Managing Soils Under Intensive Cropping in West Gippsland

Results and recommendations from a research and development project.

A National Soil Conservation Program Project
jointly supported by:

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SUMMARY

This document summarises research and development work undertaken by a Project Team comprising officers of the Departments of Agriculture, and Conservation and Environment into ways to improve sustainable soil management under intensive cropping (especially for potatoes) in high rainfall West Gippsland. The project was supported by the Gippsland Hills Potato Growers and the Gippsland Field Days, and substantially funded by the National Soil Conservation Program.

One objective of the project was to obtain information on various management techniques with respect to soil structure, soil erosion, agricultural productivity and their potential impact on water quality. The subsequent objective was to develop, and promote the adoption of, an integrated soil management package in the target area.

The region is described, particularly with regard to its soils, climate and agricultural productivity.

An early undertaking of the project was a survey of the soil management practices of Gippsland potato growers. important findings included that most growers recognised soil erosion on their own properties and believed it would continue with current practices. Many growers were already using good techniques such as growing green manure crops, ripping wheel tracks and deep-ripping during cultivation.

The project undertook land capability and erosion hazard mapping for the Thorpdale district. Guidelines for land capability classing and its relevance to intensive cropping are discussed.

Research results showed clearly that ripping of wheel tracks greatly improves water infiltration rates and thereby reduces the likelihood of erosion. The practice is highly recommended especially around planting time and in combination with minimising cultivation and machinery traffic.

Work on green manure crops indicated their value in maintaining good soil structure between production crops. Their appropriate use and management are discussed, and they are recommended between all production crops.

The use of vegetated buffers to slow water movement and reduce soil loss on long. sloping crop rows was investigated. While the lack of storm events in the experimental years prevented definitive results, the use of buffers under appropriate circumstances is recommended.

The construction of diversion banks on two Thorpdale properties assessed their value in minimising soil loss and crop damage from storms and over-irrigation. Results showed that the banks were valuable insurance and could be worked with.

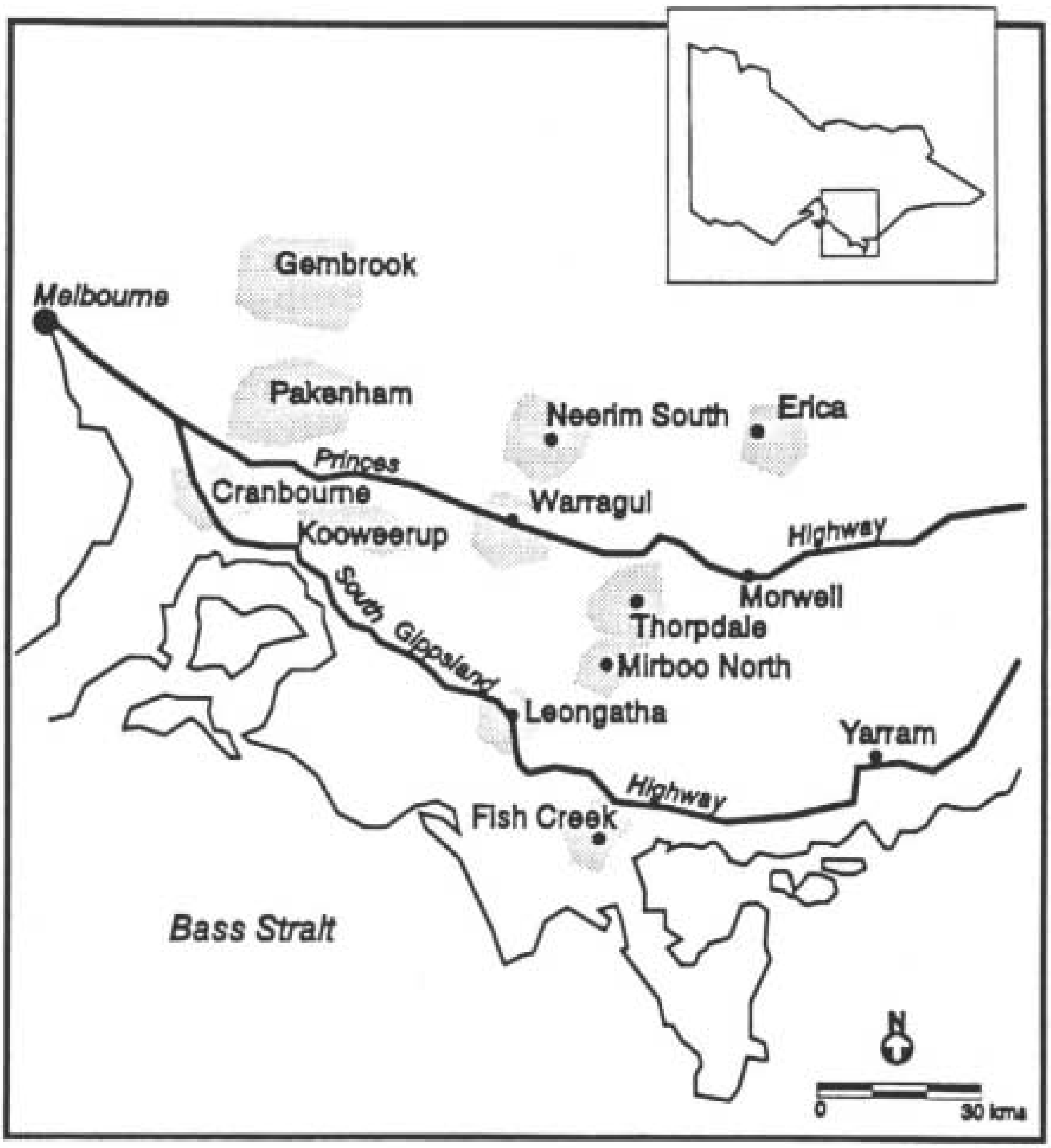
No effects on soil structure or crop growth could be found from the addition of up to 10 T/ ha of gypsum in one year to a paddock with soil structural problems. The use of gypsum and other soil ameliorants should be approached with caution.

The comments of other catchment users, especially town water supply authorities and local government, indicated a preference for the involvement of all catchment users and an educative approach in efforts to reduce soil erosion.

A summary of appropriate management practices concludes the report in the form of a chronological checklist for growers. This list places a major emphasis on planning ahead for soil erosion control.

Appendices contain lists of publications from the project, the personnel involved and the extension activities undertaken.

Figure 1 – Gippsland Horticultural areas



1. INTRODUCTION

The high rainfall areas of West and South Gippsland contain significant areas of prime agricultural land (see Figure 1). This land is important to the State particularly for its ability to be used for intensive agriculture. Such land is relatively scarce and needs to be managed to ensure it maintains its productive capacity in the long term.

Arguably, the best soils in the district are the krasnozems derived from tertiary basalt. Their value lies in their ability to produce well under intensive cropping. The climate is suitable for a wide range of temperate crops, with the reliable rainfall of around 1000 nun per year being adequate for direct use by many crops, while others are supplemented by on-farm water storage. West and South Gippsland are close to the major domestic market of Melbourne, which is also the centre of a significant export infrastructure for interstate and overseas destinations.

The main risks associated with agricultural use of these cropping soils are erosion in the cultivation phase, and loss of physical structure after regular cultivation. Some soil erosion has occurred at irregular intervals over recent years, particularly over the late spring period when heavy rains fall on land just before and after the planting of potato crops.

Soil erosion is recognised as a major cause of soil degradation in Victoria and throughout Australia (e.g. Mitchell, 1984; Mosley, 1984). The loss of soil structure due to regular cropping practices is a longer term problem that is likely to increase as there are pressures to expand cropping areas and shorten the rotation between crops. These issues are now attracting major attention from governments and interest groups such as the Australian Conservation Foundation and the National and Victorian Farmers Federations.

In 1987 the Victorian Government released its Conservation Strategy ‘Protecting the Environment’. As with the Economic Strategy for the State, this strategy recognizes the State's diverse agricultural base as a major competitive strength, but sees "land degradation as one of Victoria's most significant and widespread environmental problems". Objectives set out in the strategy relate to the restoration of land and the prevention of future degradation by the adoption of appropriate management techniques.

Likewise, the mom recently released Agricultural Strategy for Victoria, outlines the Government's commitment to sustainable agriculture. The strategy states in part, "Agricultural systems must be sustainable in the long run in that the basic resources of soil and water are maintained in a suitable state for production purposes". The strategy promotes the use of biologically sound farming systems that protect the soil from excessive damage by water, wind and traffic, and improve the infiltration of rain where it falls.

On a broader front, bodies responsible for land use planning and water resource management are developing arrangements and strategies that manage resources on a catchment basis. This approach recognises the important interactions between different segments and users of a catchment, and the need for an integrated effort if resources are to be protected and effectively used.

In Gippsland the Westernport Regional Planning and Co-ordination Committee advises on land use and planning issues in the western pans of Gippsland, while the Westernport Rivers Steering Committee has drawn up an activity plan for the rivers and streams in the Region. Much of Us plan has now been implemented by the Dandenong Valley and Western Port Authority. Further east, the Department of Water Resources has developed a "South East Region Management Strategy" which covers most of Gippsland.

Many farmers recognise the need to carefully conserve the natural attributes of their farms. Increasingly there are pressures from other community interests to ensure that individual farmers properly manage their land so that problems are not created (e.g. silting of dams, pollution of streams) and that good agricultural land will remain in a productive state.

The multi-use concept of catchments requires a responsible and educated approach by all users. At the same time, agricultural use of land will only continue if commercially viable practices are adequate to meet long term catchment objectives. Thus, from an agricultural view, there is little point in imposing conditions on farm management that prevent land use or make farm enterprises uneconomical. Accordingly, the underlying approach in the project documented in this report, is to address problems by looking for solutions that can be put together in an integrated management package that is attractive and acceptable to commercial farmers.

While the prime focus of the project is on agricultural practices, them are significant consequential issues and factors for other catchment users and managers of resources such as municipalities and water managers.

