3. Method

3.1 Introduction

Salinity is a major problem affecting agricultural productivity in south west Victoria. Existing landuse practices have the potential to cause an increase in the land affected by salinity. Without remedial action, agricultural productivity may decline and the unpriced costs incurred by downstream users will increase. To prevent this from occurring in the Gerangamete region a catchment management plan has been developed. In this chapter the catchment management plan as a safe minimum standard of resource use and the method used to undertake the analysis is outlined.

The methodology applied to this study is similar to the examples described by Ready and Bishop (1991) for dealing with uncertain costs irreversibility. In this study the catchment management plan is posed as the safe minimum standard, and the minimax decision criterion used to evaluate the plan. A flow diagram of the approach used in this study is presented in Figure 3.1. The first step was to collect all available information on the problem. For this study this meant physical, hydrological and economic information. The hydrological data and physical data for the catchment were used to develop the groundwater model, which was then combined with an economic spreadsheet model to undertake the deterministic discounted cash flow analysis. Risk analysis Stochastic simulations were then undertaken and compared with the deterministic result.

3.2 Framing the Problem

Framing the catchment management plan according to a safe minimum standard criteria means that there is a need to place monetary values on the unpriced effects, externalities and the intergenerational issues which are of major concern in traditional cost-benefit analysis.

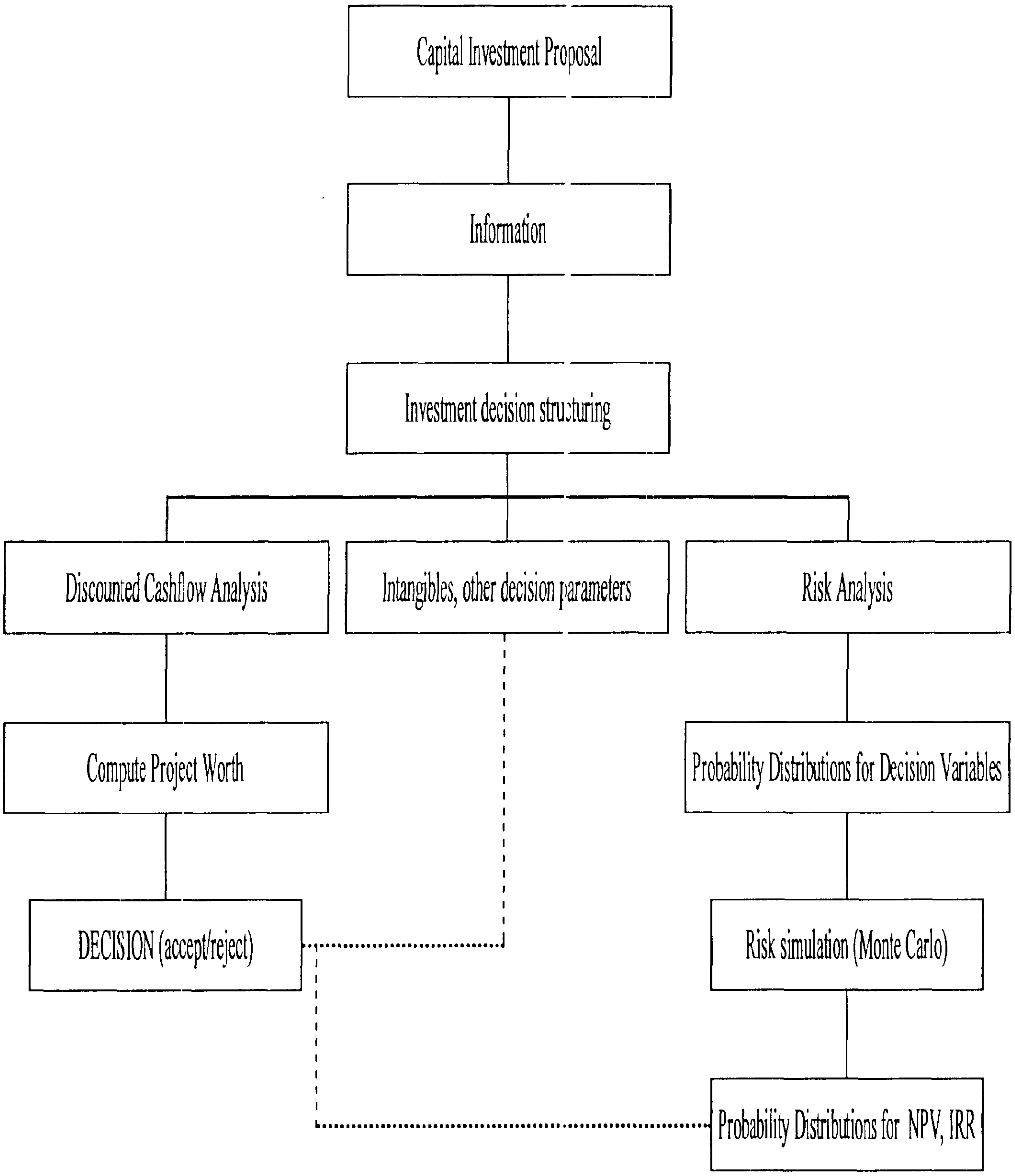

Figure 3.1 Flow diagram showing proposed investment analysis

3.2.1 The Gerangamete Catchment Problem

The minimax decision rule assumes that the probabilities of the different states of nature (outcomes) are unknown (Dasgupta and Pearce, 1974). For the Gerangamete catchment, doing nothing to redress the spread of salinity is assumed to result in a state of nature that is economically irreversible, with uncertain but potentially significant costs. The alternative state of nature is one that requires some expenditure in order to avoid the irreversible state of nature.

Hydrological modelling of the catchment provides the evidence which makes it possible to estimate the probability of each state of nature occurring. What is uncertain is the potential cost to society. In other words, it is not the state of nature that is deemed uncertain, but the value of the social costs that result from each state of nature.

3.2.2 Framing the Problem within the Safe Minimum Standard and Minimax Criteria

The two strategies identified for this study are the current agricultural practices and the catchment management plan. The latter, was developed using catchment hydrology modelling and the best current technical knowledge available to prevent resource degradation and to ensure long term sustainability of the land. It is therefore considered to represent the safe minimum standard of resource use.

