increase in Area of Saline Land (AIASL).
In which:
AVGWS = Rate of ground water rise in sub-catchment x storativity x Catchment Area
AIASL = Area of saline scalds x Multiplier for total saline area x Annual Increase Factor (AIF),
In which:
Multiplier = factor to account for total area over which a production loss occurs, not just the scalds (a value of 3 has been assumed to apply for preliminary assessment).
AIF = Factor to account for the annual increase in saline land. The MDBC review for the Murrumbidgee Region suggested that the increase from the year 2000 to 2020 would be 25% ([3]).

It may be noted that a high existing area of saline land will lead to a higher AIASL, therefore a lower VRhaSL, therefore a higher VRR. The benefits are higher if the area of saline land is more, all other factors being the same.

The above method is crude, however it leads to a realistic value per Megalitre of recharge saved, based on reductions in production loss from saline land. If other management options are used to protect saline land, for instance ground water pumping or sub-surface drainage, then an alternative, more direct method of assessing benefits may need to be employed, on a project by project basis. However, usually, sub-surface drainage would not be economic unless high value crops or assets are involved ([4]), and the need for such evaluations would be infrequent.

[3] See: “Salinity Predictions for NSW Rivers in MDB”, 1998, by DLWC. The quantification in this report is subject to the same (significant) uncertainty as used in that report.
[4] This is the outcome of studies by eg see CSIRO (2000) “On-farm and community scale salt disposal basins on the Riverine Plain”

A.03 Effect of Response Time to Recharge Reduction.

The matter of response times in achieving a salinity benefit to a recharge reduction requires attention. Without inclusion of the response times the above methods leads to a significant over-estimation of the benefits. This effect would be even more significant if the ground water system is not yet in equilibrium.

A study was carried out of ground water level data in the Yass River catchment. It was found that in ground water flow systems with more or les parallel creek lines the ground water level behaviour may be simulated using sub-surface drainage theory. Such simulation, as shown at Figure 1, may be achieved by estimation and calibration of various factors including a "reservoir coefficient", which describes the ratio of the size of the system divided by its transmissive capacity (van der Lely, 2001, [5]).

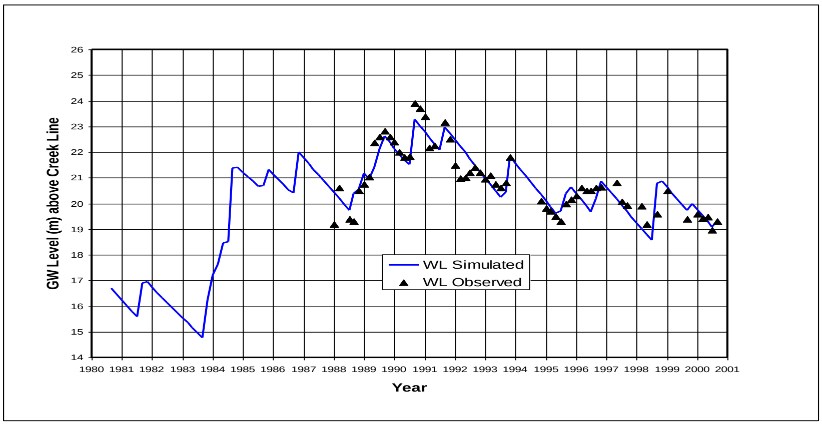

Figure 1. Simulated ground water behaviour for bores 36767/61 in Yass River catchment.

The calibration was also dependent on the values and variation in the recharge applying to the catchment in question. This averages about 60mm/year in the study area, but varied from an average of over 80mm/year in the 1980's to less than 50mm/year in the 1990's. The modelling was applied over the whole 1950 to 2000 period, and the baseline case was compared to the situation which would apply if recharge had been less by 10%, 20% or 50% after 1960. It was found that irrespective of the size of the reduction, the response in ground water level showed the curve as shown in Figure 2.

