



## Asset fixity and environmental policy An application to water quality management

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Commonwealth and state governments have agreed to develop and implement policies, including the use of market based instruments, to generate improved water quality outcomes. Policy objectives may include incentives for investment in more efficient irrigation technologies or moving irrigation away from high salinity impact areas. However, the presence of large, sunk investments in on-farm infrastructure will have an effect on the efficiency and distributional impacts of such policies, and the timing of the environmental benefits that they generate. A case study of grape production in the Victorian Sunraysia region is used to quantify the effects of the age distribution of investment in vineyard infrastructure on the effectiveness and efficiency of policy initiatives designed to generate environmental outcomes. Results suggest that targeting policies to vineyards nearing the end of their investment cycle will generate faster and more cost effective outcomes.

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## Introduction

Increasing salinity concentration of the Murray River and the resulting third party effects on both the environment and productive water use has been of growing concern for policy makers and resource managers. These effects are expected to continue to increase, with the Murray Darling Basin salinity audit predicting that salt mobilisation in the basin could double from five million tonnes a year in 1998 to 5 million tonnes in 2100 (MDBC 1999). Increases in salt mobilisation can, in part, be attributed to irrigation, particularly in areas overlying highly saline ground water systems. Advances in hydrological modeling are improving the understanding of the spatial relationship between agronomic practices and salt mobilisation. This knowledge is now assisting policy development and provides the basis for many spatially specific policy initiatives. However, while an improved understanding of physical systems may offer the technical means for addressing resource degradation problems, choosing the right solution requires a broader understanding of the economic or other incentives that resource users face when making investment decisions.

Policy instruments, such as levies and regulations, use price or quantity incentives to more closely equate private and social costs that deliver outcomes such as improved riverine health and reduce the severity of downstream impacts arising from the consumptive use of the water. These outcomes may also be derived from improved agronomic and irrigation practices or from relocating irrigation to low impact areas, such as those that are some distance from the river. However, the presence of fixed assets may be a substantial impediment to the rate of adoption of water saving technology or relocation to a new area. In any case, at the farm level the age of the existing enterprises is a critical factor in determining the timing and extent to which an economic instrument will lead to investments in new technology or relocation to a less damaging site. The evaluation of policy options that provide the required incentives to change the location and nature of current irrigation practices requires a better understanding of the asset fixity problem.

The purpose in this paper is to examine the role of fixed assets on the effectiveness and efficiency of natural resource policy. First, a case study of optimal vineyard relocation in the Victorian Sunraysia region is developed. Second, the case study is used to evaluate two policy initiatives designed to bring forward the investment relocation decision to generate environmental outcomes. The findings from the case study are used to draw general conclusions about the importance of fixed assets in developing successful natural resource management policy.

## Background

The establishment of irrigation areas has facilitated the development of high value agricultural production in Australia's Murray Darling Basin. However, it has also imposed costs where increases in the volume of water entering ground water systems has led to rising water tables. As water tables rise, there is increased discharge of salt into streams and mobilisation of salt in the soil to the soil surface. Higher stream and surface soil (dryland) salinity can reduce the productive capacity of agricultural resources, adversely affect infrastructure such as roads and rural services that support agriculture, and affect the health of a range of environmental assets including wetlands, floodplains and riverine ecosystems.

Strategies have been, and continue to be, implemented to address the problem of salinity in the riverine environment. The Salinity and Drainage Strategy was introduced in 1989 to manage irrigation salinity along the River Murray in New South Wales and Victoria, and increased salt concentration in the lower River Murray in South Australia. The Basin Salinity Management Strategy, released by the Murray Darling Basin Commission in September 2001, proposed a series of end of valley salinity targets for 2015 as well as foreshadowing the need to develop longer term initiatives. These initiatives set out by the federal and state governments culminated in the development of a National Water Initiative (NWI) released in 2004. The NWI seeks to promote and coordinate effective planning and management for the equitable, efficient and sustainable use of the water, land and other environmental resources of the Murray Darling Basin (NWC 2005).

Improved knowledge of the relationships between spatial characteristics of irrigated activities and environmental impacts has increased the range of tools available to generate improved water quality outcomes. Perhaps more importantly, this knowledge has enabled the identification of specific areas or regions that have characteristics better suited to irrigation based on offsite impacts than others. This spatial relationship between water use and salt mobilisation offers a number of policy options. For example, policies could be directed toward moving water used for irrigation from high impact to lower impact regions to reduce the volume of salt mobilised to the landscape or river system. The Victorian Government, for example, has introduced a zoning system based on the estimated impact of irrigation on river salinity at different locations along the Murray River. Water trade between these regions is restricted or levied depending on the source and destination of the water.

Targeted improvements in water use efficiency have also been shown to reduce the volume of water and salt being mobilised to the landscape or river system (Heaney, Beare and Bell 2001). One option available to government is regulation, where an outcome would be achieved through the setting of rules or standards. This approach has been adopted in South Australia, where irrigators are required to achieve water use efficiency levels of 85 per cent for highland areas and 65 per cent for lowland reclaimed swamp areas by 2005. This forms part of the licensing conditions and is monitored through an annual audit (South Australian Government 2001).

To date, however, public policy developed to address increasing riverine salinity has generally been directed at limiting increases in saline discharge from existing uses in their current location. They have not been proactive in providing the incentive to either switch to a more appropriate land use or irrigation technology in a particular location or move to a region more environmentally suited. Economic instruments can be used to alter the setting under which irrigators make decisions on future investments — including providing incentives to move to more suitable sites or invest in better technology. However, irrigators typically have significant investments in on-farm assets that have little or no salvage value. If these fixed investments (or assets) have not reached the end of their economic life, an irrigator may have limited economic incentive to respond to policy initiatives designed to encourage relocation. Consequently, the age distribution of existing investments is a critical factor in determining the timing and extent to which a policy instrument will lead to investments in new technology for current or alternative land use applications, or move irrigation water to a less damaging site.