The project deliberately involved several partners who were key stakeholders in the problems and their outcomes. This allowed people with a range of expertise and views to address problems and develop a co-ordinated approach to the project.

The following chapters give details of the various aspects of the project and general results. Specific results from various pans of the project have also been documented separately. A list of publications is included as Appendix 1.

2 DEVELOPMENT AND OBJECTIVES OF THE PROJECT

This project was initiated out of concern expressed by farmers, community members and some staff of government agencies in West Gippsland after heavy rain storms caused significant soil erosion. There was general recognition that this periodic problem had to be addressed or, in the extreme, the future of intensive crop farming in the area would be jeopardised.

At this time some research work on the use of vegetative buffers in potato crops had just been completed at the Potato Research Station, Toolangi in Victoria. This research indicated a potential use of vegetative buffers to minimise soil erosion in potato crops. However, the technique needed to be tested in a commercial situation, and on its own was unlikely to solve the whole problem. The most likely requirement was for a package of management techniques that farmers could adapt to individual situations.

A project proposal was documented by the Department of Agriculture (DofA) (Gippsland Agriculture Centre and State Chemistry Laboratory), and the Department of Conservation and Environment (DCE) (Central Gippsland Region). The proposal was successful in gaining significant financial support from the federally funded National Soil Conservation Program over five years (1986-1991).

This project had two broad objectives:

(i) To obtain information on various management techniques in intensive agricultural crops with respect to soil erosion, soil structure, agricultural productivity and their potential impact on water quality.

(ii) To develop and promote the adoption of an integrated soil management package suitable for use on a commercial scale in intensive agricultural crops (especially potatoes) in West Gippsland.

The detailed tasks involved were:

(a) To assess the extent of current management practices and detail the requirements of farmers and water supply managers.

(b) To strategically measure soil movement in agricultural catchments with respect to slope length, slope angle, land management and rainfall intensity/duration characteristics.

(c) To assess the effectiveness of vegetative buffers and diversion banks in reducing the overland flow of water and sediment.

(d) To assess the effect of selected green manure crops on potato quality and yield, soil structure, soil erodibility and soil fertility.

(e) To assess the effect of trafficking and ripping on potato quality and yield, and soil Compaction.

f) To prepare an integrated (whole catchment) management package which enables flexibility of land use and sustained productivity.

g) To produce relevant extension material and demonstrations of successful practices on a commercial scale in West Gippsland.

The project commenced in November 1986 and was completed in October 1991. At the outset a Management Committee was established to oversee the general direction, and give approval to the components of the project as they evolved. This Committee also advised on general promotion and extension of the project.

The Management Committee consisted of the agencies involved (DofA, DCE) and grower representatives from Gippsland IERs Potato Growers and the Gippsland Field Days Committee.

The project involved an in-depth survey of local potato growers, field trials, detailed laboratory work, paddock demonstrations, the preparation of technical material for farmers and a major extension program.

3. DESCRIPTION OF THE STUDY AREA AND ITS SIGNIFICANCE

The three major natural requirements for potato and vegetable crops are:

- Deep, well drained friable soils.
- An adequate water supply.
- A suitable climate. The future success of Gippsland's cropping industries will depend on how well these essentials are maintained and protected.

3.1 Soils

The main cropping areas in Western Gippsland are in the naturally well drained soils of the Gippsland hills around Thorpdale, Gembrook, Mirboo, Warragul, Neerim and Leongatha. On the Koo Wee Rup swamp, tile drains are used extensively to improve drainage and remove excess water from paddocks after rain.

Soils vary throughout the district and not all are suitable for horticulture. The best soils for horticulture are the red gradational soils of basalt origin known as krasnozems. They are deep, friable and well drained, and occur mainly in the Warragul. Neerim, Thorpdale, Leongatha and Gembrook areas.

The vast majority of Gippsland's potatoes are grown on this soil type and it has therefore been the focus of work in this project.

3.2 Climate

The climate of West Gippsland is suitable for many agricultural uses. It is particularly suitable for potatoes and other horticultural crops. Elements of the climate that affect crop growth arr. rainfall, temperature, wind and daylight.

Rainfall in the Warragul district is generally in the range of 900 mm to 1100 mm per year, which is high for Victoria. However, the annual averages range from 800 mm in the west and east, through to 1400 mm in the Strzelecki's to the south, and 1700 mm in the Great Dividing Range to the north.

Temperatures in the main agricultural areas during spring, summer and autumn are generally ideal for horticulture. Frosts do occur in some areas during winter and when combined with cold, wet weather they restrict planting, growth and harvesting operations to certain months.

The long, hot summer days and cool nights typical of the Thorpdale and Neerim areas make them ideal for potato production.

3.3 Major land uses

Agricultural land use within the area is dominated by three major industries: dairying, grazing and horticulture.

(i) Dairying

Dairying is the major livestock enterprise and is carried out on a wide range of soil types and terrains.

(ii) Grazing

(a) Beef cattle can be divided into two main groups: breeding herds producing vealers or store cattle, and non-breeders where store cattle are bought in for fattening.

(b) Sheep comprise largely cross-bred ewes for prime lamb production and are often run as a sideline by potato growers.

(iii) Horticulture

(a) Potatoes

Potato growing is the major horticultural industry with approximately 5600 hectares producing 180,000 tomes. Most potatoes from the area are sold on interstate markets while a small tonnage is exported. The crop is valued at over $40M annually.

(b) Vegetables

Vegetable growing is scattered through the district, the main growing areas being around Koo Wee Rup and Cranbourne. Main crops include asparagus, carrots, peas, and cabbages.

(b) Fruit Crops

Apples are the main fruit crop grown, mainly in the area from Pakenham to Drouin.

(d) Intensive Horticulture

Intensive horticultural enterprises which include flower growing, plant nurseries, berry crops, nut trees and kiwi fruit are also scattered throughout the area. Because of its good soils, high, reliable rainfall and proximity to markets there is potential for these crops to increase.

3.4 Water

A constant water supply during growth is crucial for high quality and yield in potato and vegetable crops. Growers need to apply supplementary irrigation over the summer months to maintain even soil moisture and thus ensure optimal crop growth and quality.

While a few stream pumping permits am allowed, nearly all potato and vegetable growers have constructed large irrigation dams to provide adequate water for their crops. These darns are filled during the winter from run-off and excess stream flow or bores.

Some of the region's rivers supply storages such as Moondara and Tarago Reservoirs and Lake Narracan. Water from these storages supplies major urban and industrial areas including outer Melbourne and the Latrobe Valley.

Water quantity and quality is critical for domestic and industrial usage. Future industrial and population development will revolve around an adequate clean water supply. Agricultural land use must be compatible with this goal or it may be forced to change.

While water quality is generally adequate for cropping situations, domestic and industrial users often experience problems. During drought or following excessive rainfall, water supply to other users has sometimes been restricted or polluted.

During excessively heavy rain and thunderstorms some catchment areas surrounded by cropping paddocks and roads experience run-off problems. Farm dam siltation also occurs during these storm events and can become a major long term problem . However, pollution has not always been the fault of agriculture as some water catchments are in non-cropping areas or surrounded by natural bush.

3.5 Productivity

Gippsland's climate, soils and adequate water supply enable professional growers to obtain high yields of quality produce or livestock for discerning markets.

While the state average yield for Victorian potatoes is calculated at around 25 tomes per hectare, yields in excess of 60 tonnes per hectare in Gippsland are not uncommon. The average yield of all potato crops grown in Gippsland is estimated at 37 tonnes per hectare.

Yields from other vegetable crops such as carrots (5 tomes per hectare), onions (50 tomes per hectare) and asparagus (7.5 tonnes per hectare) am capable of returning good profits depending on the market.

The reliable, well-distributed rainfall allows the use of the highly productive perennial pasture species needed for the intensive grazing and dairying industries.

3.6 Soil structure and fertility

The deep friable soils which are ideal for cropping in their natural state are mostly acid (pH 5.2-5.5), with low available phosphorous (6-10 ppm) and generally moderate to low potassium (140-180 ppm).

Continued cropping and use of heavy machinery cause a decline in soil structure and alter the balance of soil fertility. While the continued use of chemical fertilisers has increased the levels of available soil phosphorus and potassium, pH's are dropping. Many soils in the area now have pH readings below five and need liming to ensure that acidity doesn't limit crop and pasture growth.

3.7 Economic factors

Gippsland's climate and soils give growers a distinct advantage over other Victorian potato areas. They are able to supply potatoes and vegetables to major interstate markets at a time when normal local supplies are insufficient or unavailable.

The Koo Wee Rup swamp is considered the most stable crisping potato area in Australia. The red soils of the Gippsland Hills produce high quality, fresh market potatoes with good eye appeal for buyers. Gippsland certified seed potato growers are able to supply seed to interstate growers for almost immediate planting when other seed supplies are unavailable.

Potatoes are currently the major single vegetable crop grown in the area, grossing in recent good seasons between $6,000-$10,000 per hectare. Compared to more traditional grazing or dairying enterprises, cropping appears very attractive.

However wide price fluctuations are endemic to the potato and vegetable industries. In recent bad years potatoes have returned only $1500-$1800 per hectare gross, which is well below the cost of production.

4 CURRENT SOIL MANAGEMENT PRACTICES

4.1 Background information

In order to establish current soil management practices and attitudes to soil conservation amongst Gippsland potato growers, a survey was conducted in 1987 as part of this project.

The growers interviewed in this survey included nearly all of the commercial growers in South and West Gippsland. The survey documented current cropping practices and grower perceptions of future industry trends. The full results have been published as "A Survey of the Soil Management Practices of Gippsland Potato Growers". (See Appendix 1).