By framing the problem as a decision matrix two states of nature can be assessed, one resulting in the wide spread of salinity or one of a highly productive environment (see Table 3.1). The productive state of nature describes existing levels of productivity. Under this condition the total priced and unpriced cost to society of adopting the safe minimum standard, is the net priced cost of implementing the catchment management plan (denoted by C in Table 3.1). This cost is expected to greater than zero, otherwise farmers may already be operating under conditions set by the catchment management plan. The value of C can be determined without the need to value unpriced or external effects.

Table 3.1 Decision Matrix for the Gerangamete Catchment

Land Use Strategy	States of Nature		Maximum Loss
	Saline	Productive	
Current Land Use	B	0	B
CMP	C	C	C

The total priced and unpriced benefits to society of avoiding salinisation and irreversible resource loss, is denote by B, the monetary value of which is uncertain. The catchment management plan (the safe minimum standard) should be adopted if the benefits of avoiding salinisation and irreversible resource loss (B) is greater than the opportunity cost (C). The losses depicted in Table 3.1 are relative to the base value shown for the current strategy with a productive state of nature. Under the condition of the salinized state of nature, adoption of the catchment management plan will prevent a 'salinized' outcome.

3.2.3 Modification of the Decision Matrix Content

The catchment management plan can only be accepted if the benefits of avoiding salinisation exceed the costs of implementing the catchment management plan and if the cost is not unacceptably large. In order to make this evaluation, and to convince landholders and local government to provide funds to ensure a safe minimum standard of resource use, a quantitative evaluation of the costs and benefits is required. Where quantification is difficult, a qualitative description is necessary.

The priced cost of implementing the catchment management plan is expected to be borne by landholders in the Gerangamete catchment. The benefits on the otherhand will be partly to the landholders but also to the wider community (and thus are unpriced). The priced benefits (B(Priced)) to landholders from reducing salinity are the reduction in productivity loss and falling farm asset values, relative to the present. The unpriced benefits, on the other hand, are more difficult to quantify.

The distinction between priced an unpriced benefits and costs can be made as follows:

B(unpriced)	=	loss of current community awareness, current wildlife habitat.
B(priced)	=	yield loss, loss of capital values relative to the present.
B^*(unpriced)	=	increased community awareness, improved habitat relative to the present.
C = C(priced)	=	extra costs of the catchment management plan minus extra priced benefits.

The minimax decision criterion can now be reframed as illustrated in Table 3.2. The decision matrix outlined in Table 3.2, is an adaption of the theory to the problem under investigation, as it includes both the priced costs and benefits as the basis of the decision criterion.

While the priced costs and benefits can be quantified using traditional economic techniques, the unpriced benefits of avoiding irreversible loss due to salinity can only at best be made in qualitative terms. The net present value criterion can be used to compare the priced net benefit (priced cost minus priced benefit) against a qualitative description of the unpriced benefit of avoiding the spread of salinity and irreversible loss.

Table 3.2 Minimax Decision Matrix for the Gerangamete Catchment

Land Use Strategy	States of Nature		Maximum Loss
	Saline	Productive	
Current Land Use	B(priced) + B(unpriced)	0	B(priced) + B(unpriced)
Catchment Management Plan	C - B^*(unpriced)	C - B^*(unpriced)	C - B^*(unpriced)

The modified framework outlined above avoids the need to estimate the unpriced values, external costs and discounting that may be involved in intergenerational equity issues. Discounting is only used to provide an estimate of the opportunity cost of capital, which is borne by the current generation only. As such this technique provides a method for evaluating sustainable resource use that discriminates between economic efficiency and intergenerational equity, while at the same time forming a compromise between proponents of the traditional cost-benefit analysis and those who advocate for the maintenance of the resource base.

3.3 Identifying Priced and Unpriced Effects

Priced losses such as losses in agricultural production are factors that can be quantified using traditional farm budgeting techniques. Unpriced factors, on the other hand, are more difficult to quantify. A diagram summarising many of the priced and unpriced effects of salinity with and without the catchment management plan is presented in Figure 3.1. The purpose of this section is to detail these elements in full.

3.3.1 Environmental Impacts

Protection of the environment is paramount in any control program. While it is not possible at this point in time to fully quantify the current or future impacts of salinity on the environment, it is reasonable to conclude that:

- stream salinities will continue to rise, reducing biological diversity, reducing the breeding success of fish and other fauna, and increasing the risk of other forms of degradation (e.g. algal blooms, and bank and bed erosion);
- freshwater wetlands will experience rising salinity levels adversely affecting biological diversity and reducing the success of water bird breeding;
- low lying remnant vegetation will be further threatened when rising groundwater begins to affect the root zone; and,
- threatened species that use the river systems will be at even greater risk of local (or total) extinction.