The role of fixed assets in agricultural production (and elsewhere) has been examined at length in the literature. A fixed asset has three important characteristics: a purchase price; an economic value; and a salvage value. When considering an investment, growers compare the value of an additional asset, which is determined by the private benefit the asset provides over its lifetime — the economic value — plus its salvage value, with the purchase price. For disinvestment, the grower equates the present value of the remaining cash flow of the asset in use with its salvage value. In some cases, the salvage value could actually be negative if, for example, unused on-farm infrastructure needs to be removed. A grower's decision to invest depends on the difference between the total value (economic value plus salvage value) and the purchase price.

This is important in a public policy context as typically on-farm infrastructure and assets have long life cycles (perhaps more than 20 years) and have little or no salvage value. If the asset has not reached the end of its productive period, an irrigator will have an incentive to delay reacting to the economic signals generated by a policy initiative. The larger the net present value of the remaining cash flows of the asset, the stronger the economic incentive would have to be to induce irrigators to reinvest elsewhere. Policy initiatives designed to alter investment decisions that do not take account of the characteristics of the industry could, in the worst instance, fail or lead to unanticipated equity or economic efficiency outcomes.

The focus in the remainder of this paper is the investment characteristics of wine grape production in the context of public policy initiatives to generate improved environmental outcomes by reducing the mobilisation of salt to the Murray River system.

## **Modeling framework**

A modeling framework was developed to consider the problem of reinvestment in vineyard assets under two public policy scenarios (details on the modeling framework are provided in appendix A; data used are provided in appendix B). In the case considered here, the asset replacement problem is the abandonment of an existing vineyard along with the land it occupies for a new vineyard established in a new area. Public policy initiatives provide the incentive to move irrigated activities from high salinity impact areas to those more suited, in this instance through an environmental levy or relocation subsidy. Using the modeling framework, the optimal age from the grower's perspective to relocate to a new area is estimated from the investor's point of view. The framework is expanded to include a change in input costs, such as an environmental levy that raises operating costs in one site relative to those in another, and a subsidy on investment in a new area. The increase in the site specific operating costs and a subsidy on investment in a new area is expected to alter the decision to abandon the existing asset and reinvest in a new location. Onsite impacts of high water tables and salinity are not considered.

When a vineyard on an existing site is to be abandoned for a vineyard on a new site, the decision should be based on a comparison of the benefit from the asset on the new site with the forgone benefit from the asset on the existing site. The forgone benefit from the abandonment decision is the present value of the income stream of an infinite number of replacement cycles on the existing site. If a decision is made to abandon the existing vine-

yard when the asset reaches the optimal replacement age, then the forgone benefit is equal to the present value of an infinite number of identical cycles started from scratch. However, the introduction of an economic ‘wedge’ through a policy initiative, such as a levy, will change the point at which the vineyard on the current site may be profitably abandoned, even before the asset reaches the optimal replacement age.

The model has two components: an agronomic component and an economic component. In the agronomic component, data on water use and crop yields are used to estimate the yield response function for each age group of vines. The economic component uses the yield response function to estimate the optimal water use and grape yield for a given set of winegrape and water prices. For each age, net returns are estimated by subtracting all variable and fixed costs from the gross revenue from selling wine grapes, for both the current and proposed site.

Using the vineyard relocation example, the optimal relocation model is developed to investigate ex ante the optimal time for vineyard relocation in the Sunraysia region. In the first instance, the optimal replacement age is estimated using the optimal replacement model developed by Etherington (1977). It is assumed that the grower faces no uncertainty in future income streams and has a range of choices, including replacement of vines on the existing site or developing a new greenfield site.

A base case was developed using data provided in table 1 to represent a reference case or ‘business as usual’ scenario. This is compared with alternative scenarios consistent with public policy initiatives to encourage investment in lower impact areas. When making a relocation decision, a grower weighs the present and future profit potential of a current vineyard against that of a vineyard in a new location. In that relocation decision, a defending

## 1 Price and cost data for grape vine production

Nominal Australian dollars

		Existing (replant on current location)	New development
Land value – undeveloped	\$/ha	1 100	600
Vineyard development <b>a</b>	\$/ha	15 000	25 000
Average wine grape price	\$/t	520	520
<b>Water</b>			
Water delivery charges <b>b</b>	\$/ML/yr	65	65
Water use charge <b>b</b>	\$/ML	65	65
Water use	ML/ha	9.5	9.5
Water entitlement	ML/ha	10	10
<b>Variable costs</b>			
Total variable costs	\$/ha	5 032	5 032
– labor	\$/ha	782	782
– cropping contracts	\$/ha	540	540
– freight	\$/ha	286	286

**a** Personal communication: G. Swinburn, Scholfield Robinson, Mildura, 2005 **b** Personal communication: M. De Palma, Mildura, 2005.  
Source: Gordon (2004)

asset (in this case, the current vineyard) should be abandoned as soon as its net present value of its future net cash flows drops below those of the challenging asset (new plantings with average production capabilities).

Asset fixity implies much of the current infrastructure, such as the vine trellis and so forth, has little or no salvage value. However, re-establishing the vineyard in the current location does offer both production benefits and cost savings. For example, the current vines can be removed and new vines grafted onto the existing root stock at a lower cost than replanting in a new site. A grafted root stock may come back to full production in a shorter period than that of a new planting. Moreover, current infrastructure, such as trellis and irrigation systems can be used for the second rotation. Therefore, the new rotation is established at a lower cost than the development of a new site. In the base case, it is assumed that re-establishment of the existing vines at the optimal time to replace is around \$15 000 per hectare. This is inclusive of old vine removal and grafting costs. All other variable costs between the new and existing site are held constant. The water right is assumed to be transferable between the established and new site at no charge.

### Case study: Sunraysia

The modeling framework outlined above and described in detail in appendix A is applied to a case study region — Sunraysia in the Mildura region, Victorian Mallee (map 1). Sunraysia is the northern most irrigation section of the Victorian Mallee, stretching from Nyah to the South Australian border along the Murray River. The total value of agricultural production in 2000 was just over \$1.4 billion, principally generated by primary industries, mainly wine grapes along with plantings of citrus, vegetables and some tree crops (ABS 2001). The irrigation area covers the irrigation districts of Robinvale, Redcliffs, Mildura and Merbein and includes approximately 1100 wine grape producers, with an area of around 15 000 hectares.