4.2 Soil erosion

(i) Attitudes

The survey focussed on grower attitudes to soil degradation and some of the important findings were that:

- Nearly 80% of growers recognised that soil erosion occurred in their locality.
- 70% of growers had experienced soil erosion problems on their own properties and 40% of these recognised it to be a moderately serious to serious problem.
- 60% of growers believe that soil erosion will occur in the future if they continue with their current practices.
- 74% of growers wanted advice on how they could prevent soil erosion and other soil problems while 90% considered that more research was needed on local soil problems.

The findings clearly indicate that soil loss is seen as an important issue for the potato industry in this area.

A trend also identified in the survey is the move towards more intensive cropping practices. Continuous cropping was being used by some farmers with 24% of those interviewed anticipating that the length of rotations will decrease.

This trend without a corresponding move to increase the level of compensating practices will have the potential to substantially decrease production in the long term and increase the likelihood of soil loss as either structural decline occurs or more marginal land is used for intensive cropping.

(ii) Practices

The survey showed that the period when erosion is most likely to occur is from the final cultivation (when the soil is at its finest tilth) to two weeks after planting. Other times with lower, but still significant, erosion hazard are from two weeks after planting to fall crop cover, at or just after harvesting and during pasture establishment. Irrigation was considered a major cause of soil erosion.

Deep ripping to depths of 50 cm to allow faster and deeper water penetration was seen by 31% of growers as a means of reducing soil erosion on cropping paddocks. A further 22% suggested ripping wheel tracks within a week of planting also assisted in reducing soil loss. In fact around 70% of growers used both practices regularly.

Run-off from adjoining grass paddocks, hard, bare areas around trees and roadside drains during heavy rains were also seen as causes of erosion in cultivation.

While the use of vegetative (grass) buffers and diversion banks to slow or divert water from paddocks was not yet in practice, there was considerable interest in these concepts if they could be adapted to practical commercial use.

4.3 Effects of cultivation

The objective of potato growers when preparing a paddock for planting is to produce a deep, friable, weed-free seed bed with a minimum of clods. This has to be done as quickly and efficiently as possible to reduce costs, whilst still maintaining soil structure.

The absence of clods is especially important for potatoes because clods restrict growth and affect tuber shape and marketable quality. Dry clods at harvest will damage potatoes and their removal increases costs.

In Gippsland most farmers use four wheel drive 80hp+ tractors for cultivation work. While the most popular plough used is still the disc plough, new European reversible mouldboard ploughs are gaining in popularity because they are gentle on soil structure, larger, more easily pulled and quicker.

Power harrows are increasing in use for final seed bed preparation at the expense of rotary hoes, however rotary hoes are still the most common implement on farms and am very useful for the initial chopping of pastures.

The action of power harrows is gentle on soil structure and provides a good seed bed for planting. Power harrows keep clods below the surface thus keeping them moist which helps them to break up. Rotary hoes are harsh on soil structure and destroy organic matter. If they are used unwisely they can leave the soil open to erosion and the formation of a 'hoe-pan’.

There is an extremely large selection of tined implements on farms to cover a range of needs. These are predominantly chisel ploughs or deep rippers (59% of farmers in the survey have these) and scarifiers (49%).

A majority of growers use chisel ploughs or rippers for reducing compaction, maintaining or improving soil moisture and to help control erosion.

Most growers use a tined implement (scarifier or ripper) for scuffling or inter-row cultivation work. Ripping wheel tracks after planting was considered by 54% of farmers as useful in reducing compaction and by 24% in helping control erosion.

The survey showed a trend towards bigger machinery cropping land more frequently. However, farmers are aware of the problems caused by cultivation equipment (loss of soil structure, clod formation and erosion), and are prepared to try practical new ideas to avoid these problems.

4.4 Irrigation

Supplementary irrigation is an integral part of potato growing in Gippsland. According to the survey the amount of water applied at each irrigation is reasonably standard, while the total amount applied each year is quite varied depending on the potato variety, soil type and what the crop is grown for.

The most common irrigation system used is the travelling irrigator or "water winch". The "water winch" is adaptable to hilly terrain, relatively low priced and has a low labor requirement. However, it is severely affected by wind which causes uneven watering, and it requires high pressure making pumping costs high.

Water winches throw large droplets of water over long distances on long runs. This, combined with the possibility of wind doubling the desired rate on one side and the chance of breakdown causing further overwatering, can make irrigation more erosion-prone than a thunder storm.

Seventeen percent of growers interviewed in the survey considered travelling irrigators were responsible for causing local soil erosion.

4.5 Harvesting

While currently 60% of growers use "pickers" or hand labor to harvest crops the trend is towards more two-row mechanical harvesters.

This will impose more heavier machinery on paddocks: a two row harvester full of potatoes can weigh up to 6 tonnes. These harvesters also rely on finer soil conditions to work effectively and higher soil moisture levels to avoid damaging the potato tubers during harvesting.

Harvesters cause compaction and their large size and unstable nature means fewer options in the direction of travel and maneuverability around obstacles.

4.6 Green manure crops

Over 70% of potato growers interviewed in the area grew green manure crops as pan of their rotation with potato crops. The most important reasons for growing these green crops were to improve soil structure and fertility and to provide additional stock feed.

Cereals (oats and ryecorn) were the most popular species planted, however 21 % of farmers had problems with these crops. The main difficulties were being unable to work the crop in, and the crop not rotting down quickly enough before planting the next potato crop. Many of these problems could relate to ryecorn because of its rapid growth during late winter and early spring.

The use of green manure crops and experimental work done on them in this project are discussed in greater detail in Chapter 7.

5 LAND CAPABILITY AND EROSION HAZARD MAPPING

5.1 Background information

In determining appropriate uses for land, it is necessary to know what the land is capable of, and what management inputs are needed to achieve sustainability for each use. This involves assessing the productivity of the land and the risks involved for particular uses. An appropriate level of management is then applied in order to minimise the risks to the land.

Important factors for potato production and the growth of other intensive crops, include Tooting depth, soil surface texture, nutrient status, moisture availability and aggregate stability. In adopting cultural practices, recognition needs to be given to soil structure and permeability, slope angle and row length. Although the landform may enable long rows to be established, this is inappropriate in some instances, particularly with increasing slopes, where a high erosion risk exists following cultivation.

Responsible use of the land demands that agricultural practices are sustainable. Where land degradation occurs, production levels are likely to drop, and over time, the deterioration may prevent economic production. Expense may also be involved in restoring the land, including recovery of topsoil from dams.

5.2 Land Capability Assessment Systems

Land capability assessment provides a means of obtaining information that indicates whether:

- the land features will adversely affect or limit the proposed land use.
- the land use will damage the land environment, even to the point where the use can no longer be continued.

Where limitations,. caused by the land features exist, such as steep slopes or landslip potential, the practicality of reducing the risk of soil loss through special land management techniques needs to be known.

Land capability rating enables land to be rated from Class 1, with a very high capability for a specific use, through to Class 5 with a very low capability for the same use. The ratings are applied to areas of land which are reasonably uniform with respect to landform, soils and slopes, to reflect the kind and level of physical limitations which may occur in a given land type.

The Department of Conservation & Environment has developed land capability tables for a variety of land uses, including urban subdivision, rural residential subdivision, forestry, grazing, intensive cropping and farm dam construction. A capability rating can be given for a unit of land with consistent characteristics, by determining the factor present which is the most limiting.

The assessment of land capability is based on the performance of the land under the usual or average management inputs. The rating is expressed in terms of the level of special or additional management inputs required to overcome the limitation imposed by the land features.

The first requirement in mapping the land capability of an area for a particular purpose is to systematically describe the relevant features of each reasonably uniform area of land. These areas are known as map units.

Map units are generally coded using a combination of letters and numbers. For instance, in the study of land capability in the Shire of Narracan, described in 5.3, map units were described according to their landform, slope and soil type. Thus SC9 describes a hillslope (S), with 8-15% slope (C), and red brown gradational soils (9).

Capability ratings can be determined for each map unit for particular uses. The rating is determined by the performance of the most limiting feature of the land. Although a range of land units may have a high capability for grazing, a number of these units may rate poorly for intensive cropping because of the risk of soil erosion due to the slope or soil type present.

In deciding on the cropping capability of a land unit, extra factors such as the likelihood of flooding and the rooting depth of the crop are also taken into account according to Table I below. This table presents a generalised capability rating for intensive cropping.

Table 1- Land Capability Rating for Intensive Cropping

Land features affecting use	**Capability Class**				
	1	**2**	**3**	**4**	**5**
Gradient					
Soil Structure					
Apedal-weak	0-4%	4-8%	8-15%	15-20%	More than 20%
Moderate, S, G	0-8%	8-15%	15-20%	20-35%	More than 35%
Strong	0-15%	15-20%	20-35%	35-50%	More than 50%
Flooding return period	More than 20 years	20 to 10 years	10 to 5 years	5 to 1 year	Several times per year
Soil drainage class	Well drained, moderately well drained	Excessively well drained	Imperfectly drained	Poorly drained	Very poorly drained
Rooting depth	More than 50 cm	50 to 30 cm	30 to 20 cm	20 to 15 cm	Less than 15 cm
Texture of “A” horizon	L, SL, CL	SCL, LS, S	C	-	-
Aggregate stability of “A: horizon	1 (stable)	2	3	4, 5 (dispersing)	-
Gravels & stones	Less than 4%	4-10%	10-20%	20-30%	More than 30%
Boulders and rock outcrop	Less than 0.01%	0.01-0.05%	0.05-1%	1-10%	More than 10%

The capability class given to any unit is always defined by the factor which gives it the poorest capability. For example, if all the factors in the left column of Table 1 indicate Class 2 except for (say) a flooding return period of one in five years, i.e. Class 4, the overall capability for the land unit is specified as Class 4.

5.3 Land capability in the Thorpdale locality

A study of land capability in the southern portion of the Shire of Narracan was prepared by R D Safstrom (Department of Conservation & Environment) in the early 1980's. The area of relevance for intensive cropping is the Thorpdale locality, where two land types, Thorpdale 1 and Thorpdale 2 were identified. These areas were further subdivided into map units identified through stereoscopic analysis of 1:25 000 scale aerial photographs, separated on the basis of the factors discussed in the previous section. The identification of map units involved field verification at specific sites and examination of soil profiles.