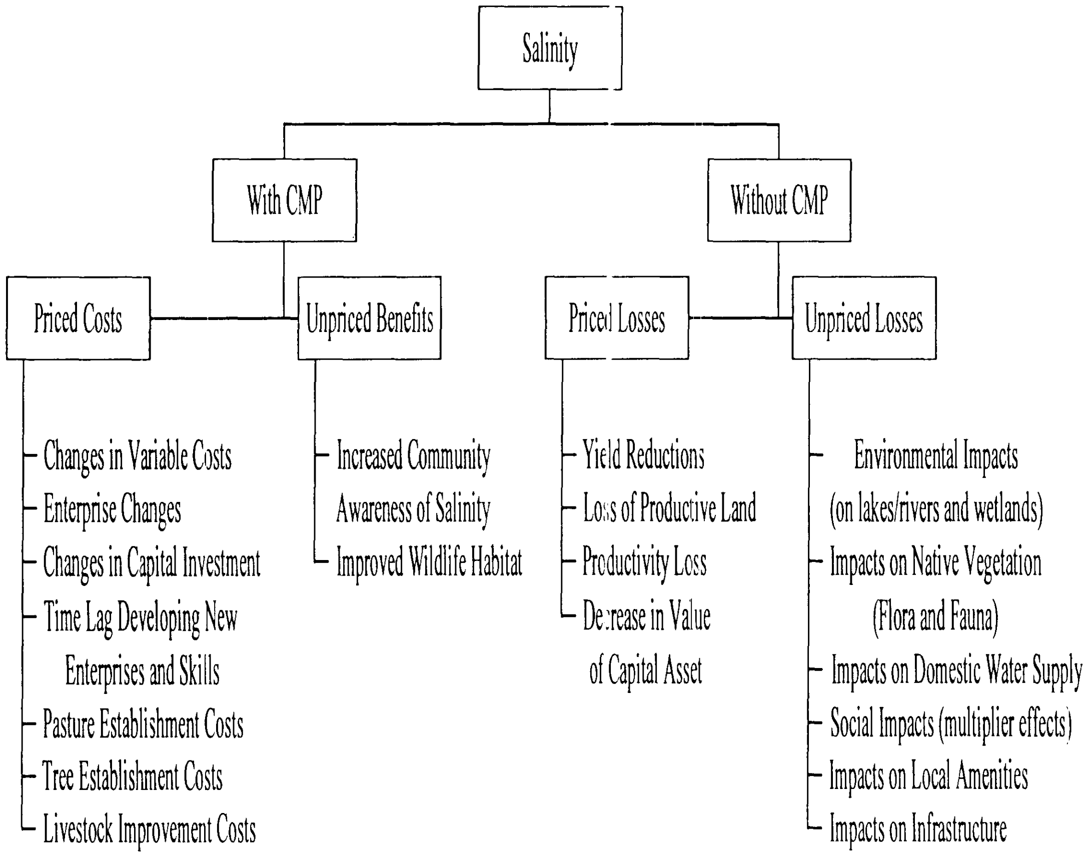

Figure 3.2 Sources of priced and unpriced effects with and without the CMP

3.3.2 Effects on Flora and Fauna

Native vegetation, and the habitat it provides for native fauna, has been cleared to provide for the expansion of agriculture. In the Gerangamete catchment, remnant vegetation is generally confined to areas where agriculture is not practical, such as wetlands, or to the narrow strips of Crown land that have been reserved along the banks of rivers and creeks. These remnants may have escaped clearing however, because of their position in the landscape, they have the potential to be threatened by rising groundwater and salinity.

The salt tolerance of native flora and fauna varies. Some species can tolerate wide fluctuations in salinity but many others exhibit only a fairly narrow tolerance. Direct, adverse biological effects are considered likely once the salinity of rivers, streams or wetlands exceeds 100 mg/L (1666 electrical conductivity). Macrophytes (large aquatic plants), microscopic algae and invertebrate animals are the organisms generally considered to be most sensitive to salinity (Glenelg Region Salinity Forum, 1993).

Species capable of tolerating wide variations in salinity often require a gradual transition from fresh to saline water, or the reverse. Rapid changes in salinity are considered fatal to many plants. These rapid changes often occur with the highly saline runoff water that accompanies the annual autumn break or with the sudden release of fresh water from reservoirs. The tolerance of species also varies with life stages. Adult fish, for example, are generally tolerant of high salinities but fish eggs are tolerant of only a relatively narrow range of salinities. Similarly, adult plants may be reasonably tolerant of salinity but seeds and seedlings may be highly sensitive.

Salinity affects ecosystems as well as individual species. The loss of one species, due to high or rapidly fluctuating salinity, will have ramifications for other species that may prey upon it or otherwise rely on it as part of an aquatic food cycling process or some other ecological role. This results in the loss of species that may be tolerant of the salinities present in a system, but which no longer have access to necessary resources.

3.3.3 Impacts on Water Supply

Increases in salinity can shorten the life of domestic and industrial reticulation systems resulting in serious economic impacts. Corrosion of water-using appliances, such as washing machines, increases. Beneficial uses may be restricted to the point where the water becomes unsuitable for human consumption and, if the problem is even more serious, not suitable for either stock watering or irrigation. Guidelines to the use of saline water is presented in Appendix B. When problems of this magnitude occur, the high capital costs associated with dam construction and the establishment of reticulation systems may effectively be wasted and alternative water sources must be obtained, often at a considerable cost to the community.

3.3.4 Impacts on Infrastructure and Amenities

Rising saline groundwater has the potential to affect roads, buildings and other infrastructure by rendering foundations unstable and by corroding structures mounted on or in the ground. Costs associated with this sort of damage include increased maintenance costs, reduced service life and increased water treatment costs. Some industries, depending on the water quality, may be unwilling to locate in the affected region if high water treatment costs are likely.

A reduction in the environmental values of waterbodies (lakes and wetlands) seriously affects recreational values, such as wildlife appreciation, fishing, hunting and boating. Tourism associated with these activities may make a significant contribution to local economies and consequently, any reduction in environmental values as a result of salinity, may result in significant costs to the community.

3.3.5 Social Impacts

The social impacts of salinity are possibly the most serious of all, but are also the most difficult to clearly identify and measure. These relate to the multiplier effects of lost income from agriculture and other industries, the concomitant declines in population and the values of a rural lifestyle. While it is difficult to separate the social impacts of salinity from the impacts of declining commodity prices and the structural change of the agricultural and service economy, it is inevitable that if salinity is permitted to spread at current rates, the viability of small rural communities are likely to suffer.

3.4 Safe Minimum Standard and the Project Life

Most of the costs incurred for the adoption of the catchment management plan will be in the early years with the benefits occurring later. The net present value criterion used to evaluate the catchment management plan only compares the total cost against the total benefits of avoiding irreversible losses. It does not indicate the size of cumulative losses incurred by landholders, nor the periods over which it occurs.

In this study however, by estimating the priced costs and benefits on an annual basis over the project life, the maximum loss can be estimated and used as a cost constraint (i.e. adopt catchment management plan if cost is not unacceptably large) for the acceptance of the catchment management plan. The maximum accumulated loss during the project life is the cost that needs to be borne by landholders and government, if the catchment management plan is to be successfully adopted. It can at best be described as the insurance premium to avoid potential irreversible losses.

3.4.1 Requirements for Analysis

The decision matrix selected to a large extent determines the data requirements. The decision matrix outlined above, (in Section 3.2.3), provides a comparison of the effects of current land management practices with those described by the catchment management plan. The basic premise is that the catchment management plan will assist to redress the problems of salinity and ensure sustainable resource use.