#### 1 The Sunraysia irrigation region – southern Murray Darling Basin



The total water allocation in the region is around 20 000 megalitres a year. The districts are managed by two water authorities; the Sunraysia Rural Water Authority (SRWA) and the First Mildura Irrigation Trust (FMIT). Private diverters account for the largest share of irrigation water and agricultural land in the Sunraysia region, with approximately 98 per cent of land irrigated.

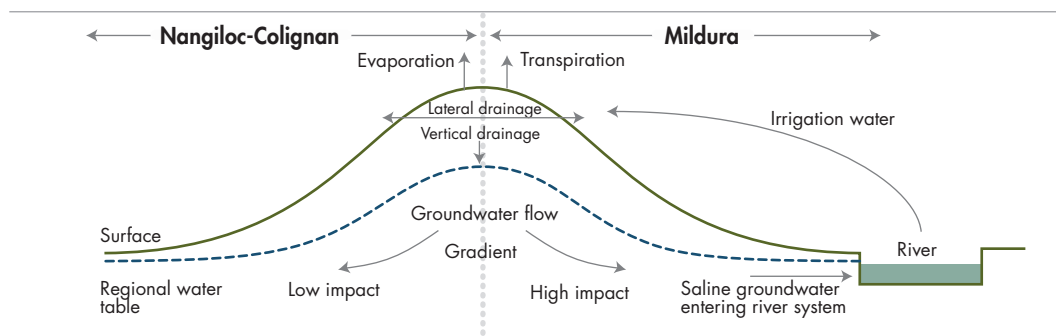
### Salinity impacts in the region

Average annual rainfall is around 290 millimetres, occurring mainly during the winter months. Average evaporation is about six times higher than average rainfall. Highly variable summer rainfall is often a significant factor affecting the yearly rainfall average. As a result, water requirements for horticultural and wine grape production in the Victorian Mallee region are met largely by irrigation from the Murray River system and irrigation water demand is highly variable.

As a consequence of irrigation, increased ground water recharge has led to rising water tables and increasing ground water discharge to the Murray River (Alexander and Heaney 2003). The impacts on overall riverine salinity are still largely determined by the gradient of the ground water flow in a particular location (figure A; Pakula 2004). For example, increased ground water pressure or rising water tables caused by irrigation activity in a location such as Mildura has much more of an impact on overall river salinity as the ground water gradient is toward the river than a similar amount of irrigation on the flood plain at Nangiloc–Colignan as the ground water gradient is away from the river (Mallee Catchment Management Authority 2005). The variation in spatial characteristics of the Victorian Mallee region has important implications for the siting of irrigated activities. For example, if vineyards are located in areas where the ground water gradient is away from the Murray River, increased discharge of saline ground water will not have significant adverse effects on river quality (see Victorian Mallee Salinity and Quality Management Plan 2003 for further discussion).

The efficiency of irrigation application technologies and practices is a primary determinant of the volume of recharge entering the ground water system as a result of irrigated production. More efficient irrigation technologies and practices tailor irrigation application to

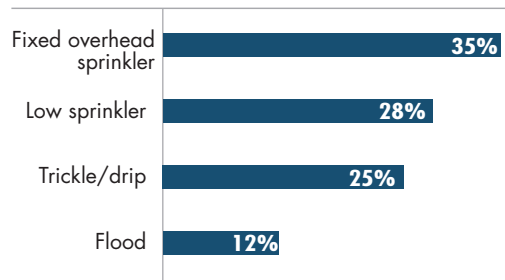
### A Gradient of ground water and the impact on river salinity



plant moisture requirements and less water is lost to evaporation and runoff or ground water leakage. Hence, salt mobilisation that arises from discharge is likely to be less when more efficient application technologies and practices are used. However, the benefits will be reduced if the saved water is reapplied in the same region.

Currently, a variety of irrigation techniques are used in the region, with overhead and low sprinklers the most common. The efficiency of different types of irrigation technologies reflects the difference between the applied amount (applied water) and the amount used by the crop (effective water). The difference between the two can be measured as runoff, deep percolation and evaporation. Technical irrigation efficiency is often measured as the ratio of effective water to applied water. A priori, drip irrigation systems would increase water use efficiency; switching from flood or sprinkler irrigation to drip technology has been shown to decrease water applications by up to 35 per cent (Schoengold and Zilberman 2005). Perhaps more importantly, given high rates of evaporation in the Victorian Mallee, greater savings may be made by switching from sprinkler to trickle or drip technologies. Despite the potential for significant savings this technology is used on only 25 per cent of vineyards in the Sunraysia (figure B; Gordon 2004).

**B Irrigation technologies used in the Sunraysia region 2003**



Such low uptake of new and more efficient irrigation technology is part of the overall asset fixity problem as irrigation technology such as drip irrigation has a high capital cost. Without adequate incentives and the presence of significant sunk costs, adoption of water saving technology will remain slow. This adoption rate is of particular interest in the high impact regions where a lower proportion of water application technologies such as drip or trickle irrigation are currently used (Pakula 2004).

**Current policy environment (or business as usual)**

In 2002, salinity zones were established in the Sunraysia region based on the relationship between ground water flow and estimated salinity impacts at different locations along the Murray River (table 2). These impact zones are divided into high impact (HIZ) and low impact zones (LIZ4, LIZ3, LIZ2 and LIZ1). The highest impact zones are those on the river side of the water table peak and closest to the designated salinity reference point of Morgan in South Australia<sup>1</sup>. A map showing salinity impact zones is presented in appendix C. Low impact zones are further from Morgan and located in flood plain regions or in regions where clay soils form a barrier between the river and the saline aquifer below.

The Victorian Government adopted a levy based approach on water traded from low impact to higher impact zones. The salinity levy is an indirect fee attached to the input (in this case

<sup>1</sup> The Australian Government and the state governments of Victoria, South Australia and New South Wales are committed to capping the salinity level at Morgan, South Australia, such that it remains below 800 EC for 95 per cent of the time (MDBC 2001) — see table 2 for definition of EC.

applied irrigation water) not the pollutant (in this case saline ground water). The levy is designed to ensure that the purchaser incurs at least some of the salinity costs imposed on others from the trade. To account for the spatial impacts along the river, the levy varies according to the source and the destination of water trade. In addition, the levy is cumulative. For example, if a trade occurs from a LIZ1 to LIZ3, the levy is payable on the transfer from LIZ1 to LIZ2 and LIZ2 to LIZ3. These levies range from around \$40/ML to \$250/ML for permanent trades (see appendix D, for the complete schedule). Temporary trade attracts a levy of around 10 per cent of that applied to permanent trades.