Even with detailed mapping, the map units used for capability ratings are based on averages and generalisations for the unit of land, concluded from a limited number of field inspections. The resulting ratings provide a sound guide for the appropriateness of a particular use on a unit of land. However before detailed application of the maps is considered, map units must be field checked and on-site surveys undertaken when specific data is needed.

The map units are shown on a 1:25 000 scale map of the Thorpdale locality attached to Abbott and Ashton's technical report (see Appendix 1). The units have been colour coded according to the land capability rating to enable interpretation of the capability of particular paddocks, or portions of paddocks, for intensive cropping (Table 2).

Table 2 – Intensive Cropping capability of Thorpdale Map Units

Land Capability Rating		Colour Coding	Map Units
Class 1	Very good	Dark green	CB9, CB4.9, SB9, SC9, SC4
Class 2	Good	Light green	SD9, SD4.9
Class 3	Fair	Yellow	
Class 4	Poor	Orange	DC
Class 5	Very poor	Red	

Note: LD10, LD4,10 Class 2-4 depending on slope
LE10, LE4,10 Class 3-5 depending on slope

5.4 Recommendations

Having mapped the area and established the land capability ratings for intensive cropping, the requirement is to specify the management inputs required in order that cropping practices on the classes identified can be sustained without resulting in either soil loss or productivity decline.

Table 2 provides guidelines for the management of land in each of the five land classes. It is imperative that detailed application of the recommendations is made only after field checking and a site-specific concept is developed after consideration of such matters as runoff rates, site drainage, slope and soil type.

The land capability information serves as an initial guide to which the level of management input must be specified.
A higher level of management input is required as the land capability decreases (hazard increases) in order to maintain a sustainable land use.

Table 3 – Management inputs required for Sustainable Intensive Cropping according to Land Capability and Erosion Hazard

Land capability rating	Limitation	Management guidelines
Class 1 Very good (dark green)	Usually slight with respect to erosion, but continuous cropping will lead to structural decline.	Row length should not exceed 150 metres without graded bank or buffer to break water flow. Green manure crops recommended.
Class 2 Good (light green)	Slight limitations exist. Any off-site effects from run-off need assessment. Continuous cropping will lead to structural decline.	Row length should not exceed 120 metres without graded bank or buffer. Green manure crops recommended. Wheel tracks to be ripped.
Class 3 Fair (yellow)	Moderate erosion hazard exists. In addition to assessing effect of water from off-site, run-off control on-site needs careful evaluation.	Row length should not exceed 60 metres without graded bank or buffer. Wheel tracks to be ripped. Irrigation bays to be reshaped to provide for disposal of on-site surface water. Green manure crops recommended. Careful consideration of disposal options required.
Class 4 Poor (orange)	High erosion hazard exists, potential for structural decline high. Impact of any roadside drainage disposal needs careful assessment. Soil type may indicate that the land is marginal for intensive cropping.	Row length should not exceed 60 metres without graded bank. Wheel tracks to be ripped. Green manure crops recommended. Any cultivation should be left in a "rough" state until just prior to planting. Irrigation management should be subject to careful control to prevent run-off occurring.
Class 5 Very poor (red)	Severe erosion hazard.	Areas regarded as not suitable for intensive cropping without an extremely high level of management input. Advice should be sought prior to cultivation.

6 THE EFFECT OF MANAGEMENT PRACTICES ON SOIL STRUCTURE

6.1 Soil structure and its significance

Soil structure can be defined as the size and arrangement of soil particles and pores. It involves both the organisation of soil particles into aggregates, and the stability of these aggregates when stresses such as raindrop impact and cultivation are applied. Soil aggregates are the building blocks of soil structure. Each soil aggregate is constructed from several structural units of varying sizes held together by a number of binding (aggregating) agents.

Soil structure is of major importance to Australian agriculture in terms of crop yield, produce quality, and sustained economic productivity. A preliminary estimate by the National Soil Conservation Unit (1987) suggests that soil structure decline is responsible for more productivity loss annually ($145 million) than salinity, erosion, shallow water tables and soil acidity combined ($70 million) in the Murray-Darling basin. Soil structural decline also results in compaction, soil erosion and poor plant water use. Deteriorating soil structure is likely to limit the productivity of many agricultural enterprises, particularly intensive horticultural industries. However, there is little Victorian information available to relate specific management practices to their influence on soil structure.

The soil's structure is a very important property particularly in agriculture, as it influences:

- ease of cultivation for a seedbed.
- crop emergence and growth.
- aeration of the soil.
- water infiltration and storage.
- erodibility of the soil.

Soil structure is largely dependent on soil type. The red clay loams or krasnozem soils of the Warragul - Thorpdale area are deep, friable, well drained and stable. In other words they are well structured and hence highly valued agriculturally. However, krasnozem soils are still susceptible to soil structural decline if mismanaged.

6.2 Soil structural decline

Over-cultivation and continuous cropping are the major factors leading to decline in soil structure. Cultivating the soil when it is not at the right moisture content (too moist or too dry) and the frequent use of heavy machinery also take their ton on structure.

The immediate effects of structural loss are depletion of organic matter, the breakdown of stable soil aggregates and soil compaction. The formation of clods, with its attendant problems as discussed in Chapter 4, also follows.

In turn these changes leave less pore space in the soil for air and water storage and the soil becomes more difficult to cultivate. It also becomes more difficult for the crop to emerge from the soil and for its roots to grow strongly, so crop production suffers.

When it comes to soil erosion, poor structure leaves the soil very vulnerable. Compaction and lack of organic matter leave the soil less able to absorb water. Thus water falling as heavy rain or applied as irrigation is more likely to flow and erode the soil.

6.3 The effect of management on soil structure in West Gippsland

Several sites were used to assess the effect of land management on soil structure during this project. The findings are summarised below.

The amount of wheel traffic had a considerable effect on soil compaction at the beginning of each growing season. Where wheel tracks weren't ripped the soil was significantly more compacted to a depth of 300 mm than in untrafficked or ripped furrows. Although the extent of this compaction decreased during the growing season, any compaction early in the season could affect crop water use and the potential for run-off. Where compaction occurred, the infiltration rate of water into the soil was significantly reduced. The data indicated that there would be less infiltration and greater run-off and erosion in the trafficked furrows compared with those that had minimal traffic or those that had the wheel tracks ripped. Clearly run-off and erosion can be reduced by minimising traffic and, where necessary, ripping wheel tracks.

Another important aspect of soil structure is aggregate stability. The study results indicated that the stability of soils against erosion and compaction depended on the previous land management and in particular, on the amount of organic matter in the soil.

For example, low organic carbon levels and low aggregate stability correspond to paddocks which have been continuously cropped for a number of years.

In addition to increasing the stability of soil aggregates, organic matter also increases the soil's water holding capacity and provides nutrients for plant growth.

The use of green manure crops to maintain organic matter levels and preserve soil structure is discussed further in Chapter 7. A full report on the research work into the effects on the soil of Tipping wheel tracks and growing green manure crops is contained in the technical report. (See Appendix 1).

6.4 Summary/recommendations

The proper management of soil structure is vital to any sustainable, economic fanning enterprise. This is particularly true for potato growing land in West Gippsland which is being utilised more intensively than ever before because of current economic pressures. Simple management techniques can greatly enhance or maintain the structure of potato growing soils. These techniques should be used in combination and include:

- the use of pasture rotations.
- working the soil only at appropriate soil moisture levels.
- initially cultivating to leave a "rough" tilth.
- minimising wheel traffic.
- preparing the final seedbed just before planting.
- ripping machinery turning areas and wheel tracks after planting.
- enhancing the level of organic matter between potato crops by growing green manure crops.

The benefits of these techniques include improved crop productivity, reduced soil loss and less siltation of dams and streams.

7 THE USE OF GREEN MANURE CROPS

7.1 Background information

Organic matter or humus both living and decaying, is an integral component of soil, and is essential if a soil is to be highly productive under cropping. However, intensive cropping and cultivation themselves, especially on our red volcanic soils that are naturally low in organic matter, quickly deplete humus levels and this leads to a decline in soil structure and eventually clod formation.

Poorly structured soils are more inclined to erode than well-structured ones as they have less ability to absorb and hold water.

It has been recognised for thousands of years that the replacement of organic matter in the soil is essential to allow continued cropping. The crop residues from potato tops and weeds alone just aren't enough to replace this lost material.

There are essentially two methods of replacing organic matter and thus repairing damage to soil structure:

- Cease cropping for a time and sow the paddock back to pasture.
- Grow a green manure crop in the off-season between successive "production" crops.

Experience has shown that a pasture phase is virtually essential for potato growing on the red volcanic soils. However, pasture only builds up soil humus gradually and the time required in pasture can be dramatically reduced by using green manure crops.

Green manure crops produce a lot of organic matter quickly and this is ploughed back into the soil to rapidly raise humus levels.

The survey referred to in Chapter 4 showed that 71 % of growers use green manure crops with 60% using them often or always between successive potato crops.

7.2 Potential benefits and disadvantages of green manure crops

Benefits
The three main reasons that surveyed growers gave for using these crops were:

- To improve soil structure.
- To improve soil fertility.
- To provide additional winter stock feed.

The many benefits of improved soil structure were discussed in the previous chapter. Soil fertility improves because green manure crops make soil nutrients, especially nitrogen, more available to the crop, and because they increase the abundance of important soil micro-organisms.

Other benefits include help in the control of weeds (including self-sown potatoes) by smothering. Green manure corps also help to control diseases such as eelworm and rhizoctonia.

Green manure crops are often used for stock feed over winter and this does not compromise their effectiveness if sufficient regrowth is allowed before turning in.

Disadvantages
The major disincentives to the use of green manure crops are the cost of seed, fertiliser and cultivation for seed bed preparation and turning in, and the time involved in growing and managing the crop.

