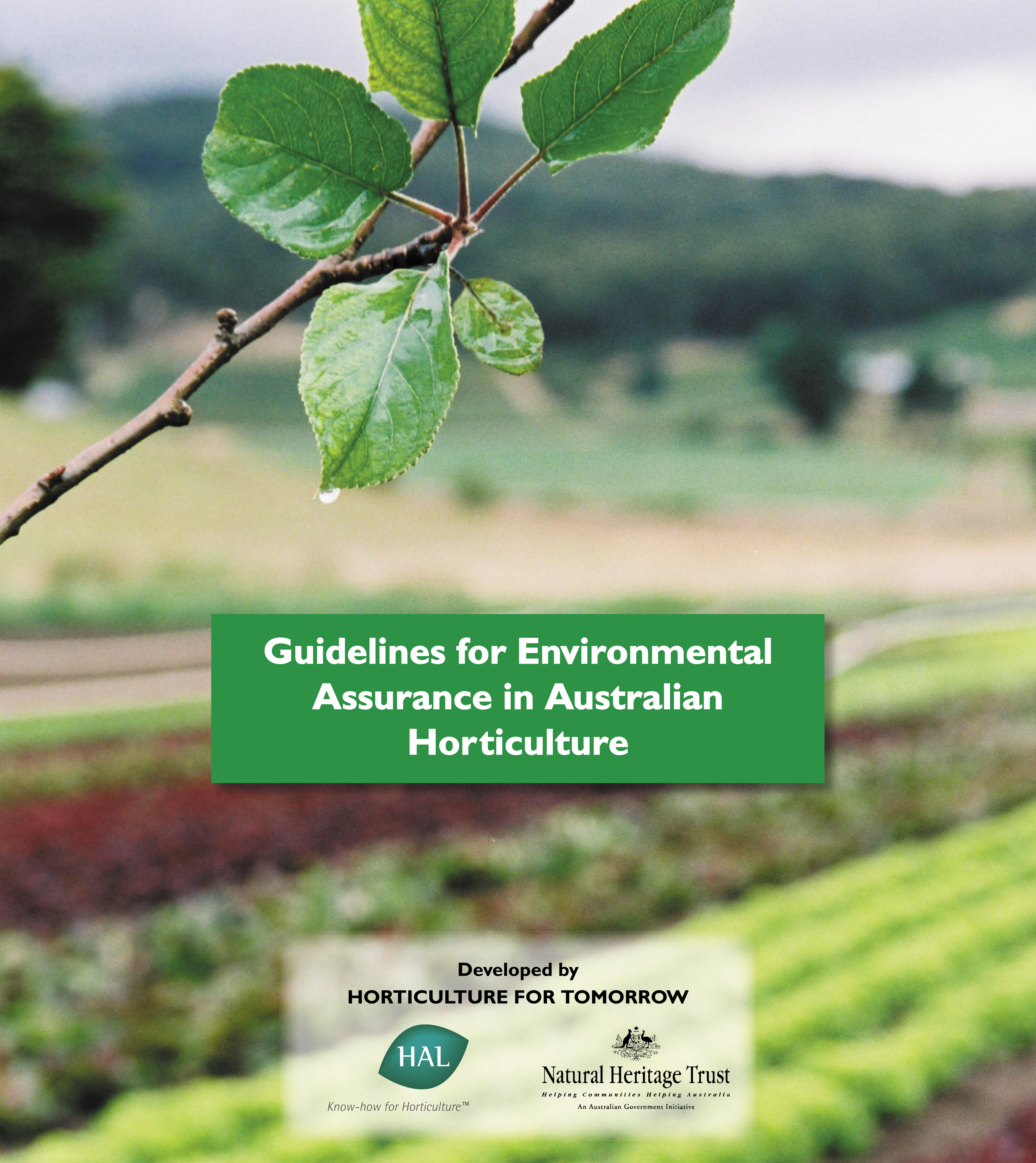


Guidelines for Environmental Assurance in Australian Horticulture

Developed by

HORTICULTURE FOR TOMORROW

HAL

Know-how for Horticulture™

Natural Heritage Trust

Helping Communities Helping Australia

An Australian Government Initiative

April 2006

Where to start!