## 2 Salinity impact zones in the Victorian Mallee

Impact zone	Salinity impact a
	EC/1000ML of irrigation water applied
HIZ	0.6
LIZ	0.2
LIZ3	0.1
LIZ2	0.05
LIZ1	0.02

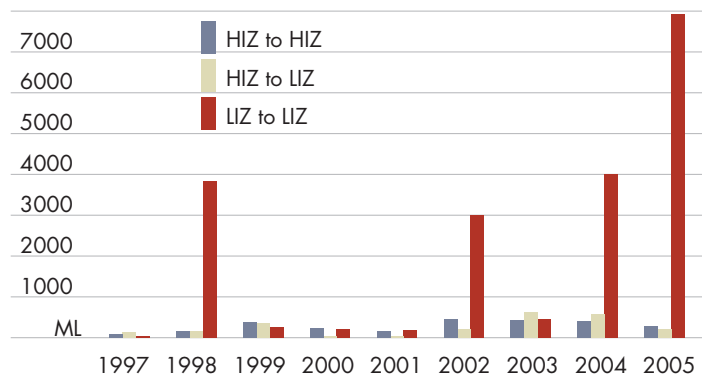
a Salinity concentration is measured using electrical conductivity (EC), where one EC unit is approximately equal to 0.6 milligrams of salt per litre.

Source: SRWA (2002).

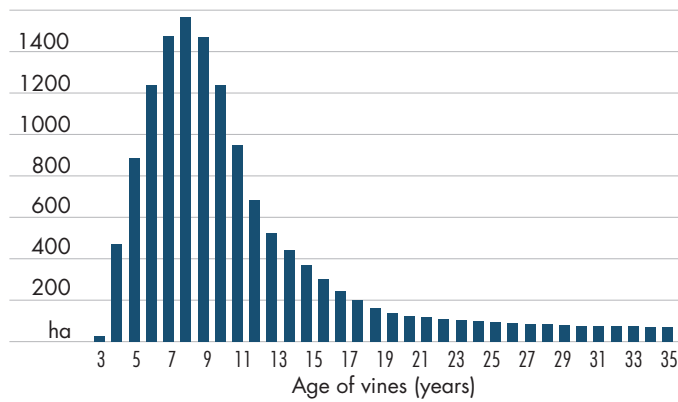
In high impact zones a trade barrier was also established to prevent significant water trades into these regions. This regulation acknowledges the higher salinity impacts associated with water use in these zones and the higher third party cost that arises. In periods of extremely low flows, such as a drought, trades into LIZ4 are also closely controlled with a cap on the amount of trade.

For the past decade, the Sunraysia region has remained a net importer of permanent entitlements from other irrigation regions with a cumulative net transfer of around 81 200 megalitres (SRWA 2005). These transfers are the result of water moving from relatively lower value enterprises such as pasture production to higher value industries such as horticulture. Within the region, the most significant trading activity remains between the low impact zones (figure C). Low impact zone trades account for an average of around 60 per cent of total water traded within the region, whereas trade from high impact zones to low impact zones accounts for only 17 per cent on average. The remainder of intrazone or intraregion transfers occur between the high impact zones, primarily around Mildura. Land use in the high impact zones around Mildura is dominated by irrigated properties producing grapes.

C Permanent water transfers in Sunraysia



### D Age profile of vines

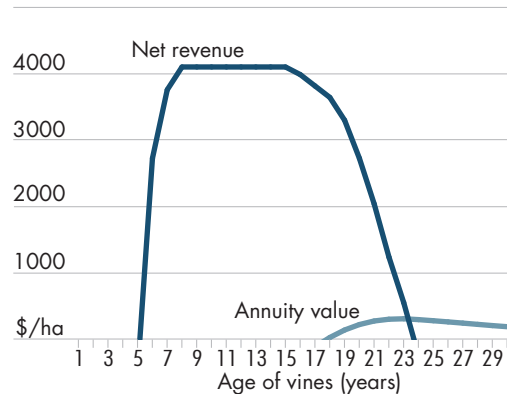


From a policy perspective, the age distribution of current vineyards provides insight into the potential delay in a grower’s response to policy initiatives developed to generate environmental outcomes. In the Sunraysia region, around 70 per cent of the area of vines currently planted is approximately ten years old or younger (figure D; Sunrise21 2003). Just 5 per cent of the area planted to grapes is more than twenty years old. This skewed distribution is consistent with the observation of small increases in plantings until the early 1990s, followed by a period of significant growth in the industry. Reflecting the significant capital costs associated with vineyard development (around \$25 000 per hectare) and the fact that benefits are realised over the life of the vines, the younger the vines the larger the forgone benefit of relocation to a new site becomes. This suggests that the predominance of vineyards that are in the early stages of their investment life cycle will present an impediment to vineyard relocation. Under present economic conditions, the reinvestment decision for the majority of vineyards will not occur for about two decades without intervention.

## Results

The model was used to estimate the net present value for the business as usual scenario based on a discount rate of 5 per cent. The optimal time for the replacement of a vineyard in the Sunraysia region was estimated to be 23 years in the base case. The optimal age to replace is when the annual net returns are equal to the annuity calculated from the net present value of the cash flow up to that age. Replacement of the vineyard at this age perpetually maximises the average long term return or annuity. For this example, the equivalent annuity associated with this 23 year cycle is estimated to be maximised at around \$307 per hectare (figure E).