In order to undertake an evaluation a quantitative analysis of the flow of costs and benefits under the current and catchment management plan is required. Discounted cash flow analysis is a widely used technique in project appraisal, because not only does it provide net present values for each strategy, but it also displays the cumulative difference between strategies on an annual basis. While the results derived using this technique are deterministic, sensitivity analysis are normally undertaken evaluate the effects of various scenarios on the final outcome. However, when judging risk and uncertainty surrounding a project, Anderson and Hardaker (1985) point out that sensitivity analysis is inadequate. They suggest that the social expected present value E[PV] is an inadequate criterion to use under circumstances where benefits are uncertain and irreversible costs are relatively high. They advocate a more formal analysis of risk assigning probabilities to a range of alternative assumptions.

3.5 Discounted Cash Flow Analysis

Discounted cash flow analysis involves estimating the amount of cash flowing into and out of a business venture over the life of the investment. Put simply, the discounted cash flow analysis considers the time value of money by discounting future cash flows back to their present worth. This approach provides three discounted cash flow measures of project worth, namely:

- the net present value (NPV);
- the internal rate of return (IRR); or
- the net benefit cost ratio (BCR).

A detailed description of the formulas used to calculate each of these measures is presented in Appendix D. Such a technique is necessary if the decision maker has limited funds and if the projects under consideration are mutually exclusive or independent.

'Discounting is essentially a technique by which one can reduce future benefit and cost streams to their present worth...' (Gittinger, 1982, p304). The discounting technique enables a comparison of different projects that have costs and benefits falling at different times during the project life and also between projects of different duration. The reference point for these measures is the present, the reference concept is the net present value and the procedure of discounting future streams of benefits and costs allows them to be compared at present values.

3.5.1 Discount Rates

Most investment decisions involve some element of choice between present and future income. When making investment or resource use decisions which have effects spread over time, the costs and benefits of the alternatives under consideration must be converted to a comparable basis. The commonly recommended procedure is to convert the future stream of expected net benefits to its discounted present value (Pearce *et al.*, 1990; Makeham and Malcolm, 1993).

The interest rate factor used to reduce income received in later years to its current income is referred to as the discount rate or the rate of return. As the discount rate increases the present value of future income declines (see Appendix D). Thus the choice of a discount rate plays a crucial role in investment project appraisal and private decision making, both generally and with respect to resource conservation issues.

Two approaches are commonly used to determine the appropriate discount rate used in cost-benefit analyses. The first approach is to use the social rate of time preference, which is based on the degree to which individuals are willing to trade off reductions in current consumption for gains in future consumption. People with a higher rate of time preference place greater weight on the present. They are more willing to accept long-run costs for short-run benefits, and less willing to accept short-run costs for long-run gains (Boyce, 1994). A person's rate of time preference will be a function of existing wealth, expected income, certainty of future income, age, health and concern for future generations (Schmid, 1989).

The second is the opportunity cost approach, which is based on the rate of return which could be achieved by investing in some activity other than the one being evaluated. In the ideal theoretical case of a perfect capital market, all investors would operate with the same discount rate, which would equal the market rate of interest. In reality however, the discount rates used by most investors in decision making depend partly on their preferences for present and future income and the situation involved (Pearce *et al.*, 1990; Howarth and Norgaard, 1993).

Because most practices resulting in resource use or degradation are likely to increase present income at the expense of future income, the higher the discount rate used, the more rapid will be the rate of land degradation. Higher discount rates provide relatively greater weight to costs and benefits occurring in the near future and would, other things being equal, increase the likelihood of judging as unprofitable any investment or resource use decisions tending to result in high net returns in the more distant future (Mishan, 1982; Pearce and Turner, 1990).

One of the questions commonly raised is whether or not the rates of discount, used by individuals in making decisions about resource use, accurately reflects society's valuation of future costs and benefits (Burton, 1993). Some argue that they do not and that private discount rates are too high. If this were true, there would be a persistent tendency for private resource use to be in excess of those preferred by society. For instance, environmentalists argue that environmental assets constitute a special case for which a zero rate of discount is appropriate. A zero rate of discount would justify almost any project which reduced resource degradation, while a rate of ten per cent would justify high rates of resource use and perhaps resource use in excess of those preferred by society. On the other hand, lowering the discount rate in order to deal with this problem may also be counter productive as it would result in a disproportionate level of investment in those projects with long streams of benefits but whose costs are incurred at an early stage. It could also result in higher levels of investment and hence demand for natural resources, leading to greater levels of degradation (Pearce and Turner, 1990,).

3.5.2 Pricing Adjustments

The shadow price is the value used in economic analysis for a cost or a benefit in a project when the market price is felt to be a poor estimate of economic value (Gittinger, 1982). For intermediate goods and services, the shadow price is the opportunity cost, the benefit foregone by using a scarce resource for one purpose instead of its next best alternative. The opportunity cost is equal to the marginal value product, the value of additional output generated by an additional unit of variable input.

In a perfectly competitive market, the opportunity cost of a good is its price and is equal to the marginal value product of the item. When the market price is a good estimate of the opportunity cost, the market price can be accepted directly as a measure of its economic value. If however, there are distortions in the market, for institutional reasons of one kind or another (e.g. due to monopolies, taxes or subsidies) the market prices can vary significantly from the shadow prices (Sugden and Williams, 1978; Schmid, 1989).

For most investment projects the interest rate used is that which applies to government bonds. These rates are however nominal rates and need to be adjusted to account for the effects of inflation. The procedure for converting nominal to real rates is presented in Appendix E.

3.6 Risk Analysis

Almost all social choices relate to actions whose consequences are highly uncertain. Project appraisal techniques, such as investment and cost-benefit analyses, are widely used and well accepted in several areas of social policy making. Too often however, social choice options are analysed under the assumption of perfect certainty or the recognition of uncertainty is confined to a limited amount of sensitivity analysis. Seldom are appropriate distributions for the relevant uncertain quantities included explicitly in the analysis.

Jayasuriya (1992), states that no comprehensive analysis of sustainability can ignore risk and uncertainty considerations. This is supported by Anderson *et al.* (1977) who suggest that while accounting for risk adds an extra dimension of complexity to an already complex task, it is well justified in that it will provide a more complete and valid representation of the possible consequences of alternative actions.

'A risky investment is one for which the cash flow stream is uncertain...' (Anderson *et al.*, 1977, p249). Risk in a production process is when an individual is aware of all possible outcomes that could result from the process and could attach a probability to each outcome. Uncertainty, on the other hand is when an individual is unable to associate probabilities with the outcomes of the production process (Doll and Orazem, 1984). Writers in modern decision theory often use either of the terms risk or uncertainty to refer to situations where complete information is lacking. As Anderson *et al.* point out,

> 'Decision analysis, by its formal procedure, enables a manager better to ensure that his risky choices are in line with his preferences and beliefs and that full value is extracted from all the information available to him' (Anderson *et al.*, 1977, p12).