How you use these guidelines is a matter of personal choice. Some people may like to start at the front cover and read to the last page – but you don't have to! The Guidelines are designed so you can get a quick overview of the issues and then prioritise the areas on which you want to focus for your business.

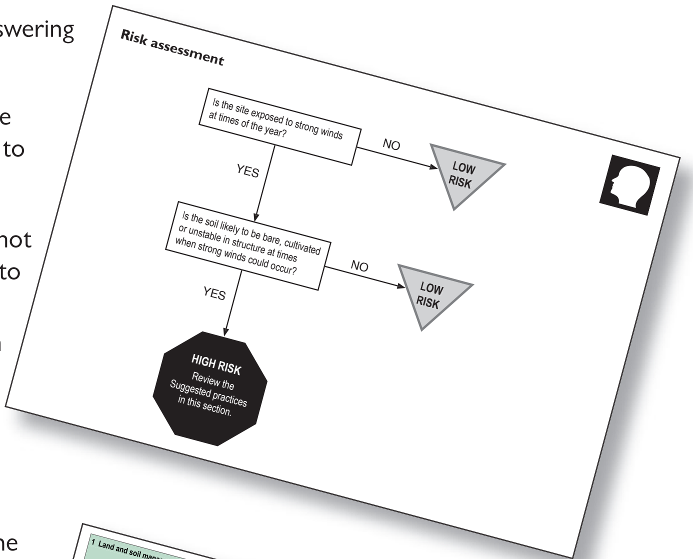
These guidelines have three main components:

- Introductory sections that provide background information about the issues and the guidelines (manila-colored tabs).
- The main working sections to help you assess and manage your enterprise (the eight brightly-colored tabs). These sections cover risk assessment, suggested practices, monitoring and recording options, and references and further resources.
- A series of practical tools and resources to help you (grey tabs).

We recommend that you choose to start in one the the following ways:

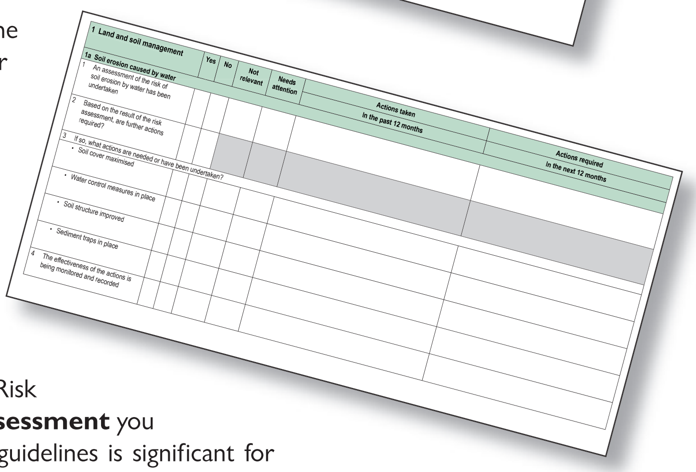
1: Start with the Risk Assessments

- The guidelines cover a total of 20 different topics, divided into eight numbered sections. At the start of each major topic, there is a simple **Risk Assessment** diagram which asks key questions about your enterprise.
- Work your way through each **Risk Assessment**, answering the questions.
- If you end up at a stop sign you need to take some action. Read the **Suggested Practices** for the topic to explore your options.
- If you end up at a Give Way sign you probably do not have a significant problem. However, you may need to read on to check your understanding of the issues.
- By working through all the Risk Assessments you can prioritise issues that may need attention on your property.