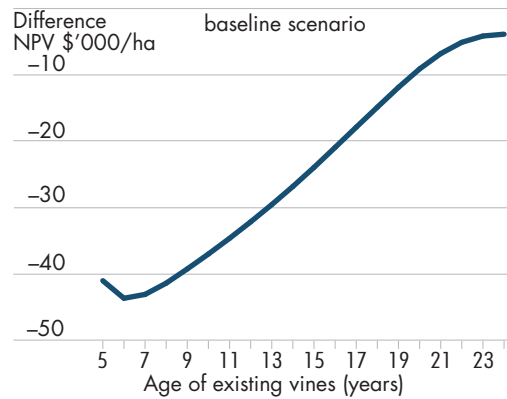
### E Optimal vineyard replacement business as usual scenario



If a decision to relocate is to be considered for each age of the existing vineyard, the incremental benefit from relocation is the net present value of the perpetually replacing vineyard in the new location less the forgone benefit that would be received from the existing vineyard over the remainder of the lifecycle and all future replacement cycles. With the current level of wine grape prices and production costs given for the base case in table 1, relocation is not profitable. In other words, the grower will be better off in continuing with the current site. This is shown by the incremental benefit curve remaining negative for the life of the asset.

In other words, the net present value of the vineyard in the new site is not large enough to offset the cost of asset fixity. From this analysis, it is clear that current areas under grapes in high salt impact zones will remain as the private benefits from relocation remain negative (figure F). This estimation of the benefits of relocation does not, however, take into account the public benefits of relocation that are derived from improved environmental outcomes. A subsidy on relocation is introduced to provide the incentive for growers to account for these benefits when making their reinvestment decision.

**F Incremental benefit curve: net present value of vineyard relocation decisions**

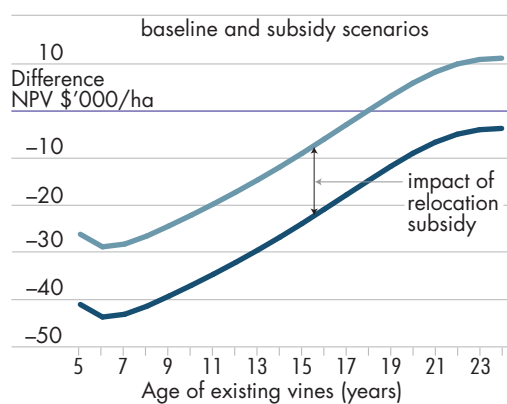


**Policy scenario 1: relocation subsidies**

A relocation subsidy is introduced to the model as a one off payment to existing vineyard owners on the development costs of greenfield vineyards in low salinity impact regions. This subsidy is designed to eliminate the difference between the forgone benefits of the existing site relative to those benefits of a new greenfield site. For this simulation, a subsidy of \$10 000 per hectare is introduced. This represents around 40 per cent of the total greenfield site development cost.

The net present value of the vineyard relocation decision after the introduction of a development subsidy is presented in figure G. This simulation shows that a subsidy would shift the incremental benefit curve upward so that it would intersect the horizontal axis at age 18, which means that all vineyard relocation would be profitable after they reached the age of 18 years. At the age of 23, this subsidy could be reduced to around \$2800 per hectare, all else being equal, to leave grape growers indifferent to replanting on existing sites as opposed to relocation to new lower impact sites.

**G Net present value of vineyard relocation decisions**

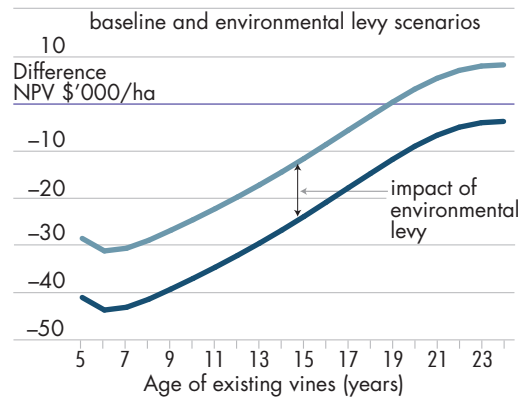


## Policy scenario 2: environmental levy

Alternatively, an environmental levy could be introduced. In the scenario presented here, the levy is applied to the volume of water diverted for irrigation in the high impact zones increasing the cost of production in the high impacts zones relative to the lower impact zones. It is assumed that growers will retain their current levels of irrigation application efficiency, although the levy will also provide an incentive to improve irrigation practices. The levy is applied at 100 per cent, effectively doubling the per unit charge of water. The fixed charges associated with water delivery are unchanged.

If the water levy is applied at 100 per cent, increasing the unit charge for water by \$65 per megalitre, the optimal age of vineyard relocation falls to nineteen years, four years less than the optimal replacement time for redevelopment on the existing site given the base case assumptions (figure H).

### H Net present value of vineyard relocation decisions



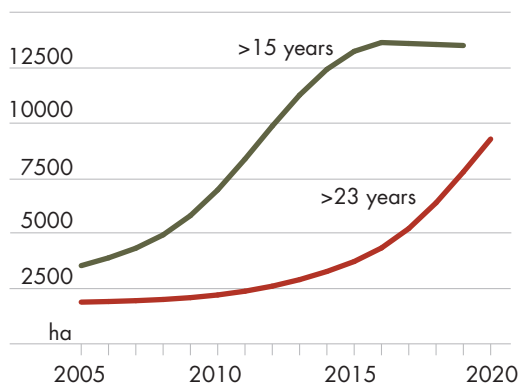
## Predicting vineyard relocation

Without intervention, growers in the Sunraysia region will not relocate to a new site as it is not profitable to do so, even at the optimal age for vineyard replacement of 23 years. If the optimal age to relocate was brought forward through intervention to fifteen years, around 14 000 hectares of vineyards would be profitably relocated by 2016 (figure I). This suggests that there is considerable opportunity to promote relocation over time. However, as previously discussed, there would need to be a significant incentive to accelerate this process due to asset fixity. Clearly the desired rate of relocation would depend on the nature of the impact of declining water quality. If these effects are incremental then the first best policy solution may be to wait until these assets reach the end of their economic life to minimise the incentive needed to promote relocation. Alternatively, if there is, for example, a critical environmental threshold, a greater incentive may be warranted.

## Concluding remarks

The third party effects of water use arise because the water market is incomplete — irrigators do not take into account the water quality effects their actions impose on downstream water users and the environment and those affected are not represented

### I Prediction of vineyard relocation, by critical age



in the market. The market is incomplete in the sense that there is no exchange institution where the downstream user is compensated or the upstream user pays a price for imposing third party costs. Further, as the benefits of improved water quality are diffuse, it is not feasible for downstream water users to cooperate to effect a change in the technologies or practices of upstream water users. Consequently, there is a role for government to generate improved water quality outcomes. The choice of policy instrument is important, however, because it will create different efficiency and equity outcomes.