When using stochastic simulation in decision analysis different variations are sampled from probability distributions specified within the model. The process of simulation can aid in investment appraisal by exploring possible investment strategies and their uncertain consequences (Pandey and Hardaker, 1995). For instance, it is useful for exploring the consequences of stochastic dependence resulting from the joint dependence of some variables on other common variables. (Anderson *et al.*, 1977; Pandey and Hardaker, 1995).

Cassidy, Rodgers and McCarthy (1970), when evaluating a pasture improvement program, used triangular distributions to derive probabilistic estimates for the stochastic events considered. The triangular distribution is unimodal and is defined by estimates of the mode (most likely), along with minimum and maximum values. The method can be used to derive expected values (E[V]) from data used to describe triangular distributions. It can be described as;

$$E[V] = (\text{minimum} + \text{mode} + \text{maximum}) / 3 \qquad (3.4)$$

3.6.1 Stochastic Budget Components

The risk analysis approach for decision making builds upon the basic project appraisal framework by explicitly recognising the uncertainties which exists. This is done by specifying decision variables for each uncertainty and eventually generating a probability distribution for the decision criterion.

The variables to be considered when accounting for risk in budgets are related in the simple gross margin equation specified below:

$$G = Y(P - YC) - VC, \qquad (3.5)$$

where G denotes gross margin ($/ha);
Y denotes physical yield (t/ha),
P denotes price per unit of Y ($/t);

YC denotes unit variable costs that vary directly with Y ($/t); and
VC denotes other variable costs ($/ha).

The main advantage of undertaking stochastic analysis is that gross margins may be subject to a diversity of decision-oriented applications, such as the probability of encountering negative margins, or used to compare and contrast several competing activities (Anderson, 1976).

3.6.2 Choice of Probability Distribution

There are a number of distributions that could be used to describe the component variables used in a gross margin budget. Anderson (1976) provides a list of the suitability of some common distributions that can be used to describe the component variables. He states that certainty, normal, triangular and beta distributions are all applicable for describing each of the components of the gross margin equation. Other literature however express contrary opinion, notably on the use of normal distributions.

Day (1965) studying field crop yields concluded that distribution of yield is not described by normal probability distributions. Cassidy *et al.* investigating investment in pasture improvement point out that normal distributions are severely limited for such use, as they cannot be skewed and because of, '... the need to predict higher moments and not simple parameters may exceed forecasters capabilities' (Cassidy *et al.*, 1970, p6). To overcome this shortcoming they chose a triangular distribution. Anderson *et al.* (1977) also suggest the use of triangular distributions as they are easy to use. They point out that its clear nonnormality, and '... its economy in elicitation and parametric description' are also beneficial (Anderson *et al.*, 1977, p268).

3.6.3 Correlation Between Variables

A wide variety of possibilities exist for interdependencies among variables. An independent variable is one that is functionally unrelated to one or more independent or predictor variables used in the model. This means that the occurrence, or non-occurrence, of one of the events does not change the probability of the occurrence of the other event. In risk analysis this leads to independent sampling of uncertain variables.

A dependent variable by contrast is one which is functionally related to one or more independent or predictor variables used in the model, whereby the outcome of one event can affect the outcome of another event (Mendenhall and Reinmuth, 1982). On each simulation run, a value is sampled for the independent variable and this in turn is used to determine which of the series of conditional distributions would be utilised for subsequent sampling.

Hertz and Thomas (1983) point out that first applications undertaken of risk analysis ignored the existence of correlation between variables because correlation patterns were difficult to identify and measure and also because it simplified model development and enabled the results to be analysed quickly and efficiently. They point out however that,

> '.... overlooking correlations in project variables would probably lead to a misleading risk analysis and worse still, it would allow incorrect conclusions to be drawn on the basis of the results of the decision analysis' (Hertz and Thomas, 1983, p170)

Despite the difficulties in modelling correlation patterns, Hertz and Thomas suggest that it is most crucial that these correlation structures between variables be established at the stage of decision structuring, as at this point trade-offs can be made between model complexity and problem reality.

3.6.4 Selection of a Decision Criterion

The outcome from a particular simulation depends on the combination of input variables. Each input variable provides a range of possible results and the probability of their occurrence, which is described with a cumulative distribution function (Cassidy, Rodgers and McCarthy, 1970). Risk analysis using this sort of decision criteria are stochastic dominance, and stochastic dominance with respect to a function.

With the stochastic dominance approach the entire range of likely outcomes for a project investment are examined, rather than concentrating upon parameters of the distribution of outcomes, such as the expected value or the variance. This provides a way of ranking risky alternatives without detailed knowledge of the decision makers preferences (McCarl, 1990). It is therefore seen as an additional refinement to the mean-variance type of analysis, rather than as an alternative (Hertz and Thomas, 1983). Analysts assess stochastic dominance in terms of a first or second degree.

> 'First degree stochastic dominance impl es that any decision maker who prefers more wealth to less should never choose a portfolio whose cumulative distribution function curve lies anywhere to the left of any other portfolio under consideration' (Hertz and Thomas, 1983, p135).

In graphical terms, the distribution function B is stochastically dominant over A (see Figure 3.3). Distributions that are dominated are said to be stochastically inefficient, while those (in general intersecting) distributions that are not so dominated are said to be stochastically efficient to the first degree.