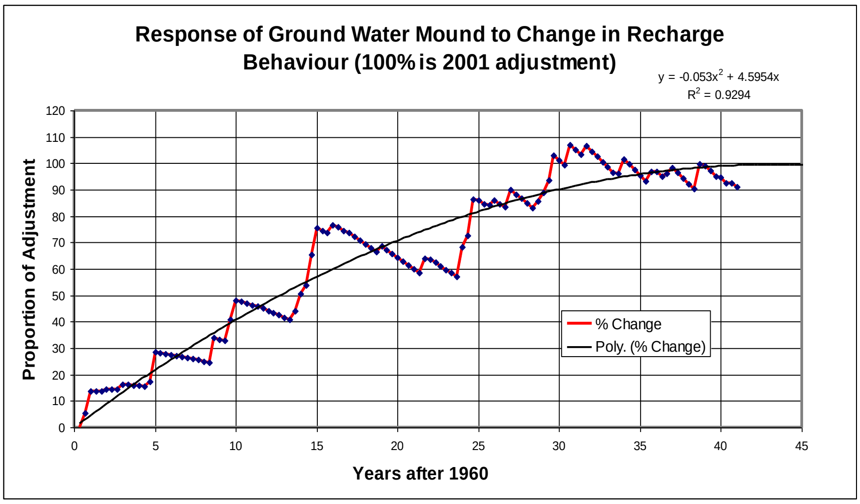

Figure 2: Gradual response of lowering of ground water mound to 100% of its maximum following a reduction in recharge.

[5] See Footnote 1 for reference.

The curve of Figure 2 shows that for the study area, a 50% response is achieved 12.5 years after the recharge reduction commenced. A 90% response was achieved after 30 years. These periods depend on the reservoir coefficient, which incidentally, has a time dimension.

By assessing the value of the reservoir coefficient between catchments for which the assumptions of the model apply (), it is possible to adjust the curve of Figure 2 to individual catchments. This type of assessment has not yet been carried out. It is likely that the response times for other catchments are longer than for the Yass River catchment, perhaps by a factor 2 or more.

Since discharge behaviour is analogous to the behaviour of ground water levels, the curve of Figure 2 can be applied to the economics discount analysis of the salinity benefits discussed at sections 1 and 2. However, the qualification is that the ground water flow system being examined is similar than that of the Yass catchment. This may apply to for instance the Jugiong Creek, Muttama Creek and Tarcutta creek systems, but it is unlikely to apply to the Kyeamba, Billabung, and Houlaghans Creeks catchments, where a down valley permeable alluvium exists which increase response times signififantly (eg see ([1]) and Gilfedder et al, 2001) ([6])

For the analysis of this report the response values found fort the Yass Valley were adopted, to at least account for some of the effect. This means that if the response times are actually longer for the other catchments considered (Muttama, Jugiong and Kyeamba Creeks), there still is an over-estimation of the salinity benefits in this report compared to the actual situation.

A.04. Results.

A preliminary use of this model for a hypothetical sub-catchment assumed values for key factors as shown at Table 1 ([7]).

Table 1: Values of input factors for assessment of salinity benefits in the Murrumbidgee Region.

No	Factor	Value
1	Value/tonne of salt at Wagga Wagga	$17.60
2	Rate of Ground water rise	0.15m/year
3	Effective Porosity ground water system	0.05
4	Productive land value	$1500/ha
5	Average production loss in saline area	50%
6	Discount Rate	7%

For the area of saline land in the catchment which may benefit, it was assumed that 1% of the land in the sub-catchment is saline scald ([8]). The values of recharge reduction achieved by the option and the ground water salinity ([9]) were varied and the model applied, resulting in Figure 1 below. The causal effect of ground water salinity and recharge rate saved by the management action is clear.

[6] Mat Gilfedder, Chris Smitt, Warwick Dawes, Cuan Petheram, Mirko Stauffacher, Glen Walker, 2001, "Impact of increased recharge on ground water discharge". CSIRO, Canberra, ACT 2601.

[7] The values are as close as possible to values found for priority Murrumbidgee Region sub-catchments.

[8] Catchment data show that overall the area with scalds is 0.5-1.0% of typical catchments. For some sub-catchment the value may be significantly above 1%.

[9] The median salinity of tributaries in the Murrumbidgee Region is base flow salinity. This was assumed to be the typical salinity of the discharging ground water in the catchment.