Relocation subsidies and environmental levies would each provide an incentive for growers to consider the third party effects of irrigation and to relocate to more suitable areas sooner than under a business as usual scenario. However, the analysis in this paper suggests that such policy interventions would need to create a substantial incentive to change investment behavior that ultimately generates environmental outcomes within a short time frame. Small incentives may still affect investment decisions but the lag between policy introduction, the investment response and the environmental outcome suggests the full impact of the policy may not be realised for several years, possibly decades. Targeting policies toward those vineyards nearing the end of the investment cycle will generate faster and more cost effective environmental outcomes.

Although the policy scenarios presented here would generate similar environmental outcomes in terms of altering the decision to relocate, the equity or distributional effects vary considerably between the two policy alternatives. Clearly, the imposition of a levy will have different effects on grower income than the granting of a relocation subsidy. However, there will be a considerable difference in distributional effects if the levy or relocation subsidy is uniformly applied across all growers regardless of the age of their vineyard. For example, imposing a levy on growers with relatively new investments raises their costs of production in a situation where they have limited ability to respond due to asset fixity. This leads to rent being transferred from growers to the government until the time it becomes profitable to relocate to the new site. A relocation subsidy can be targeted to older vineyards and paid at the time of relocation.

The desired rate of relocation will depend on the nature of the impact of declining water quality which, in turn, will be an important determinant of the most appropriate policy response. If the effects on water quality are incremental, then the first best policy solution may be to wait until assets reach the end of their economic life. If, on the other hand, declining water quality is approaching a critical environmental threshold, a greater incentive to hasten relocation may be warranted.

Given the lag between policy implementation and the relocation of vineyards to more appropriate sites, it may be faster and more effective to promote the adoption of more efficient irrigation technologies and practices as a means of generating environmental outcomes. While on-farm irrigation infrastructure is also characterised by asset fixity, it is not as extreme as that of vineyard infrastructure. In addition to the use of levies and subsidies, there are other policy tools that could be implemented to promote the adoption of more efficient water use. These include blunt policy instruments such as regulation, or property right solutions such as water use rights. Water use rights place conditions on use that may be dependent on factors such as soil type, underlying ground water hydrology, irrigation technology or crop type.

# Appendix A: the model

A model was developed to estimate the optimal relocation time for a vineyard. The framework is then expanded to include policy initiatives that provide an incentive to move production to a more suitable site. These policy initiatives include a relocation subsidy that reduces establishment costs in lower impact areas and an environmental levy designed to raise operating costs in the higher impact site relative to those in the lower impact site.

## Optimal age to replace an asset

For simplicity assume that an asset to be created in year  $o$  is to be replaced perpetually every time it reaches an age of  $s$  years by a series of assets of the same vintage. Assuming that the asset has no salvage value at the time of replacement and discrete annual interest rate,  $r$ , the present value of an income stream of  $R(t)$  realised in a single cycle,  $\pi(o,s,1)$ , can be given as:

$$(1) \quad \pi(o,s,1) = \sum_{t=0}^s R(t)(1+r)^{-t}$$

Following Etherington (1977), when an infinite number of identical cycles are considered, the present value of their income streams can be given as:

$$(2) \quad \pi(o,s,\infty) = \frac{1}{1-(1+r)^{-s}} \pi(o,s,1)$$

This can also be seen as the present value of an equal payment of  $\pi(o,s,1)$  received every  $s$  years. The optimal age  $s$  at which the asset should be replaced can be found by looking for the value of  $s$  which maximises equation 2. The right hand side of equation 2 attains a maximum at an age of  $s$  where discounted marginal return equals the average annual return (the equal payment or annuity calculated from the discounted total earnings) (Etherington 1977).

At this point average annual earnings are also maximised. The resulting decision rule can be simplified into equation 3.

$$(3) \quad R(s) > \left[ \sum_{t=0}^s R(t)(1+r)^{-t} \right] \frac{r(1+r)^s}{(1+r)^s - 1} > R(s+1)$$

The middle term in equation 3 is the equal annual payment or annuity calculated from the discounted total earnings. The optimal value of  $s$  is found by sequentially comparing at each age of the asset the annual return at that age  $R(s)$  and the annuity formed (the middle term) if the asset were to be replaced at that age. If at age  $s$ , the annuity just exceeded  $R(s)$  but fell short of  $R(s+1)$ , the age  $s$  is the optimal time to replace.

The above decision rule can be observed when replacing an asset perpetually on an existing vineyard or replacing an asset perpetually on a new site is considered in isolation. In each situation, the asset is replaced at an optimal  $s$  so that the present value of infinite cycles of identical replacement is at maximum. At any given time  $t$ , the replacement decision thus

depends on the annual return,  $R(t)$  of the existing asset and the annuity calculated from the discounted present value of the new asset. The annual return,  $R(t)$ , of the existing asset depends on the yield, price of produce and operating cost in year,  $t$ , while the annuity calculated from the new asset depends on the entire stream of cash flows over  $(t=1,2,\dots,s)$ , which in turn depends on crop yields, quality of produce and prices of inputs and outputs over  $(t=1,2,\dots,s)$ . The method used in calculating annual net return is given in box 1. Due to continuing improvements in the production technology, a new vintage asset such as a new wine grape variety provides higher return than the existing asset and consequently it may pay for an earlier replacement.

## Abandonment of an asset on an existing site for an asset in a new location

Just as an asset of a new vintage with higher profits could hasten the decision to replace an existing asset, any increase in the site specific operating costs such as an environmental levy or a relocation subsidy is expected to hasten the decision to abandon the existing asset for an asset in a different location where these site specific costs are less. The special case of asset replacement considered here allows for abandoning the existing asset along with the land it occupies for a new asset created in a new area.