There are other disadvantages which can generally be avoided by good management:

- **Loss of nutrients to grazing.** Oats for example take up a lot of potash. This could be lost from the paddock by inappropriate grazing.
- Loss of nitrogen. If the crop is strawy, post maturity or ploughed in too late, large amounts of nitrogen can be used up as it breaks down.
- **Loss of soil moisture.** Breaking down the green manure crop can use up valuable soil moisture in a dry season.
- **Problems with turning in.** Where the crop is over mature, turned in under very wet conditions or not chopped up well before incorporation, straw can make cultivation or planting difficult by building up on the fines, blades or planter shoes.
- **Disease.** Under certain conditions green manure crops can cause damping-off in vegetables.

7.3 Results from the Lardner trial

Three replicates of six green manure crop types were planted across the slope in a randomised block design, at the Gippsland Field Days' property, "Lardner Park."

The six crops tested were peas, oats, Tetilla ryegrass, peas and oats, Gippsland and Northern, fodder mix and ryecorn.

The findings from the Lardner trial indicated that:

- The cloddiness of soil can change markedly throughout the year.
- The size of soil clods is mainly influenced by the amount of cultivation and the soil moisture at the time of cultivation.
- Soil clods were less persistent where green manure crops were used compared with bare fallow. This observation is attributed to the higher organic matter content of soil under green manure crops.
- In paddocks continuously cropped for many years green manure crops did not influence the size distribution of clods immediately after cultivation.

In summary, the results indicate that the number, size and persistence of soil clods can be minimised by reducing cultivation, cultivating at low-moderate soil moisture levels, using pasture rotations and by growing manure crops between successive potato crops.

A fuller analysis of the green manure crop work is contained in the technical report "The Effect of Land Management on the Structure of Intensively Cropped Soils in West Gippsland" (see Appendix 1).

7.4 Green manure crop management

A successful green manure crop is one which:

- **Suits local conditions.** Soils and climate will effect crop selection. For example, some crops won't thrive in low pH (acid) conditions. Frost incidence and whether irrigation is likely to be needed should also be considered.
- **Produces a bulk of green material.** The time available for a green manure crop is limited by the cash crops grown either side of it so it must grow quickly. If the preceding potato crop isn't harvested until May, a fast growing crop such as ryecorn is needed so that it can be ploughed in before September.
- **Has a fibrous root system.** Top growth decomposes quickly in the soil to form humus but a fibrous root system remains to bind the soil particles and help maintain good soil structure.
- **Complements the farm work program.** Being able to use existing equipment and not interrupt other farm work are important considerations for a green manure crop.
- **Can be worked in easily.** Green manure crops must be ploughed in before maturity while they are still succulent. Ibis is because a mature crop will take too long to break down in the soil, can cause machinery problems as alluded to in Section 7.2, and robs the soil (and thus the subsequent potato crop) of available nitrogen.

  The ideal time between working-in a green manure crop and planting the potato crop is between 4 and 8 weeks. It can be reduced to nearer the lower figure if the crop is young and well incorporated.
- **Costs as little as possible** to plant, maintain and incorporate into the soil.

7.5 Crop selection

Most of the cereals and annual ryegrass species are cool season crops, that is they grow well during autumn, winter and spring and are normally adaptable to a wide range of soil types.

The two most popular cereals used for green manure crops are oats and ryecorn while Tetilla and Tama ryegrasses are quickly becoming popular because of their versatility. Ryecorn is generally affected less than other crops by low pH.

Rape, which grows well in winter has the advantage of a large, deep tap root that is ideal for penetrating plough pans or hard soils.

Legume crops such as field and dun peas, lupins, tick and faba beans, and annual clovers generally don't produce large quantities of organic matter but are valuable for adding nitrogen to the soil.

Mixtures of cereals and legume crops are popular with some growers because they supply nitrogen and organic material to the sod. This extra nitrogen helps the crop grow over winter and then assists with the rotting down process.

7.6 Recommendations

Green manure crops are an ideal, economical way of improving or maintaining soil structure, organic matter and general soil fertility, and help to reduce erosive potential.
There will be a move towards more intensive cropping in Gippsland in the future. This move, combined with shorter rotations between crops and the use of larger and heavier machinery, will make soil structure a major limiting factors in crop production.

The need to use green manure crops will thus become even greater than it is now and should be encouraged at every opportunity. Ideally, green manure crops should be grown between all successive potato crops and all the material grown incorporated into the soil.

8 VEGETATIVE BUFFERS TO MINIMISE SOIL LOSS AND DAM SILTATION

8.1 Background information

Overland run-off within agricultural crops usually occurs during infrequent, intense rain storms and can result in substantial crop damage, soil erosion, loss of soil nutrients and siltation of dams and streams. The key to avoiding these potentially large economic losses is good soil management. The introduction of green manure crops, minimising tillage/ traffic and long rotations are a few of the methods which promote good soil structure, maintain soil permeability and hence minimise run-off. However, ran-off cannot always be avoided and requires careful planning and management.

Vegetative (or grass) buffers are one technique that can be used to minimise the amount of run-off flowing through a crop. Research indicates that vegetative buffers can be placed within and below crops to reduce the amount of sediment leaving the land and reaching streams. Buffers have been successfully used in the forestry, intensive animal and intensive cropping industries. The ability of a vegetative buffer to reduce run-off and sediment loads depends on its ability to slow down the run-off. The slower the run-off water flows the less sod it can transport.

Most of the previous research relating to the effectiveness of agricultural buffer zones has been done overseas. This research notes the effects of buffers in controlling sediment and nutrient run-off from feedlots, forests and construction sites. Data on more conventional Australian cultivation practices was sparse, so a study was implemented at the Toolangi Potato Research Station to identify if buffers had the potential to reduce run-off in potato crops. The results of this work showed that buffers could dramatically reduce ran-off below experimental plots (50 metre length rows). The study in this project planned to assess the effectiveness of vegetative buffers under conditions typical of those used on commercial farms in West Gippsland.

8.2 Effectiveness of buffers used at Thorpdale

The effectiveness of buffers depends on many environmental and management factors including:

- Placement of buffers.
- Width of buffers.
- Species composition and weed growth.
- Stage of buffer growth.
- Land slope/row length/slope shape.
- Likely rainfall intensity and duration.
- Dispersibility of the surface soil.
- Soil permeability.
- Ability of the buffer to reduce the run-off velocity. During the study period at Thorpdale there were few severe storms where run off occurred however the following observations were made:
- Run-off from higher paddocks must be controlled before buffers within a crop will work.
- Placement of buffers at or above the "break" in land slope is important.

-
- Buffers did appear to effectively reduce the movement of soil down the slope.
- The effectiveness of buffers was minimised where the buffer had been heavily trafficked.
- The buffers were most effective when there was a dense cover of spring pasture compared with less dense cover during winter and summer.
- Buffers were most effective when they were cross-ripped.
- On very steep country, buffers would need to be used in conjunction with diversion banks.

8.3 Management and economic considerations of using buffers.

The general perceptions of growers who have previously utilised buffers am summarised below. The perceived advantages of using grass buffers included:-

- Shortening the row length in each paddock.
- Providing access tracks across paddocks in crop.
- Useful for turning machinery on.
- Dividing large paddocks into more manageable blocks for planting/harvesting operations.
- Can be used as storage sites.
- Assist in erosion control and more effective crop water use.
- Minimise the amount of sediment reaching streams and darns.

The main disadvantages perceived by growers who have used grass buffers are the loss of valuable cropping ground and the inconvenience of working over a buffer during cultivation and planting. On steeper ground some growers are wary of using buffers in case heavy machinery such as planters cause accidents when lifted out of the ground to cross them. Other considerations of using buffers include:-

- The cost and time of establishing and maintaining any buffered area.
- The potential use of buffers for various cash crops
- The potential for planting a "forested" buffer adjacent to streams.

8.4 Summary and recommendations

While the lack of a storm event during the research phase of the project did not allow definitive results to be achieved, the research work by Weston and others has provided a sound basis on which to recommend the use of grass buffers. If carefully sited and managed, vegetative buffers can reduce run-off, prevent soil loss and dam siltation as well as reducing the amount of treatment required for off-site water supplies. These benefits result in reduced medium-term costs to both the individual farm manager and the wider community. Grass buffers should be considered as an option for reducing soil loss:

- where consistently long rows are being used.
- where there is a critical break in slope within the potato paddock i.e. where there is a sudden increase in gradient.
- adjacent to streams as a means of stopping water-borne soil before it enters the stream.

Grass buffers need to be established on a permanent basis and managed accordingly. Preferably they should never be taken out of pasture, but if they are cultivated, the area should be re-established with vigorous pasture as quickly as possible. Grazing or occasional slashing of the area to maintain a vigorous cover can also help.

Grass buffers are most effective if they are:

- at least 10 metres wide.
- restricted to slopes of 15 %or less.

- properly established and maintained.
- cross ripped and lightly harrowed during the season.
- subjected to as little machinery traffic as possible.

Buffers will be most effective when used in association with other soil conservation techniques such as ripping wheel tracks and maintenance of good soil structure.

9 DIVERSION BANKS TO REDUCE RUN-OFF THROUGH THE CROP

9.1 Background information

One of the main risks to the cropping soils used for potato production is erosion resulting from high intensity storm events when ground cover is minimal, especially around planting time.

Early thunderstorms during the peak planting season from October to December are the major problem. Storms tend to be sporadic in distribution and can result in very significant soil loss.

Soil loss tends to be worst where slopes are moderate to steep (up to 35%) and the paddock runs are long. A further factor to consider is that equipment currently used for soil preparation and harvesting cannot be used on the contour except on very gentle slopes.

The need therefore is to identify practices which can be applied in a commercial situation. The use of contour banks, graded banks and diversion banks has been recognised as an effective means of reducing the concentration of water and thereby reducing soil loss.

Research work by McFarlane and others in Western Australia found that soil savings of I following order can be achieved by the use of bank systems that are properly planned and constructed.