OR 2: Start with the Review Checklist

- Another way to get an overview is to start with the **Review Checklist**. The checklist covers the major environmental assurance issues dealt with in the main text of the guidelines. By working through the checklist you will get an idea of your priority areas and you can then read the relevant topic in more detail. (We have provided a second 'working' copy of the checklist under the **Work sheets** heading. Use these to complete your first review.)
- The Checklist is divided into tables covering a range of topics. Select a topic and turn to the matching section in the guidelines and look for the Risk Assessment diagram. By working though the **Risk Assessment** you can quickly determine if that particular topic of the guidelines is significant for your business.
- If the topic is significant for your business, complete the relevant checklist table and record the answers.
- Read the **Suggested Practices** for the topic to explore your management options.

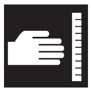


1 Land and soil management						
1a Soil erosion caused by water	Yes	No	Not relevant	Needs attention	Actions taken In the past 12 months	Actions required In the next 12 months
1 An assessment of the risk of soil erosion by water has been undertaken						
2 Based on the result of the risk assessment, are further actions required?						
3 If so, what actions are needed or have been undertaken?						
• Soil cover maximised						
• Water control measures in place						
• Soil structure improved						
• Sediment traps in place						
4 The effectiveness of the actions is being monitored and recorded						

The guidelines also provide information about monitoring options and sources of additional information for each topic.


Risk Assessment


Suggested Practices


Monitoring and Recording


References and further resources

Guidelines
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Editor – Jane Lovell, Tasmanian Quality Assured Inc.

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The Guidelines for Environmental Assurance in Australian Horticulture has been prepared by Horticulture for Tomorrow, a national project supported by Australia's horticultural industries and funded by the Natural Heritage Trust, through the Australian Government's Pathways to Industry EMS Program.

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The Committee comprises:

- John Bagshaw, Department of Primary Industries and Fisheries Queensland,
- Richard Bennett, Horticulture Australia Ltd,
- Elliot Dwyer, Primary Industries and Resources South Australia,
- Joseph Ekman, NSW Department of Primary Industries,
- Tom Harris, Northern Territory Horticultural Association,
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- Sarah Hearn (until November 2004) and Helena Whitman, AUSVEG Ltd
- Jane Lovell, Tasmanian Quality Assured Inc.,
- Anne-Maree Boland, RMCG (formerly Department of Primary Industries Victoria),
- Jane Muller, Growcom,
- Graham McAlpine, McAlpine Management Services Pty Ltd, and
- Charles Thompson, RMCG.

The project was also guided by the Horticulture for Tomorrow Industry Leadership Group (ILG), appointed by the Horticulture Australia Council (HAC) on behalf of industry. The ILG comprises:

- Dr Jack Sinden, University of New England (chair)
- Neil Eagle, citrus grower, Barham NSW
- Jeffrey McSpedden, vegetable grower, The Lagoon, NSW
- John Gillett, macadamia producer, Brooklet, NSW
- Vicky Kippin-O'Connor, banana grower, Innisfail, Queensland
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Darry & Cherelle Hardman
Tom Harris
John Hawtin
Susan Haywood
Lincoln Heading
Andrew Heap
Ross Hitchcock
Ben Hoffman
Thom & Shirley Holm
Al & Narrelle Holtham
Brian Hopkins
Margaret Howie
Andrew Hudson
Paul Humble
John Jeffs
Wayne Jensen
Ian Johnston
Ashley Johnstone