When an asset on an existing site is to be abandoned for an asset on a new site due to higher operating costs on the existing site, or in response to the relocation subsidy, the decision should be based on a comparison of the benefit from the asset on the new site with the forgone benefit from the asset on the existing site. The forgone benefit from the abandonment decision is the present value of the income stream of an infinite number of replacement cycles on the existing site. If a decision is made to abandon the existing site when the asset reaches the optimal replacement age, then the forgone benefit is equal to the present value of an infinite number of identical cycles started from scratch  $\pi(o, s, \infty)$  given in equation 2.

With the introduction of a levy or subsidy, the age at which the asset on the existing site may be profitably abandoned changes. To make the decision rule more flexible so that abandonment before optimal replacement age can also be considered, for each age of the existing asset, the present value of the remainder of the current cycle and an infinite number of future cycles from the end of the current cycle need to be calculated. If the existing site with its asset is to be abandoned in  $n$  years into current cycle, the present value of the remainder of the current cycle and an infinite number of future cycles henceforth  $\pi(o, s, \infty)$  can be estimated as:

$$(4) \quad \pi(n, s, \infty) = \sum_{t=n}^s R(t)(1+r)^{-(t-n)} + (1+r)^{-(s-n+1)} \left[ \frac{1}{1-(1+r)^{-s}} \pi(o, s, 1) \right]$$

For simplicity assume that an infinite number of identical cycles can be decomposed into one current cycle (first term on RHS of equation 4) and the remainder of all the infinite number of cycles henceforth (the second term). More specifically, the first term on RHS of equation 4 is the present value evaluated at age  $n$  of the stream of annual earnings in the remainder  $(t=n, n+1, n+2, \dots, s)$  of the current cycle while the second term is the present value evaluated again at age  $n$  of the current cycle of the infinite number of identical cycles

### Box 1: Estimation of annual net return

For each area and age of vines, net return  $R_t$  per hectare of the vineyard equals the gross revenue from selling wine grapes less all variable and fixed costs. The variable costs include volume sensitive cost of irrigation, pump maintenance cost and all overhead costs while fixed costs include one off vineyard set up cost in the first year and each age of vines, annualised cost of on farm and off farm irrigation infrastructure.

$$(1.1) \quad R_t = \bar{Y}_t P^g - \bar{X}_t P_t^w - C_t$$

Where

$\bar{Y}_t$  = optimal per hectare yield with respect to water input at age  $t$  (tonnes/ha)

$\bar{X}_t$  = optimal quantity of water applied given price of grapes, cost of irrigation water, water allocation and production technology at age  $t$  (ML/ha)

$P_t^w$  = price of water which includes the delivery charge and the scarcity value of water input, at age  $t$  (\$/ML)

$C_t^w$  = all other costs at age  $t$  (\$/ha)

Optimal yield,  $\bar{Y}_t$  and water use  $\bar{X}_t$  are derived from the following short run profit maximisation problem.

$$(1.2) \quad R_t = Y_t P^s - X_t P_t^{dw} - C_t$$

subject to

$$(1.3) \quad Y_t = a_t + b_t X_t + c_t X_t^2; \text{ and}$$

$$(1.4) \quad X_t \leq \bar{\omega}$$

Where  $a_t$ ,  $b_t$  and  $c_t$  are parameters of quadratic yield response function or the production technology given in equation (1.3) and  $P_t^{dw}$  denotes water delivery charge. The equation (1.4) states that the quantity of water applied cannot exceed per hectare water allocation. First order conditions for this short run profit maximisation problem are derived as follows.

$$(1.5) \quad L = (a_t + b_t X_t + c_t X_t^2) P^s - X_t P_t^{dw} - C_t + \lambda(\bar{\omega} - X_t)$$

$$(1.6) \quad \frac{\partial L}{\partial X_t} = (b_t + 2c_t X_t) P^s - P_t^{dw} - \lambda = 0$$

The Lagrangian for this problem is given in equation (1.5) where,  $\lambda$  is the Lagrangian multiplier or the scarcity value of water. The optimal quantity of water applied,  $\bar{X}_t$  and then the optimal yield,  $\bar{Y}_t$  can now be derived as follows.  $\bar{X}_t = P_t^{dw} - b_t P^s + \lambda / (2c_t P^s)$  and  $\bar{Y}_t = a_t + b_t \bar{X}_t + c_t \bar{X}_t^2$ . These values are then substituted in to equation 1.1 and  $R_t$  estimated.

each replaced optimally at age  $s$ .

The optimal age to abandon the existing asset and the site is found by sequentially comparing at each age  $n$  of the existing asset the present value of the existing asset if it were to be abandoned at that age,  $\pi(n, s, \infty)$  with that of an asset initiated from scratch on a new site  $\pi^*(o, s^*, \infty)$ . If at any  $n$ ,  $\pi^*(o, s^*, \infty) > \pi(n, s, \infty)$ , it is optimal to abandon the existing asset and the site. This decision rule is stated in equation 5.

$$(5) \quad \pi(n, s, \infty) > \pi^*(o, s^*, \infty) > \pi(n+1, s, \infty)$$

The age  $n$  that satisfies expression 5 divides the time period between  $t$  and  $s$  into two regions: region 1, where,  $t < n$  it is not optimal to abandon and region 2, where  $t > n$ , it is optimal to abandon.

# Appendix B: Data sources

## Land and water prices

Land fully developed with water and new planting (and trellising for grapes) in Mildura sold for \$35 000 to \$45 000 per hectare. Land with water that was either vacant or ready to be replanted sold for \$15 000 to \$25 000 per hectare. When a water entitlement is attached, an approximate \$7000 per hectare is additional to the basic selling price. Developed land that included roads, access to a dam as a holding storage and infrastructure (pipes) to transport water to the property boundary or to the central storage sold at a price of \$6000 to \$9000 per hectare.

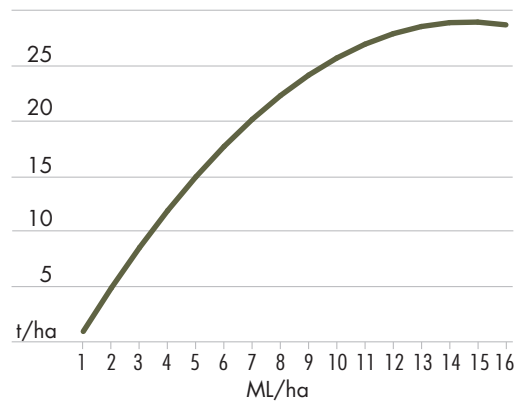
No information on vines specific to Mildura (or Mallee region in general) was available. After discussing with local agronomists and irrigation scientists, a quadratic yield response function, as specified in equation 1.3 of box 1 in appendix A, has been estimated for the region. The yield response function is presented in figure J.