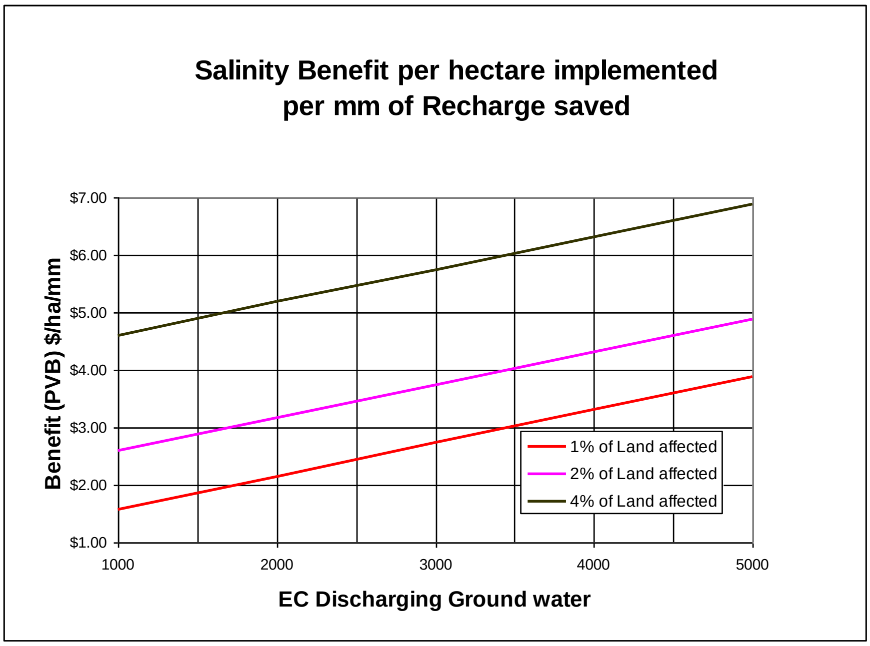

Figure 1: Salinity benefits as a function of salinity of discharging ground water and variable reductions in recharge due to management actions, for fixed values of several other factors (shown at Table 1)

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The general equation describing the salinity benefits for implementation of one hectare of an option achieving one mm of recharge saving is as follows:

$$\$\text{Benefits/ha/mm} = 0.0542 \ * \ [\ 18.6 * \%\ \text{Land affected} + 17.6\ \text{GWEC} * 0.6\ ] \qquad (1)$$

To get the overall benefits per hectare implemented, multiply the result of Equation 1 by the number of mm's saved. This may be 15 mm/year for perennial pastures in Class 3/4/5 land and over 30mm/ha for forestry. The 5.42 factor is an aggregated benefits factor over 50 years including the effect of delayed response times ([10]).

For forestry options the recharge reduction achieved generally would not exceed about 30 mm/year ([11]). This means that only where the discharging ground water salinity is above 3000EC and 1% of the land is salt affected, an upper estimate of the combined salinity benefits is about $2.73 * 30 = $ 82/ha ([12]). Similarly, with perennial pastures a recharge reduction of 15 mm/year may be achievable. In that case the benefit would be in the order of $2.15 * 15 = $32.25/ha implemented where the discharging ground water is 2000EC.

The above results would be sensitive to the discount factor.

The method may be used to evaluate the merit of perennial pasture options, forestry options and native vegetation options, including production benefits and the above salinity benefits. Other benefits such as bio-diversity benefits, soil improvement and water quality benefits,

[10] Based on the Yass Valley study, which is probably optimistic when applied to for instance Jugiong, Muttama and Kyeamba valley situations.

[11] Total discharge from catchments in the Murrumbidgee Region, such as the Yass River, Jugiong Creek and Muttama Creek overall is about 40-50mm/year, of which the ground water component is about 20 mm. Consequently, in Class 3/4/5 land, for which forestry and perennial pasture options are considered, the recharge may only be about 30mm, and higher rates may occur in Class 6/7 lands only.

[12] The effect of inclusion of the response time is a reduction of about 50% compared to ignoring this factor.

may be considered via the LAMPS evaluation process to evaluate the overall merit of proposals.

The size of benefits identified above is likely to be an upper bound for any incentive government could justify, to increase the implementation rates of options. If a map could be produced showing the relationship between ground water salinity, areas of saline land, and the variation of recharge in the catchment, then it could show how incentive availability should be varied across the region. Unfortunately, such a map at present is not feasible, mainly due to the lack of information on the variation of recharge rates. However, better ground water level information over time and its analysis will make this scenario possible.