Peter Jones
Jurgens Produce Pty Ltd
Robert Karoschke
Shane Kay
Jim Kemp
Tim & Robert Kemp
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Don & Peter Lavers
Stephen & Linda Layall
Stan Leach
Paul LeFeuvre
Clint Lette
Daryl & Linda Lohrey
Tony Loverso
Robert Mansell
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Paul Martin
Tony Martin
Paul Mason
Matthew McAulay
John McCormack
Allan McKay
Paul McLisky
David Menzel
Peter Middleton
Tanya Mijak
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Dennis Moon
Cameron & Glenn Moore
Mark Morey
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Bruce & Darrell Munro
David Nabbs
Dominic Nardi
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Steve Newman
Jerrod Nichols
Damon Nicol
Michael Nicol
Mark Nucifora
David O'Donnell
Roger Orr
Panda Ranch
Dick Passfield
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Max & Jenny Payet
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Andrew Pergoliti
Lewis Perkins
Steve & Sharon Peruch
John Pettigrew
Doug Phillips
Graeme Pitchford
Gavin Plummer
Rohan Prince
Des Rackley
Heidi Radcliff, Rhebanvale
Richard Reardon
Chris Riggall
Tim Ring
Guy Robertson
Andrew Roberts-Thomson
Chris Robinson
Mark Roche
Lionel Sach
Ken Sampson, Goulburn Broken Catchment Management Authority
Trevor Savins
Carlo Scamuffo
Roger Schmitke
Carey Schultz
Ray Sellwood
Jon Shaw, Surelines produce
Leanne Sherriff
Maurice Silverstein
Leroy Simms
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Bill Sinton
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Significant information was drawn from:

- Farmcare. Code of Practice for Sustainable Fruit and Vegetable Production in Queensland. QFVG, 1998,
- Enviroveg Program. Vegetable Growers Association of Victoria, 2002.

Disclaimer

This guide has been produced by Horticulture Australia Ltd (HAL) to provide general information on environmental management in horticulture. The information has been provided in good faith, and the views expressed do not necessarily represent the views of HAL. HAL does not accept responsibility for the accuracy of the information provided and no responsibility or liability will be accepted for any use or reliance on the material contained in the document.

Laws governing environmental protection and management by horticultural producers can be complex, and may be include numerous Federal, State and Local Acts and Regulations. In addition, changes to these laws may be made from time to time. The user of this guide should seek expert advice from an appropriate professional or the relevant government agency to ensure the precise effect of current laws is fully understood before implementing any course of action referred to in this guide.

Printed on recycled paper with vegetable-based inks

Introduction

What is environmental assurance?

Environmental assurance is a relatively new term being used across many industries tackling community and industry concerns about the environmental impacts that can be caused by business activities.

For a horticultural business, environmental assurance is a means of demonstrating the use of management practices that achieve the level of environmental protection expected of itself and by its customers, the community and other interested parties. A key feature of the environmental assurance process is risk assessment and using recognised practices to minimise or prevent environmental impacts. A business can demonstrate management of environmental issues through self-assessment, or by seeking assessment from its customers or an independent (or third) party, typically an auditor.

Why are horticultural industries interested in environmental assurance?

Horticultural producers have a fundamental interest and pivotal role in protecting, and where necessary and practical, enhancing and restoring natural resources. Assuring the long-term sustainability of natural resources directly affects the long-term sustainability of horticultural businesses.

There are many drivers for the development of environmental assurance programs in horticulture.

An environmental assurance process gives a horticultural producer confidence that their chosen management practices are effective in protecting natural assets such as soils and water, and minimising the risk of causing negative environmental impacts.

The process may highlight areas where improvements can be made to benefit the sustainability of the business, for instance by reducing waste or nutrient leaching and thereby saving money.

The notion of 'clean and green' has been used to market Australian horticultural produce for years. Industry and government have put considerable effort into developing and implementing food safety programs that clearly justify the 'clean' label.

But can we justify the 'green' part of the label? Most growers would say "yes" – many Australian producers use advanced technologies to manage water use, monitor nutrients and minimise pesticide use. However, in general, horticulture has little proof of its environmental credentials.

Put simply, community interest in environmental issues is increasing and our competitors are catching up fast. So it makes good business sense for the horticultural sector to develop a way to demonstrate its commitment to sound environmental and natural resource management.

Many horticultural markets are beginning to demand that their suppliers demonstrate an acceptable level of environmental management. Access to key markets may be jeopardised if horticultural businesses cannot provide this, in addition to food safety and quality assurance.

Developing an industry-driven and industry-wide approach to environmental assurance demonstrates a broad commitment to environmental management. In turn, this commitment should alleviate the need to resort to increased regulation. Industry will also be in a better position to maintain long-term access to natural resources (especially water) by demonstrating sustainable use and management of these resources.