On a 10% slope (I in 10) and row length of 120 metres, one bank (reducing row length to 60 metres) resulted in a 29% reduction in soil loss.

Two banks (row length reduced to 40 metres) resulted in a further 10% savings.

Two trial sites were set up to assess the potential of these banks in the potato growing are of Gippsland.

9.2 Design of experimental diversion banks

The farm selected for the initial work in the 1987-88 season was that of Mr Colin Hill at Childers using a site where there are generally steep slopes (18-30%) and long row length up to 500 metres. The site selected did have natural advantages in that a defined depression existed which was designated to convey diverted run-off to the bottom of the slope.

Using guidelines developed by the Soil Conservation Authority, Victoria (1979) diversion banks were designed to cope with a one in five year storm.

The steep slopes were a constraint to the type of treatment that could be applied. Of pH importance was the requirement that any bank system must be trafficable to all machine This required a minimum width of 12 metres on the steepest slope.

A cross-section of the diversion banks used on Hill's property is shown in Figure 2 where Figure 3 shows the paddock layout.

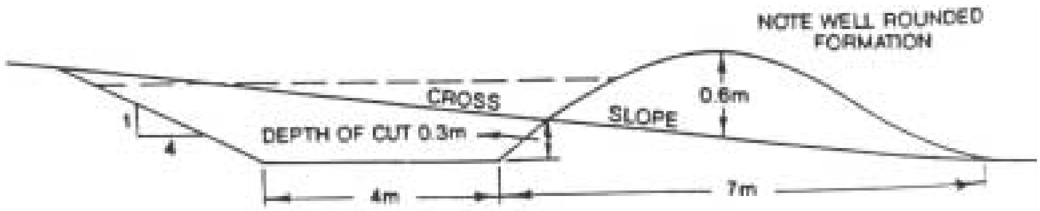


Figure 2. Dive Diversion bank cross-section, C. Hill's property.

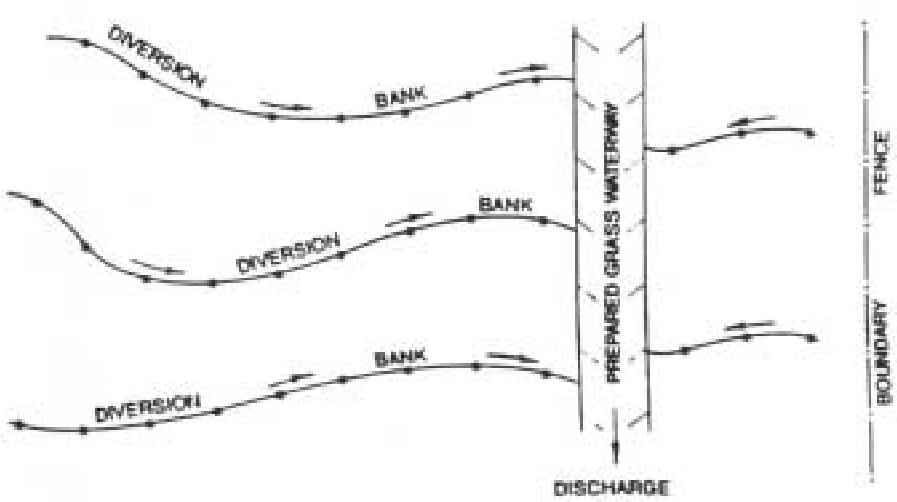


Figure 3. Layout of diversion bank system, C. Hill's property.

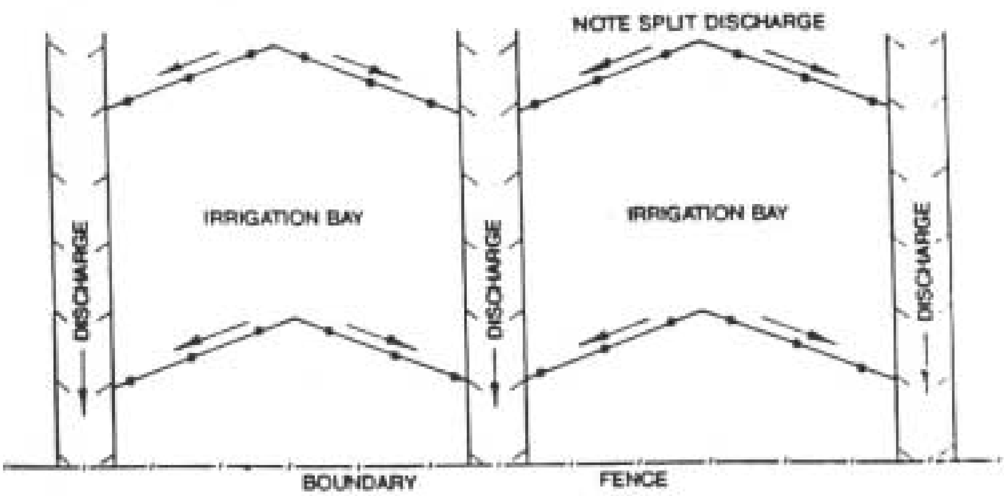


Figure 4 – Layout of diversion bank system, W. Robinson's property

As the system was experimental it was necessary to adjust the final form based on the landholder's requirements and to ensure that the banks were easily trafficable.

For the 1988/89 season a further development in the use of diversion banks saw a move to a site on the property of Mr Bill Robinson at Thorpdale. This property had a slope range (around 18%) more typical of potato country in Gippsland.

As there was no natural drainage depression in the paddock chosen here, the irrigation lanes were used to dispose of run-off. This meant that no additional land was required to handle the run-off but a little more effort was required to prepare the bays to take storm water flows. The gentler slopes on this property enabled the bank discharge to be split either way. The earthwork required for actual bank construction was also much reduced and, using a small bulldozer, the system was built in less than a day. The configuration used is shown in Figure 4.

Complete design details for diversion banks on both properties are contained in the technical report by Abbott and Asthenia. (See Appendix 1).

9.3 Efficacy of experimental diversion banks

Unfortunately, from an experimental point of view, the diversion banks at Colin Hill's property were not tested by a major storm event.

However, the banks were tested in part by the breakdown of an irrigation line. Significant all soil loss was prevented in this instance by the banks, thus demonstrating the value of the concept.

They were also subjected to a number of "normal" rainfall events where soils were saturated to the extent that run-off occurred but without concentrating to the level where significant soil loss would have occurred without the diversion system.

The next year at Bill Robinson's trial site there was a very intense summer storm which dumped 45mm of rain on the paddock while the potato plants were small.

In this instance the banks were filled to capacity with soil thus preventing a much greater level of soil loss from the paddocks.

It was interesting to note that for an untreated section of the same paddock immediately above the house, soil moved to the extent that it covered the back yard and patio area and threatened to move into the house. This was despite trenches being dug during the storm. Soil soon filled these and moved on towards the house.

Where soil loss did occur from the trial section, it was in the irrigation bay where grass had not been sufficiently well established to handle the peak flows.

9.4 Management considerations

The banks as constructed at Hill's, have meant that there is an inconvenience factor during seed bed preparation, crop growth and harvesting operations. This inconvenience, plus the small area of ground that is taken out of production must be weighed up against the potential reduction in soil loss.

Having experienced previous difficulties in this area Mr Hill was of the opinion that diversion systems have a place in a commercial cropping situation providing they are properly planned and constructed with a ready run-off disposal system.

The banks at Robinson's site presented no difficulty in working the paddock and only a very small percentage of the paddock was taken out of production.

The landholder in this instance has experienced the very significant run-off that can be generated by the summer storm events and while banks would not work in every situation, be also feels that there is a place for them.

The safe disposal of run-off is a prime consideration. The use of banks must be one element of a total package as there is no point in being able to safeguard one area at the cost of another.

The move to use the irrigator lanes to discharge run-off from the site was effective but adequate ground cover is required or the lanes themselves can erode.

Where a natural drainage system exists on or close to the cropped land, then that area should be left in pasture and utilised for the safe disposal of run-off water. If this is not possible then the impact before the point of discharge must be considered.

9.5 Recommendations

Diversion bank design will need to be varied according to the slope and discharge opportunities. Cultivation on slopes exceeding 20% (1 in 5) is considered to be marginal in terms of the risk of soil loss occurring. Diversion banks of a cut and fill configuration will be required and, while the project has shown that they can be used on slopes of 28% (close to 1 in 3) and remain trafficable for planting and cultivation equipment, the construction costs are relatively high. There is also a reduction in the area planted and this must be evaluated in terms of soil potentially saved on site compared to a small loss of production.

Given the lack of data from this project due to the climatic conditions, it is considered that similar levels of soil loss reductions to those measured in Western Australia can be expected given the observations of the value of the work on the two properties.

It is further recommended that maximum row lengths be applied as in Table 4 below:

Table 4 – Recommended Diversion Bank Spacing on Sloping Land

Slope %	0-10	10-20	20+
Spacing (metres)	80	60	50

Any system must be designed according to the limitations of the site, with particular attention given to the requirements for the safe disposal of run-off water and any soil type variations.

On flatter sites, rather than a cut and fill system being used, smaller "graded" banks can achieve a similar result. These banks are much easier to construct and provide a reasonable level of protection. They do not have the same capacity as a cut and fill system, but in designing them consideration can be given to gradients on which they operate to either allow for maximum soil detention (very flat gradient of I% or less), or for a self-flushing effect (gradients of 3% maximum). On gradients steeper than 3% there is a high risk of scouring which tends to defeat the purpose of the banks.

9.6 Summary

Where intensive cropping is intended on sloping ground, particularly greater than 10% slope, and soil erosion is a possibility, the use of diversion banks should be carefully considered.

Diversion banks provide an effective means of reducing soil loss, but they need to be individually designed for each situation. The design needs to take into account the steepness and length of slopes, soil type, and the overall erosion hazard. Of prime importance also is the availability of suitable locations for discharging water from the diversion bank system.