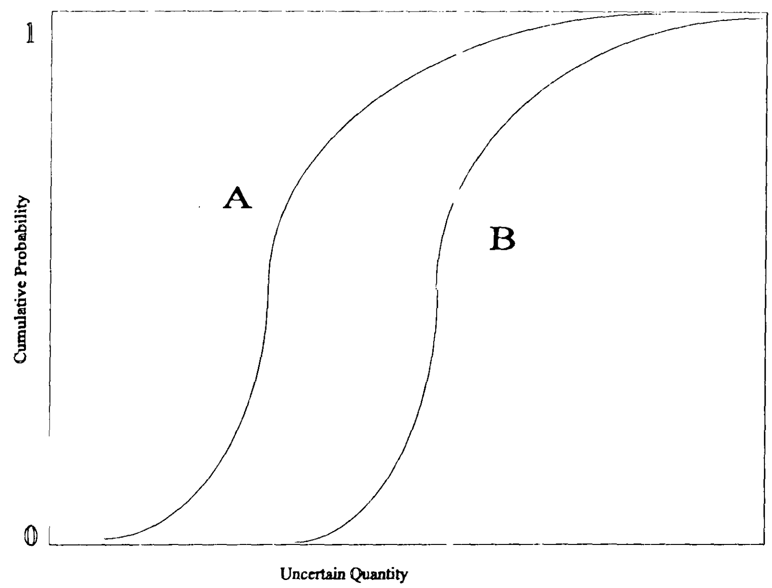

Figure 3.3 First Degree Stochastic Dominance

Second degree stochastic efficiency (SSE) provides a means for eliminating distributions from the first degree stochastic efficiency set that are inefficient or dominated in the sense of second degree stochastic dominance. Second degree stochastic dominance depends on the additional assumption that the decision maker is decreasingly risk-averse with increasing wealth. A distribution function B dominates another A (dominance in the second degree) if, (i) it lies more to the right in terms of differences in area between the cumulative distribution function curves cumulated from the lower values of the uncertain quantity, (ii) its mean is greater and, (iii) the smallest value of a dominant distribution cannot be less than the smallest value of a dominated distribution (Anderson, *et al.*, 1977). Second degree stochastic efficiency is illustrated in Figure 3.4, where the area marked A exceeds the area marked B.

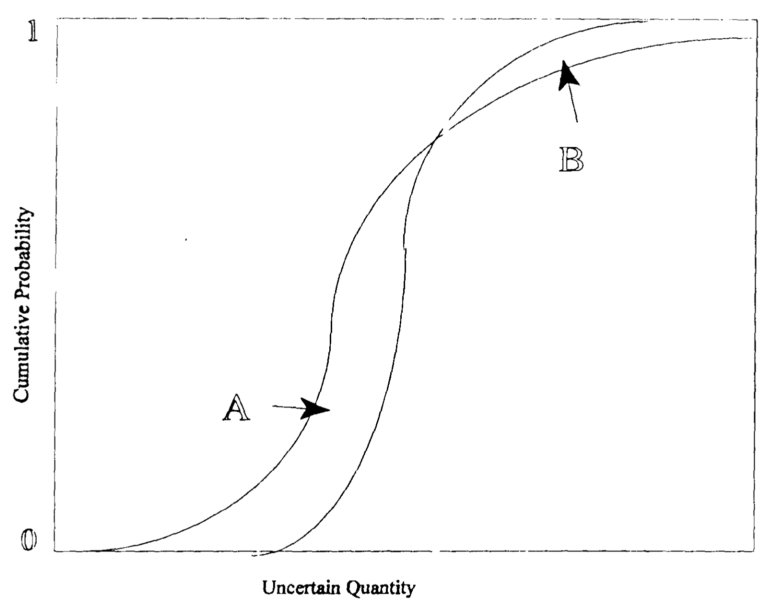

Figure 3.4 Second Degree S:ochastic Efficiency

3.6.5 The Simulation Model

In this study a deterministic discounted cash flow model is used to estimate the priced net social benefits from implementing the catchment management plan. Then a stochastic risk analysis using Monte Carlo simulation is undertaken on the model. The discounted cash flow analysis is combined wi!h an add-on program, @Risk™, which is used to undertake the risk analysis. The risk analysis program enables incorporation of the probability distributions into cells in the spread sheet that display a determinant value. The simulation process was used to ca.culate cumulative distribution functions for a range of decision criterion. Each simu'ation represents a very large number of 'what if' scenarios.

In the spreadsheet model development stage, uncertain values in the model were defined. The factors that have a major influence were identified as being probabilistic. These were inputs, yields and prices. Once uncertain variables were identified, the probability distribution that best describes thai uncertainty and the dependence on other key variables had to be determined. While identification of the active variables was simple, quantification of their inherent variability proved to be very difficult. This limitation was removed using triangular distributions as described by Cassidy *et al.* (1970) where uncertain variables were described in terms of mode, minimum and maximum values for use in the triangular probability distribution. These data were obtained from Australian Bureau of Statistics, interviews with some farmers, agronomists and economists in the region.

In addition to identifying certain and uncertain variables, variables were also identified for their dependancy on other variables. Where correlation between variables were identified, correlation coefficients had to be specified (between -1 and 1). If coefficients were not specified @Risk uses the default value of zero.

A techniques known as Monte Carlo sampling, which uses random numbers to sample from a probability distribution, was then used. The process of selecting values from the probability distributions is called sampling and each calculation of the worksheet is called an iteration. With sufficient iterations Monte Carlo sampling recreates the input distributions through sampling. One of the problems that can arise when a small number of iterations are performed is that of clustering. Clustering becomes especially pronounced when a distribution includes a set of low probability outcomes. This problem however can be overcome by using a stratified sampling technique known as Latin Hypercube sampling (Palisade, 1994).

Latin Hypercube sampling is designed to recreate the input distribution through sampling in fewer iterations. This is done by stratifying the cumulative curve into equal intervals on the cumulative probability scale (0 to 1.0) and then taking a random sample from each interval or "stratification" of the input distribution. The technique being used in conjunction with Latin Hypercube sampling is "sampling without replacement". This means that once a value is taken from a stratification, the stratification is not sampled again. The number of stratifications of the cumulative distribution is equal to the number of iterations performed. In this study 600 iterations were undertaken.

3.7 Summary

In this chapter, the method used to analyse the study was outlined. In this study the priced benefits and costs of adopting the prescribed catchment management plan for the Gerangamete catchment will be compared against current land use practices. The minimax decision criteria will be used to compare the net present value of priced benefits and costs against unpriced benefits and costs (descriptive) of avoiding irreversible loss. The priced effects will be quantified using a spreadsheet that combines a deterministic discounted cashflow model and a risk analysis model. The risk analysis will be undertaken using a Monte Carlo type simulation.

The safe minimum standard approach for empirically estimating the benefits and costs of the catchment management plan was examined for its usefulness and applicability to problem under investigation. This technique was selected as it avoids the need to estimate unpriced values, external costs and procedures of discounting that may involve intergenerational issues. Discounting need only be used to provide a present value estimate of priced benefits and costs.