A widespread uptake of environmental assurance processes that are credible and consistent will help to maintain community confidence in the professionalism of the horticultural industry and its commitment to careful environmental management and protection of Australia's natural resources.

The potential for proliferation of environmental systems in Australia's agriculture and food sectors is widely recognised. One of the criticisms of quality assurance has been that there are too many systems and different customers requiring different things, all of which leads to confusion, duplication and inconsistencies in interpretation and implementation and, therefore, additional expense for growers.

In late 2003, the Australian Government consulted with industry and community groups on its Environmental Management Systems (EMS) policy. Following these consultations, the Australian Government announced new directions, which included a Pathways to Industry EMS Program. Through the program, the Australian Government offered to assist industry to implement an EMS or environmental assurance 'pathway' that positioned its members for the future. Horticulture Australia Limited (HAL) and the Horticulture Australia Council (HAC) accepted the invitation to lead, coordinate and manage the project to ensure whole-of-industry goals were identified and addressed in developing a pathways framework for industry environmental assurance. As part of the process, they have included some 30 industry members and organisations as well as stakeholders of importance in the sector.

What are these guidelines?

The guidelines have been developed to provide a common platform for all horticultural industries in Australia interested in implementing an environmental assurance process.

They are the first attempt to establish a national, industry-wide approach to recognising sound environmental and natural resource management in the horticulture sector. They provide a variety of suggested practices to address common environmental issues, whether the enterprise produces fresh or processing produce, cut flowers, nuts, turf or potted plants. It is recognised that the suggested practices need to be considered in combination with other, sometimes competing, environmental and business issues. Changing one component of a farm system can impact on other practices. Management is often about balancing competing resource requirements.

The guidelines provide:

- an overview of the priority environmental management issues of concern in the horticultural sector in general;
- guidance on how a business can assess its environmental risks;
- guidance on practices that are recommended for addressing environmental and natural resource management issues; and
- suggestions for monitoring and recording to demonstrate that environmental management outcomes are being met.

The guidelines can be used by:

- individual businesses to implement an environmental assurance process;
- horticultural industry groups to guide the development of environmental programs tailored to their needs on a product or regional basis;
- established food safety and quality assurance schemes that offer optional environmental certification choices; and
- other stakeholders such as government, education and training, catchment management bodies, retailers, financial institutions and utilities.

The guidelines also provide a platform for creating environmental auditing and certification options that deal with Australian environmental issues. Currently the options for businesses wishing to achieve certification are limited and concern has been expressed as to the appropriateness and applicability of some of these options, particularly for smaller-scale Australian horticultural enterprises. These guidelines provide another approach to substantiation of environmental credentials.

Who are the guidelines for?

Creating a single set of environmental assurance guidelines for horticulture in Australia has not been without its challenges! The guidelines cannot be all things to all people.

A trial phase including more than 150 growers and feedback on draft versions indicated that some people wanted them further simplified, while others were looking for more detail. The guidelines are targeted at horticultural enterprises with a basic understanding of production and environmental issues. Businesses further down the formal EMS path may need to seek more site and crop-specific information.

Where possible, references to sources of information have been included in these guidelines for people who want to pursue issues further.

What's the difference between environmental assurance and EMS?

Environmental assurance provides a generic checklist of recognised environmental best practices. An Environmental Management System, or EMS, describes any systematic approach to managing the impacts an enterprise has on the environment. EMS is one of the tools available to help a business deliver environmental assurance.

EMS provides a process for the business to keep track of all the information needed to demonstrate to both business managers and external parties it is meeting the environmental assurance standard established. A business would not necessarily need a comprehensive EMS in place to demonstrate compliance with the environmental assurance standard.

Both environmental assurance and EMS involve assessment of environmental impacts or risks, and both advocate appropriate actions to address environmentally significant issues.

How the guidelines were developed

The guidelines have been produced by Horticulture for Tomorrow – a national project supported by Australia's horticultural industries and funded by the Natural Heritage Trust, through the Australian Government's Pathways to Industry EMS Program.