While diversion banks cause some inconvenience in traversing the paddock, they can be made fully traffickable and easily cover their costs in terms of soil retention. Like other soil conservation measures, diversion banks need to be used in conjunction with other good soil management practices.

10 GYPSUM TO IMPROVE SOIL STRUCTURE?

10.1 Background

Responses from the "Survey of the Soil Management Practices of Gippsland Potato Growers", revealed that several growers were applying gypsum to their cropping soils to alleviate soil structural problems which were occurring despite the continued use of green manure crops.
The perceived benefits from gypsum were:

- improved soil structure,
- a decrease in the number and size of clods,
- improved water in filtration,
- easier cultivation,
- improved potato quality.

Some potato growers on the Koo Wee Rup swamp with similar soil problems have made the same comments after applying gypsum to their soils.

Because of the lack of Victorian data on the structural response of the krasnozem soils of Gippsland to soil ameliorants, it was proposed to assess the effectiveness of gypsum on soil structure at Lardner.

Initially, this proposal was to set up an observation trial looking for any changes to soil structure following a spring application of Pivot by-product gypsum at three different rates. If any changes in aggregate stability or soil structure were observed or measured a properly conducted trial could then be initiated.

10.2 Experimental design

The area used for the trial was part of a potato paddock at Warragul South that had been cropped for the previous three years and was considered to have soil structural problems. The trial area was only used for one observation trial then resown to pasture.

Before applying gypsum, laboratory measurements were made of aggregate stability, while visual and photographic assessments of clod formation and soil structure were also made.

Gypsum was applied in late September to mid October before the growing green manure crop was cultivated in.

Twenty metre strips of Pivot by-product Gypsum at 2.5, 5.0 and 10 tomes per hectare, separated by 20 m control strips were broadcast across the paddock.

10.3 Results and discussion

Differences between plots during the growing season were minor and couldn't be verified by measurement. At one stage it appeared as if the treated plots were more even in growth and slightly greener, however they did not grow on any longer nor were there any differences in crop yield or quality.

The experience of soil scientists suggested that this soil type was unlikely to be improved by gypsum application and thus the result was not surprising. This result doesn't mean however, that gypsum will not be of some benefit in some intensive cropping situations in West Gippsland. Some growers report pleasing results from using gypsum over a longer period.

What the result does mean is that growers who decide to try a soil conditioner such as gypsum should do so cautiously. Use it on only part of a paddock so that it can be compared with where none was used and keep good records of where it was used and what happened.

If soil conditioners do have a role in maintaining soil structure there is no doubt that they are no substitute for the proven management practices discussed in this report.

11 COMMENTS OF OTHER CATCHMENT USERS

11.1 Background information

When soil erosion occurs on cropping farms it is of concern to other catchment users as well as the property owners where it happens. Of particular importance in this regard are water supply authorities and local government bodies as they often suffer the "downstream" effects of erosion.

Because of this connection, the Soil Management Project Team convened a Land and Water Managers Workshop on November 29,1989.

Specifically the objectives of the workshop were to:

- Provide an opportunity for the direct participation of land and water managers in the future development of the project
- Encourage a better understanding of catchment issues (both on and off farm) relating to soil and water quality within the context of the project.
- Identify opportunities for integrating catchment management needs into the further development of the project.

While a full report on the workshop entitled "Land and Water Managers Workshop" has been printed separately, the sections below summarise how the three main players (water and agricultural industries, and local government) saw the issue of sustainable land management and its relationship to them.

11.2 Water supply industry

The quality of water coming from waterways in Gippsland's cropping areas was raised as a concern. Participants held the view that cropping practices contributed to polluting waterways, thereby lowering water quality. It was agreed that the project should investigate the effect of different farm practices on long-term water quality.

Data derived from such research could assist later in developing codes of practices. Also, specific farm practices which prove to be conducive to good water quality should be advocated by the project team during its extension phase.

Management of catchment areas should be controlled by a catchment group. Such a group should be community driven. It should include representatives from the local farming and urban community, shires, water boards and government agencies such as the Department of Agriculture and the Department of Conservation and Environment

Who would initially instigate and co-ordinate such a catchment group was questioned by participants. Several participants wondered if it was within the scope of the current project. The aims of a catchment group in the area were not specifically outlined.

Encouraging the local community, especially landholders, by education and example to adopt practices conducive to good water quality was seen as preferable to regulating farm practices.

The development of a Code of Practices for agriculture in the area was raised. This task, it was considered, could be adopted by the project team.

Concern was expressed over who would be the long term users of the finite water resources in the research area. Participants believed there may be conflicting demands on water use in the future especially between in-stream and off-stream users.

11.3 Agricultural industries

Off-farm effects of agriculture should be monitored. Workshop participants suggest that this was within the realm of the current project. Measuring sediment loading into streams from cropped paddocks was one example of monitoring that could be undertaken by the project.

Agriculture in the area must be maintained through sustainable management practices. These practices should have both on-farm and off-farm benefits. For example, the use of green manure crops improves the soil structure which has an on-farm benefit. By improving soil structure, soil erodibility is reduced and therefore off-farm benefits from minimised soil erosion can also be expected.

The project is currently investigating sustainable farm practices. The practices when developed must be practical and should not impose an economic hardship on local landholders or they won't be used.

Educating landholders on how to overcome soil degradation was seen as the prerogative of the project and local shires. Education of landholders and other community members as opposed to regulation was highly supported by the workshop participants. Any educational/extension program would succeed best if co-ordinated by local landholders and/or Shire personnel. The use of programs such as LandCare was advocated by the group. What role the project would have in such an activity was also raised.

11.4 Local Government

Local government was seen as extremely important in any catchment co-ordination program.

Participants felt local government should become involved in the current project, particularly with its extension phase. Sentiments were expressed that local government could achieve a lot in the cropping areas through planning and other activities.

11.5 Recommendations

While many views were expressed at the workshop the recommendations were quite clear and generally agreed. They were that the project team should:

i) identify and research practices which will lead to sustainable and productive intensive agriculture, and minimise any effect on land and water off-site.

ii) monitor the off-farm effects of agricultural practices. Measuring sediment loadings into streams would be a prime method.

iii) help to set up and coordinate catchment management groups whose role it would be to encourage landholders to adopt practices conducive to sustainable agriculture and good water quality down stream of the farm.

Whilst (i) has clearly been the major focus of the project, (ii) is seen as generally beyond the scope and resources of the project. Item (iii) will be the focus of the approach used to extension following up the project.

12 SUMMARY OF APPROPRIATE MANAGEMENT PRACTICES

12.1 Background

Towards the completion of the project, on 28 November 1990, a "Soil Management Extension Workshop" was held in order to summarise the findings of the project to that date, and suggest future directions.

As a result of this workshop the following summary of appropriate management practices for intensive cropping in West Gippsland was prepared. It is based around a chronological sequence beginning with forward planning up to 18 months before the first cultivation, and takes the form of a check list for growers.

12.2 Good soil management - A check list for growers

12.2.1 The Planning Stage (up to 18 months before first cultivation)

(a) Catchment or Sub-catchment Level

- look at how your farm sits in the catchment.
- what "downstream" effects will soil and water coming from your farm have?
- what will be the effects on your property from "upstream"? How can they be averted? e.g. culverts, cut-off banks.

(b) Farm Level

- consider what rotation length is sustainable with your conditions and management.
- which paddocks should be cropped and which not. Only parts of some will be appropriate. Redesign paddocks?
- look at individual paddocks in relation to rest of farm.
- recognise land capability. The land around Thorpdale has been assessed as to its capability for intensive cropping as pan of this project.
- check where water runs from paddock to paddock within the farm and plan to
- divert it or take it through.

(c) Paddock Level

Aim to

- stop water entering.
- stop water moving from within the paddock.
- prevent water from taking soil off the paddock if it does move.

i. Water Entering

- liaise with Shire to divert water from roads e.g. cut off banks, moving culverts and drain exits.
- liaise with neighbours to do the same or leave natural flow course uncultivated.

ii. Water moving within paddock

- leave natural drainage lines in grass and fit cultivation around them.
- check hard, bare areas (e.g. under old trees) where water may start flowing. Construct a cut-off bank if necessary.

iii. If water does move

- what is the first area that would go in a storm and how can you prevent it.
- are *grass buffers* or *diversion banks* appropriate? See sections 8.4 and 9.5 of this report for guidelines.
- a *grassed landing* at the bottom of the paddock can catch any washed soil above your dam or the creek.

Also consider before breaking up the paddock:

- fallowing in summer prior to first crop for disease control.
- reducing cultivation by chemical fallowing.

12.2.2 The Cultivation Stage

- select equipment and techniques to suit conditions.
- timing of first cultivation - optimum moisture levels (soil not wet enough to stick to machinery, not dry enough to form powder and clods).
- deep ripping (across the slope if possible) is often appropriate as pan of primary cultivation.
- look at cultivation method with a view to moving soil back uphill whenever possible.
- leave seedbed rough until just prior to planting.
- don't make it too fine - planting is effectively another cultivation.

12.2.3 The Sowing Stage

- wait for optimum soil moisture and temperature.
- rip wheel tracks straight after sowing.
- consider sowing down irrigator lanes e.g. with millet.

12.2.4 The Growing Season

In general try to minimise the number of machinery passes; irrigate carefully.

(a) Tractor Operation

- consider ripping again after early tractor operations (e.g. hilling up). This can be done in the same pass.
- assess timing of operations: too early increases likelihood of erosion while too late may affect potato plant roots.

(b) Irrigation

- look at the pros and cons of various irrigation systems.
- ideally a little water often is best.
- low pressure and small nozzles giving low precipitation rates are best for the soil.
- service and maintain irrigators well in order to avoid breakdowns which can lead to local flooding and erosion. irrigate strictly in relation to crop needs, varying the application rates across the paddock in relation to soil type and slope.
- set up irrigation to account for wind if you can't avoid it.