4. Data

4.1 Introduction

The aim in this chapter is to outline the data needed to undertake this study. The data on the hydrological effects of different salinity reducing strategies including continuing the current land practices, was obtained form the Mike-SHE model. This model needs to be combined with farm level data to assess the economic effects of the catchment management plan. The data needed to complete this task is reported below, while details of the hydrological model was reported in chapter 1.

4.2 Catchment Management Plan

The wide variation in groundwater characteristics and surface physiography of the catchment will be reflected by an equally wide variation in the nature, cause and severity of dryland salinity. These variations require that physical control measure for salinity are tailored to suit the nature and cause of the problem and local land characteristics.

The Gerangamete catchment management model and plan was developed by Sinclaire Knight Merz, in conjunction with the Department of Natural Resources and Environment (DNRE), Victoria. The aim of the model was to prevent the spread of salinity and rising watertables in the catchment. Prior to developing the catchment plan a number of possible management scenarios were simulated to examine their impact on groundwater recharge and the spread of salinity. The results of the various scenarios generated by the Mike-SHE model were then used to establish a planning framework for the development of the catchement management plan.

Within the sub-catchment model an assessment was made of the nature of groundwater conditions. The groundwater flow system have been categorised in terms of whether it is local or regional in character and a generalised description of the location of high recharge areas was made. Where possible, schematic landscape and groundwater profiles were also developed to elucidate the processes occurring. Detailed hydrogeologic modelling of infiltration rates and bore response characteristics enabled the estimation of recharge rates in millimetres per year to be estimated.

In this study, three qualitative recharge classes were established, moderate (50-500 mm/day), slow (5-50 mm/day) and very slow (less than 5 mm/day). This is a proportional assessment based on the likely range of recharge to groundwater and therefore the absolute rate of recharge for the high recharge class may differ from one part of the catchment to another. Estimates of the proportion of the landscape contributing to each recharge class were made by determining the soil characteristics most likely to support rapid infiltration rates. These soils will usually be associated with a particular landscape position and the proportion of the landscape occupying this position was estimated.

4.2.1 Current Land Use

The Gerangamete catchment covers an area of 2000 ha. Livestock-related agricultural enterprises are most dominant, particularly dairy farming and beef production. Vegetable production, particularly potatoes are a minor enterprise in the catchment (less than ten hectares).

The existing improved pastures are predominantly perennial ryegrass/white clover mixes. The ratio is about 60 per cent perennial ryegrass to 40 per cent clover. The pastures used for beef production are not as good as those used for dairy production, with considerably less clover and ryegrass and more weeds such as fog grass and bent grass. Pastures are rotationally grazed under dairy and set stocked for beef. Dairy farmers on average apply about 300 kg of super/ha/yr, while beef farmers apply about 100 kg super/ha/yr.

4.2.2 Recommended Agricultural Practices

The catchment management plan outlines planting about 20 per cent of the catchment (half of the existing areas of unimproved pasture) to trees (322 ha) and improving all native (unimproved) pastures to improved perennial pastures (322 ha).

The implementation targets for the pasture and tree programs are based on an estimation of annual groundwater infiltration for soil type, combined with a detailed knowledge of plant water use. These estimates of the area requiring treatment by either trees or deep rooted pastures was made in consultation with relevant Department staff which was thought to be sufficient to either reverse groundwater trends where salinity is currently a problem, or to stabilise trends where salinity is not yet a significant problem.

4.3 Commodity Prices, Yield and Variable Cost Data

For each enterprise commodity prices, yield and variable costs were obtained as mode, minimum and maximum values. From this the gross margins were estimated (see Table 4.1). Expected values were calculated as a mean of the three parameters for use in the discounted cash flow analysis. The mode, minimum and maximum values provided the points for triangular distributions used in the risk analysis.

Commodity prices were obtained from the Australian Bureau of Agriculture and Resource Economics (ABARE,1996). These annual prices were used so as to avoid price fluctuations and were adjusted for the CPI to reflect current prices. Variable costs were estimated after discussions with the appropriate staff from the Department of Natural Resources and Environment while stocking rates were obtained from local landholders in the catchment.

To estimate the cost of dryland salinity in the catchment, gross margins were used to reflect the value of the productive capacity of land lost to salinity. Gross margins are defined as the income minus the variable costs for a particular enterprise. They are usually expressed in dollars per hectare and are used to compare enterprises with similar overhead costs. Overhead or fixed costs will not be taken into account as they will not vary directly with the size of the enterprise. The extra costs and benefits of each strategy was identified.

4.4 Effects of Salinity

The rate of expansion of salinity will largely depend on the rate at which water tables rise but will also be influenced by local topography. From the model, it was forecasted that the area of salt affected land would double from 80 ha to 190 ha over the next thirty years. The future costs of salinity were therefore based on a range of nominal expansion rates from two per cent per annum (considered to be a probable minimum) to five per cent per annum (a likely maximum).

4.4.1 Groundwater Trends and Projections

Within the modelled area in some parts of catchment the watertable can be as high as two metres from the ground surface. This tends to occur primarily during the winter and spring months, when infiltration is above evapotranspiration.

Table 4.1 Gross Margins for Agricultural Enterprises ($/hd)

Commodity	Min	Mode	Max	E[V]
Beef Cows	150	180	200	174
Steers	80	100	130	104
Dairy Cows	658	732	805	732
Potatoes ($/tonne)	200	260	300	253

4.4.2 Estimating Costs and Benefits of the Pasture Program

Research shows that upgraded perennial pastures have a higher water use than native pastures and will therefore reduce recharge to the watertable thereby reducing saline discharge. The costs and benefits of perennial pastures establishment will therefore be evaluated. The pasture mixes to be promoted in this study was a Phalaris/sub clover and Perennial ryegrass/Phalaris/sub clover pasture. Pasture establishment and maintenance costs are given in Appendix F.

Stocking rate increases were obtained from information provided by local extension staff in the district. The existing stocking rate on unimproved pastures was estimated to be 0.54 cows/ha. In the year following the pasture renovation, stocking rates were assumed to increase to 0.7 cows/ha, and the full stocking rate (0.9 cows/ha) in all subsequent years. Annual maintenance, the life of the pasture stand, and the expected time (years) required for the targeted area to be sown to pasture were also estimated.