It is assumed that yield response functions (t/ha) will be the same for existing and new vineyards and in the case of existing vineyards a proportion of full production will apply depending on age of a vineyard. The salinity impact on on-farm production is negligible because of the high quality irrigation water applied in both cases.

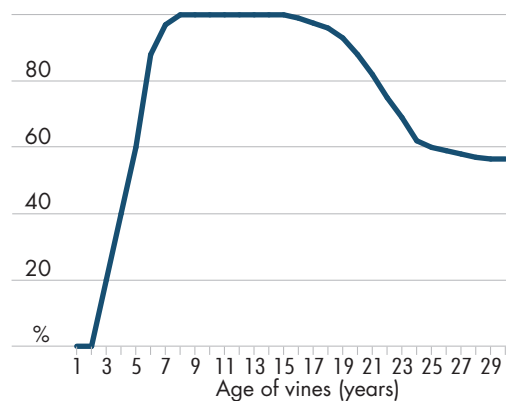
## Economic component

The price received for grapes (\$/t) depends on yield (t/ha) and quality. The price received includes bonuses or penalties based on baume (a system of measuring the sugar content of grape juice by its density; each baume is equal to approximately 1.75 per cent sugar in the juice). Generally, an increase in yield is associated with a decline in quality, which is ultimately reflected in a lower price for additional units. Initially, an economic life of thirty years has been assumed for this analysis. The years taken to develop produce are critical in the economic evaluation. For example, wine

**J** Yield response to water



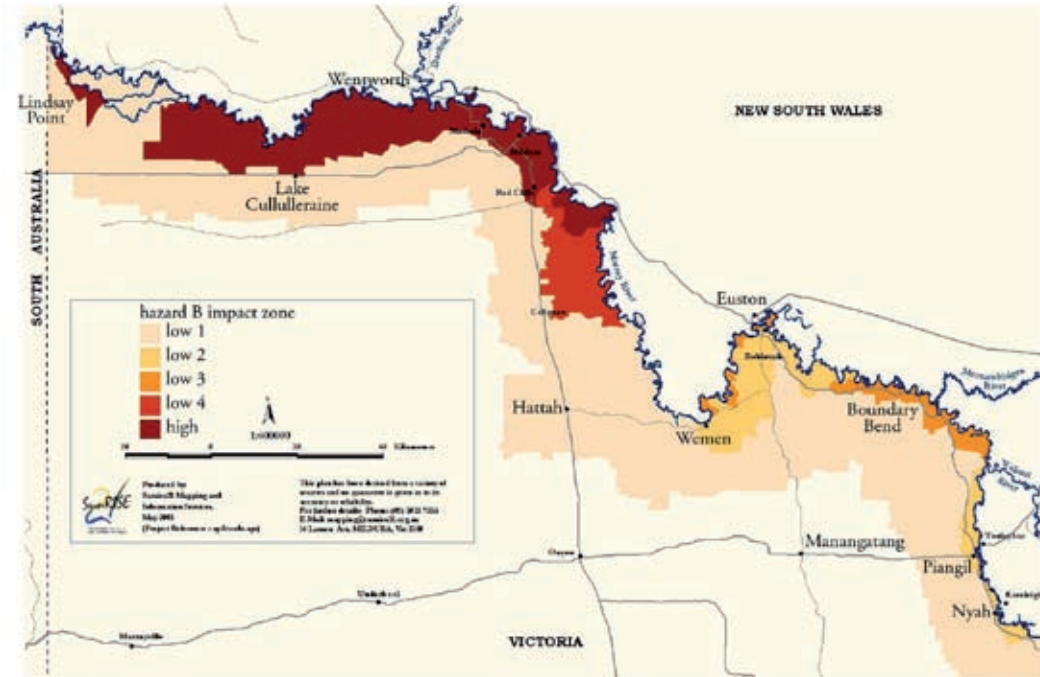
**K** Proportion of vineyard yield over time



grapes in Mildura are expected to take two to three years to bear fruit. An allowance for the delay in time to reach full maturity must be made. During this period little or no revenue is generated. Also, a number of years are required to reach maturity and full fruit production. A yield response function over the age of the vines has been established to estimate the proportion of full yield over each age of the vineyard (figure K).

The development of a new vineyard requires both on-farm and off-farm infrastructure development. The on-farm infrastructure includes irrigation systems including pumps and dripper/spray systems, plants, trellising, establishment, landforming and on-farm drainage, on-farm tracks/sheds/power and whole farm plan and farmer education. The off-farm infrastructure development covers all irrigation water delivery and reticulation, regional drainage infrastructure, water access and delivery and environmental compliance. The on-farm and off-farm infrastructure development (capital) costs used were around \$25 000 per hectare on a new site, and \$15 000 on an existing site. The (annualised) cost for the preferred option of water delivery infrastructure was \$130 per megalitre or \$1170 per hectare when water use is 9 megalitres per hectare. These costs have been used in this analysis. A weighted average price of \$525 a tonne was assumed (AWBC 2005).

# Appendix C: Sunraysia region: salinity impact zones



# Appendix D

**Fee schedule for permanent trades in salinity impact zones <sup>a</sup>, 2005**

Water traded from:	Water trade to:				
	HIZ	LIZ 4	LIZ 3	LIZ 2	LIZ 1
HIZ	0	0	0	0	0
LIZ 4	NT	0	0	0	0
LIZ 3	NT	139	0	0	0
LIZ 2	NT	209	70	0	0
LIZ 1	NT	252	112	42	0

<sup>a</sup> All permanent and temporary trades incur a charge for monitoring and maintenance charge of salt inception schemes of \$3.47 per megalitre. Temporary trades incur a charge of 10 per cent of the permanent water trade fee. NT: Currently no trade is allowed between regions.  
 Source: SRWA (2005).

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