12.2.5 The Harvesting Stage

consider desiccation or pulverising of tops, or both. restrict the number of areas where bins are handled then rip them after harvesting. rip wheel tracks after harvesting to reduce compaction and make ground absorbent again.

12.2.6 Green Manure Crop/Pasture Stage

After harvesting, either plant a green manure crop or sow down to pasture according to sustainable rotation plan.

(a) Green Manure Crops

aim to get the maximum possible amount of organic matter back in the soil in the time available.

- consider the pros and cons of the various alternative crops.
- provide the best conditions for growth (seedbed, moisture, fertilisers).
- don't graze unless absolutely necessary as this partly defeats the purpose of the crop.
- work in at the optimum time - when crop is still young and sappy and there is at least 6 weeks until the potato crop is to be planted.
- if 6 weeks for rotting down isn't available then pulverise or mulch to incorporate into soil.

(b) Pasture

- choose pasture species which will grow vigorously and increase organic matter in soil rapidly.
- sow down pasture under optimal conditions (moisture, warmth, tilth, fertility) to get rapid cover.
- consider rolling after sowing - improves early germination.
- grazing new pasture too heavily could lead to poor density and increased soil compaction.

12.2.7 Next Potato Crop (second year running)

- you will need to re-plough.
- there will always be more clods to contend with, therefore may need mom cultivation. Soil ameliorants may be appropriate but check them carefully.
- try to use "first year" ground (straight out of pasture) more often as it has the
- following advantages. It:
    - ❖ is easier to get good tilth.
    - ❖ has good moisture-holding ability.
    - ❖ is less susceptible to erosion.
    - ❖ has less clods.
    - ❖ grows less weeds.
    - ❖ produces a better crop.

APPENDIX 1. DOCUMENTS PRODUCED FOR THE PROJECT

Project reports

Abbott I.D., and Ashton, K.M. (1991) "Soil erosion control for intensive cropping: land capability and diversion bank studies in the Thorpdale locality." Department of Conservation and Environment, Central Gippsland Region, November 1991.

Hirst, F.S. (Ed.) (1991) "Managing soils under intensive cropping in West Gippsland. Results and recommendations from a research and development project." Department of Agriculture, October 1991.

Hirst, K.M., Imhof, M.P., and Weston, B.A. (1991) "The effect of land management on intensively cropped soils in West Gippsland." Department of Agriculture Research Report Series, October 199 1.

Volum, A.G., Myers, A.J., and Biasi, R. (1988) "A survey of soil management practices of Gippsland potato growers." Department of Agriculture and Rural Affairs Research Report No. 76, November 1988.

Information for farmers

Information Sheets "Improving soil management for intensive cropping in Victoria." Four sheets produced, 1987-1989.

Article Biasi, R. (1989) "Our soils, our future". Rural Quarterly, Summer 1989.

Newsletter "Gippsland Potato Grower." Three issues produced and distributed to all potato growers in high rainfall Gippsland, October 1989 - July 1990.

Booklet Halvorsen, L., and Hirst, F.S. "Caring for cultivated soil." Distributed as above, October 199 1.

Presented Papers

Imhof, M.P., and Hatton, R.A. (1987) "Development of techniques for measuring aggregate stability of intensively cropped krasnozem soils in south-eastern Australia." In K.J. Coughland and P.N. Truong (Eds.) "Effects of management practices on soil physical properties." Proc. Nat. Workshop, Toowoomba, 1987. Queensland Department of Primary Industries Conference and Workshop Series QC87006: 109-114.

Volum, A.G. (1991) "Key land management issues - an agricultural perspective." Paper at the Sixth National Potato Research Workshop, Healesville, February 1991.

Weston, B.A. (1991) "Soil management packages for intensive cropping in Victoria." Paper at the Sixth National Potato Research Workshop, Healesville, February 199 1.

Posters

Hirst, K.M., Biasi, R., and Abbott, I.D. (1987) "Improving soil management for intensive cropping in West Gippsland." Poster paper, Aust, Soc. Soil Sci. (Riverina Branch) Annual Conference, Deniliquin, N.S.W., May 1987.

Imhof, M.P., and Hatton, R.A. (1988) "Development of wet-sieving techniques for assessing aggregate stability of intensively cropped krasnozem soils in south-eastern Australia." Poster paper, Nat. Soils Conf., Aust. Soc. Soil Sci., Canberra, 1988.

Seminars/Workshops

Biasi, R. (Ed.) "Land and water managers' workshop." Warragul, November 1989.

APPENDIX 2 – MAJOR CONTRIBUTORS TO THE PROJECT

Ian Abbott	*Department of Conservaiton & Environment, Traralgon*	Soil movement studies, diversion banks and lad capability works.
Ken Ashton	*Department of Conservation & Envirnment, Traralgon*	Co-ordinated DCE's invovement. Designed and implemented diversion banks.
Rocky Biasi	*Department of Agriculture, Warragul*	Project Technical Officer (NSCP funded). Conducted day-to-day work of project including grower survey, field work, publicity, etc.
Greg Creek	*Department of Conservation & Environment, Warragul*	Conducted initial work on grass buffers.
Richard Habgood	*Department of Agriculture, Warragul*	Project Manager 1989 and 90
Colin Hill	*Potato grower, Childers*	Collaborating farmer with diversion bank trials.
Frank Hirst	*Department of Agriculture, Leongatha*	Co-ordinated extension and project documentation in final year. (NSCP funded)
Kathleen Hirst	*State Chemistry Laboratory, Melbourne*	Project Technical Officer (NSCP funded). Planned and carried out field and laboratory work on soils.
Geoff Hobson	*Potato grower, Thorpdale*	Representative of Gippsland Hills Potato Growers on Management Committee.
Mark Imhof	*State Chemistry Laboratory, Melbourne*	Advice and support on technical aspects of soil stucture studies.
Maurice Lloyd	*Potato grower, Thorpdale*	Collaborating farmer with grass buffer and ripping trials. Member of Management Committee
Kevin Love	*Department of Agriculture, Leongatha*	Project Manager, 1991.
Con Murphy	*Farm Manager, Gippsland Field Days, Lardner*	Collaborating property with green manure crop trials.
Tony Myers	*Department of Agriculture, Warragul*	Provided link with growers, project supervision and technical support
Bill Robinson	*Potato grower, Thorpdale*	Collaborating farmer with diversion bank trials.
Sam Tumino	*Potato grower, Warragul South*	Collaborating farmer with gypsum trials.
Andrew Volum	*Department of Agriculture, Ellinbank*	Provided project concept and plan. Project Manager 1986-88 and ongoing guidance throughout.
Bruce Weston	*State Chemistry Laboratory, Werribee*	Co-ordinated State Chemistry Laboratory involvement. Substantial inputs to project planning and documentation

APPENDIX 3 – PROJECT PUBLICITY AND EXTENSION ACTIVITIES

1986	November	Press release introducing project.
	December	Briefing day on grass buffers.
		Briefing day held in conjunction with Irrigation Research and Advisory Committee.
		Signs erected at demonstration sites, stating project details.
		Information Sheet No. 1. Improving Soil Management for Intesive Cropping in Victoria.
1987	February	Tour of experimental sites by DPI-NSCP team member from Canberra and NSCP Co-ordinator, Victoria.
	March	Farm World display. Effects of selected green manure crops on soil structure, and crop yield quality.
	April	Talk to agriculture students at Salesian College, Sunbury.
		Project presented on regional television program, “Farming Today”
	June	Poster idsplay at Grassland Conference
		Poster display presented at Australian Society of Soil Science Conference, Deniliquin
	August	Project discussed on regional television andin local press. Also published in Sa, NSW and Qld.
	October	Information Sheet No. 2. Green Manure Crop Trials, Lardner.
	November	Information Shett No. 3. Diversion Banks and Grass Buffers, Thorpdale.
		Signs and information boxes erected on research sites.
	December	Briefing day tour to grass buffers, diversion banks and green manure crops research sites.
1988	January	Field day at grass buffers and diversion banks sites. Thirty farmers attended,
	March	Farm World display. Ripping wheel tracks, diversion banks, grass buffers.
	May	Poster presentation at National Soils Conference, Canberra.
	September	Field day. “Green manure crops – good management”, Lardner Park. Thirty five farmers attended.
	November	“A Survey of the Soil Management Practices of Gippsland Potato Growers” report released. Five hundred copies, distributed to local, Victorian and interstate potato growers, industry personnel and government bodies.
1989	January	Interviews on regional television and local radio.
	March	Information Sheet No. 4. Program for this year’s trials.
		Farm World. Major display covering all aspects of project.
	May	Local radio interview on green manure crops.
	June	Poster display and bus tour to research site from Soil Conservation Society of Victoria Conference, Rawson.
	October	“Gippsland Potato Grower” newsletter No. 1. Article on diversion banks.
		Potato seminar, Ballarat. Work discussed with farmers.
		Local radio interview “Preparing for Planting.”
	November	Land and Water Managers Workshop with key farmers, water authorities and local government.
	December	Display at Soil Science Institute of Australia workshop.
		Article in Department of Agriculture magazine for farmers “Rural Quarterly”.
1990	February	“Gippsland Potato Grower” newsletter No. 2. Articles on geen manure crops.
	March	Envirnmental science students, Monash University, toured experimental sites.
		Farm world display.
	April	Display in Department of Agriculture Head Officer for one week.
	May	Poster display at Soil Conservation Association of Victoria Conference.
	July	“Gippsland Potato Grower” newsletter No. 3. Articles on green manure crops and ripping wheel tracks.
1991	March	Farm world display. Working model of potato paddock showing soil conservation techniques.
	October	Launch of project final report, Thorpdale Hall. Presentation of farmer booklet, model and general and technical reports. Speakes on project achieves and how similar problems are being tackled in north west Tasmania

Numerous press releases were made throughout the course of the project and talks were given to agriculture students at local schools and colleges. Visits to the experimental sites were made by farmers from Queensland, New South Wales, South Australia, Western Australia and Tasmania.