Included as a cost is the extra stocking rate required with a new pasture as stock need to be bought in or retained to make use of the extra feed. This cost was only applied in the two years after renovation as the stock assumed to be bought in will be self replacing. The opportunity cost of land in the year of establishment was not included, as a stocking rate is at least equal to the previous rate can be expected in this year. Those benefits that cannot be quantified include an improvement in soil structure and a reduction in the discharge of salt to rivers, streams and reservoirs.

4.4.3 Estimating Costs and Benefits of the Tree Program

The tree program involves the planting of trees on recharge areas in order to reduce groundwater flow to discharge areas. For the tree program it was assumed that blue gums will be planted on a contract basis, with lease payments paid annually to the landholder. Lease payments were estimated in terms of mean, mode and maximum values (see Table 4.2). The total area to be planted to trees was 322 ha. The adoption rate for tree establishment was assumed to be 10 years, (or 32.2 ha/yr). The lease period is for the entire 30 year study period. Under the lease arrangements trees will be harvested twice, at years 12 and 24. Once the total area to be planted to trees has been reached, it is aaumed that this area will be maintained for the entire study period. Under the lease arrangement landholders responsibilities are limited to providing a fenced off paddock, maintenance of stock proof fencing and the payment of rates. All other costs incured in the establishment and maintenance of the blue gum plantations will be met by the leasing company.

Lease payments vary with the potential productivity of the land and haulage distance to the processing plant/port. The estimation of total tree benefits also include savings in labour costs associated with land taken out of dairy production for trees, and have been included in the analysis.

Other than the timber benefits mentioned, gains from honey production are also possible. Planting trees on a property will also have an added benefit of attracting native wildlife and improving the appearance of the property, often resulting in increased land value. These benefits were not included in this analysis.

4.4.4 Governement Costs

Common (1989) suggests that most analyses of policy instrument choices are based on the assumption that monitoring is costless or unnecessary. To overcome this, Poulter, (1991) suggests that monitoring costs must be considered along with information and enforcement costs when evaluating various policy alternatives and when determining whether the total costs of government intervention exceed the benefits. The two major government costs relating to this study are those costs associated with undertaking the hydrological modelling and future monitoring and extension costs in relation to implementing the catchment management plan. The research cost was a one-off cost of $50,000 in year one. Extension and monitoring costs were estimated to be $10,000 per year for the first four years of the projects life.

Table 4.2 Annuities for Blue Gum Plantations ($/ha)

Commodity	Min	Mode	Max	E[V]
Blue Gums	120	150	180	150

4.5 Data Treatment

The Mike-SHE model was used to generate (sythetic) climate sequences of rainfall and corresponding evaporation. The generation was based on 15 years of actual climate data. During the simulation 100 sets of 30 year sequences were generated and the 10th, 50th and 90th percentile sequences were selected. That is, for each model prediction run the wettest, mean and driest climatic records were simulated. The data generation process was undertaken in preference to simple historic data repeated for the 30 year period, as it enabled better representation of the likely trends of climate variation. A description of the parameter requirments for the model is provided in Table 4.3.

In order to investigate the costs and benefits of implementing the catchment management plan, gross margins were prepard for each of the agricultural activities present in the catchment. The gross margins were then aggregated to give the net margin for the catchment under both strategies. The net margins for the current landuse took into account reduced area available for agriculture due to increasing salinity and associated yield reductions.

The area of agricultural land lost to salinity was described as a cumulative loss function, whereby the area of salt affected land and estimated production loss was assumed to be vary between years, increasing at an average of 2 per cent per annum. The production loss from saline land was assumed to be 100 per cent.

A study period of 30 years and a social discount rate of five per cent was used to represent the opportunity cost of capital. The 30 year study period used to model the groundwater hydrological proesses enabled all costs and the majority of the benefits associated with the plan to be accounted for.

Commodity prices, crop yields, capital and variable costs and the rate of salinisation were all identified as uncertain variables. Stocking rates and pasture growth were assumed to be dependent variables.

Table 4.3 Parameter Requirements for MIKE-SHE Model

SHE Input Data	Parameter Requirements	Source of data	Data Confidence
Topography	DEM areal data	1:25000 Gerangamete Topographic map sheet	Whole catchment[1]
Geology	Geological layers	1:50 000 Colac Geological map sheet CLPR Bore Logs; GDB Bore Logs	Whole catchment[1]
	Geological Parameters (Kh,Kv,Sy and S)	Lakey & Leonard 1984: Regional pump test data	Whole catchment[1]
Groundwater Data	Monitoring bore network (rwl)	CLPR (1989-current); GDB	Sub-catchment[2]
	Watertable elevation	CLPR (1989-current); GDB	Sub-catchment[2]
	Initial heads	CLPR (1989-current); GDB	Sub-catchment[2]
Climate	Rainfall		Whole catchment[1]
	Evaporation		
Soils	Areal distribution	CLPR soil logs and land system division	Sub-catchment[2]
	Soil parameters (Ksat etc)	CLPR infiltration test parameters	Sub-catchment[2]
Vegetation	Areal distribution	CLPR	Sub-catchment[2]
	LAI, root depth	CLPR	Sub-catchment[2]
	Land use	CLPR	Sub-catchment[2]
Surface Water Data	Barwon river system flow data	Theis	Whole catchment[1]

Whole catchment[1]- Data based on information relevant to whole model area

Sub-catchment[2] - Data covering model grid sourced from information from Gerangamete pilot site and extrapolated to whole catchment

CLPR -Centre for land protection; DEM -Dept. of Energy and Minerals; LAI - Leaf area Index;

(Source: Sinclaire Knight and Merz,Victoria).

4.6 Summary

In this study the catchment management plan reflects a safe minimum standrad of resource use by describing land use practices that need to be implemented to minimise groundwater recharge and to ensure sustainable resource use. The cost of adopting the catchment management plan will be borne by existing landholders in the catchment and local government. The benefits of the catchment management plan were measured in terms of increased agricultural production and farm assets not lost to salinity.

A spreadsheet model which combines a deterministic cash flow analysis and risk analysis will be used to evaluate the catchment management. Data were obtained for minimum, mode and maximum yields which provided the points for triangular distributions to be used in the risk analysis. Expected values were calculated as an average of the three parameters for use in the discounted cash flow analysis.