The model assumptions require more detailed scrutiny by peer review. In the end, however, the making of assumptions regarding the value of specific parameters in the models can not be avoided. The algorithms of this model are crude approximations of the processes actually occurring in the field. Nevertheless it is felt this tool may be useful until succeeded by other, more comprehensive tools (based on CATSALT and FLAG, FLOWTUBE, or other models).

PART B: OPTIMISATION OF MANAGEMENT ACTIONS TOWARDS A TARGET.

In the Murrumbidgee Valley four catchments, namely the Muttama Creek, Jugiong Creek, Kyeamba Creek and the Yass River discharge a large proportion of the existing salt load in the River over and above the background levels in normal run-off. The water quality, ground water and hydro-geological aspects of these catchments are being investigated to identify the sub-catchments producing most. It is in these sub-catchments that the largest salinity benefits relative to costs of remedial actions such as agronomic options, forestry options and engineering options are expected. Part A describes the size of these benefits.

The end of valley target for the Murrumbidgee River is that salinity at Balranald should not exceed 245EC by 2010, which is 5EC below the predicted No Plan scenario. Water quality and hydrological assessment and various considerations has shown this means that about 12,000 tonnes of salt needs to be prevented to enter the river upstream of Wagga Wagga. The salt load needs to be reduced without affecting flow significantly. Salt loads enter the streams as ground water discharge directly, or as wash off from saline lands, which also is a ground water driven process ([13]). In near equilibrium conditions it is a reasonable assumption that a volume of recharge reduction will lead to an equivalent volume of discharge reductions over time. Consequently, management options need to target methods of effective recharge reduction, or prevent salt to be accumulated in saline scalds, or washed off. Perennial vegetation solutions are prominent in achieving such aims. On the other hand, engineering solutions such as ground water pumping and re-use may be seen as discharge diversion options rather than discharge reduction (see Part A).

Modelling Optimal Solution Combinations.

Catchment data such as areas of various land classes, areas of saline scalds, length of gullies, and statistics of water quality (flow, EC, salt load, turbidity, TSS) data, were compiled for the above four catchments. Such information identifies the maximum extent over which various actions potentially can be implemented. The areas of various Land Classes, multiplied by a

[13] Wash off salt loads are subject to time lags. Direct seepage affects base flow salinity and the median salt load, wash off salt loads may predominantly affect the higher flow conditions, eg the 80% salt loads.

likely adoption rate regarding the proportion of farmers who may participate in an incentive scheme, are the basis for evaluating the overall scheme.

Table 2 shows the management options, which were considered:

Table 2: Management actions considered for selecting optimal solution combinations.

No	Action (*1)
1	Fence Saline Scalds
2	Diversion Banks Saline Scalds
3	Fence Class 6/7 land with remnant vegetation.
4a	Plant Class 6/7 to native vegetation
4b	Sow Class 6/7 to native vegetation
5	Plant Forestry Class 3/4/5
6	Plant Interception Forestry
7	Fence + Plant Riparian Gully near saline scalds
8	Perennial pasture establishment. Class 3/4/5
9	Ground water pumping + Use

(*1) This action list varies somewhat from the official list, but includes consideration of the actions, which influence sediment reduction (actions 1,2 and 7).

Cost data to implement these options were compiled from sources such as economists, foresters and catchment managers. Production benefits exist for some options such as perennial pastures, forestry, and ground water pumping and re-use. These were also compiled. All costs and benefits were converted to Present Value by using a discount rate of 7%. A long time span of up to 50 years was used for discount analysis ([14]). Where appropriate the marginal increases in costs and benefits of applying options was considered, eg with perennial pastures only the extra costs and increased benefits should be used, not the totals.

The salinity benefit of the various management actions is based on the discussion of Part A. Each management action was assigned a benefit in terms of recharge or salt load per hectare saved. This information may be gleaned from research on the subject ([15]). The assessment of the volumes of recharge saved was converted to a salt load saved per hectare. This in addition to the costs and production benefits for each hectare implemented allowed for a complete economics assessment.

Some of the actions may lead to a reduction in sediment load washed off to streams, eg actions 1,2, 4, 5, and 7 may have benefits. This aspect was also added to the model, however, few suitable data regarding likely savings (t/ha), or the value of one tonne of sediment saved are available at present, hence this aspect requires follow up. The preliminary data evaluation suggests that these type of benefits are small relative to for instance salinity benefits.

Having compiled the data, the problem of finding an optimal option combination was reduced to working out how many hectares of each management action should be implemented to achieve the combined salinity reduction target of 12,000 tonnes. This problem may be solved by optimisation using the linear programming facility available with EXCEL SOLVER. The objective function is to achieve lowest cost per average tonne of salt saved for the option combination, which achieves the salinity target, subject to a number of complementary and necessary constraints.

[14] This aspect needs review. For some forestry options the duration of one cycle of planting (30-38 years) only was used. This has little effect on the analysis if the discount is 7%.

[15] Updating of this information in the model is on-going and would vary from catchment to catchment.

The maximum areas of each catchment to which the management actions may be applied were determined from the GIS. As mentioned, the likely maximum adoption rate by farmers is less and this was introduced into the model as constraints. The spreadsheet model then calculates multipliers varying from 0 to 1 for each management option. This produces the areas of each option to be implemented. The spreadsheet model was developed to allow examination of each catchment individually, or all catchments combined as a group. In the first mode the adoption rate for a management action in each catchment may be different, in the second mode the adoption rates are applied equally across all catchments.

Some of the actions identified, if implemented, may have additional benefits in terms of other targets apart from the salinity, soil and water quality (turbidity) targets, eg bio-diversity. Where a bio-diversity benefit for a management action is considered significant, and this may be identified by application of the LAMPS (GIS based) tool ([16]), such can be added as a constraint in the model, eg forcing a certain area of revegetation in Class 6/7 land to occur. However, the model does not deal with any other actions for the other objectives, which do not produce salinity co-benefits. Such actions would need to be costed separately.

The matter of response times before the salt load reduction due to a recharge reduction of a management strategy is achieved was included in the Present Value assessment of the cost / benefits analysis. However, in terms of target the long term values only were used, not those which may be achievable by 2010. A study on response times ([17]) found that generally, the benefits cannot be achieved by 2010. The quickest benefits would be achieved by options 1, 2 6 and 9 of Table 2. However, these options are probably insufficient to get the overall required 12,000 reduction in salt load, and benefits are restricted to stream salinity benefits only.

All variable input values or factors subject to uncertainty may be changed in the model to determine the sensitivity of various factors to the result.

Results of Optimisation Model.

The 12,000 tonne target at Wagga Wagga is modest relative to the potentially achievable salt load reduction from land areas available for implementation of options, hence the solution tended to drift towards that option with the highest net present value per hectare, influenced by production benefits. For perennial pastures the implementation is economic without consideration of the salinity benefits. This also applies for the forestry option in the rainfall zone above 700mm. The other options of Table 2 except ground water pumping and use have costs, but no other benefits than those related to recharge reduction and salinity benefits ([18]). It is found that the latter tends to be small relative to the costs. The end result is that dependent on the input values for costs and production benefits, the optimal solution will be to just apply perennial pastures, or to only apply forestry. For maximum economic benefits the other options will drift to zero implementation.

If the CMB desires to implement other options based on perceived other benefits (bio-diversity, soils, water quality), for instance planting native vegetation on Class 6/7 land, then choices such as these may be introduced in the model as constraints. The model may then be

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[16] The LAMPS tool is based on spatial units related to each target area, management actions, and a matrix in which the potential of achieving outcomes in a spatial unit is scored. This produces "action maps" after application of some filters, eg applicable only to a specific rainfall zone, a Land Class, or a native vegetation layer.

[17] See van der Lely, 2001. "Response Times in Dryland Salinity", DLWC report.

[18] And perhaps some sediment load reduction benefits, which help towards the water quality and soil objectives.

run to determine how much of the more economic options need to be implemented to achieve the salinity target, whilst at the same time still achieving a reasonable outcome in terms of Net Present Values of costs and benefits, or the Benefit Cost Ratio. These model runs are still to be carried out, preferably in consultation with the Murrumbidgee Salinity Project team and/or the Catchment Management Board.