The developed of this document has been overseen by the project's Technical Steering Committee, and produced under the auspices of Horticulture Australia Limited (HAL), which is managing the project in partnership with industry.

The Technical Steering Committee (TSC) comprised 10 leading practitioners from across Australia with diverse experience in developing on-farm assurance programs and environmental issues management.

A series of meetings reviewed and discussed existing environmental management programs and supporting resources developed for horticultural industries in recent years. A scoping study identified the key regulatory and market drivers in Australian domestic and export markets and provided context for the guidelines.

A risk assessment approach, consistent with HACCP (Hazard Analysis Critical Control Point) and traditionally used for food safety, identified processes used in horticulture industries and the potential for significant environmental impact if process steps were not managed appropriately. Further information resources were also identified to link these guidelines with other industry-specific guidelines and programs.

This publication was then created by building on existing material and work in progress, and by drawing on information from a number of sources to develop a consolidated reference document based on the most up-to-date scientific and industry knowledge available at the time.

Key resources and references for these guidelines were:

- Farmcare. Code of Practice for Sustainable Fruit and Vegetable Production in Queensland. QFVG, 1998;
- Enviroveg Program. Vegetable Growers Association of Victoria, 2002; and
- Water Initiative Steering Group (HAL).

The first draft of the guidelines was released in November 2004 and critically reviewed at the Horticulture for Tomorrow Environmental Assurance Workshop later that month. A second draft of the guidelines was extensively trialed during 2005, by a diverse range of horticultural operations across Australia, as well as technical experts. The document was also reviewed by state agencies for consistency with existing legislative requirements.

Additional guidance was provided throughout the project by the Horticulture for Tomorrow Industry Leadership Group, which was appointed by the Horticulture Australia Council on behalf of industry.

It is recognised that the guidelines will need to be periodically reviewed due to changing understanding of the issues, risks, technologies and management approaches. Feedback on the guidelines and suggestions for future improvement are welcomed and can be directed to Horticulture Australia Limited.

How to use the guidelines

Scope of the guidelines

The guidelines are designed to:

- identify significant environmental impacts that may result from horticultural production practices;
- outline the level of environmental management that is expected of horticultural enterprises;
- provide information on suggested agricultural practices to prevent or minimise these environmental impacts and achieve the expected environmental outcomes; and
- give guidance on the information and records required to provide credible evidence to an interested party that the expected environmental management outcomes are being achieved.

A significant environmental impact is defined as any negative change to the environment resulting from business practices that varies from the environmental outcomes acceptable to industry, the community, regulators and markets.

The guidelines cover the growing, harvesting, packing, storage and dispatch stages of horticultural production. Horticultural production includes fresh fruit, vegetables, flowers, nursery products, nuts, herbs, mushrooms, grapes and turf supplied for sale to customers in the wholesale, retail, and food service sectors or for further processing across all climate zones in Australia. It does not cover the production of sprouts and minimally processed products (e.g. fresh cuts) or grapes for wine production.

In effect, we have endeavoured to produce a guide that applies to a hypothetical Australian horticultural business that grows every conceivable horticultural product. Not all issues will apply to every business. If the issue applies, you should address it; if it doesn't apply, move on to the next one.

The suggested practices and potential environmental impacts have been identified from existing industry guidelines, environmental assurance programs and work in progress.

It is important to recognise that the guidelines are not a substitute for local, state or national legislative requirements. Given the breadth and variation of legislative requirements across Australia, it is strongly recommended that specific information is sought from relevant authorities to ensure compliance.

Guideline sections

- **Introduction**
  Introductory sections provide background information about the issues and the guidelines. These sections have the manila-colored tabs. A table summarises the key environmental impacts associated with horticultural production, giving a useful overview of topics covered in the main part of the document.

- **Assessing and managing your enterprise**
  The main working sections – the eight brightly-colored tabs at the centre of the folder – help you assess and manage your enterprise. These sections cover risk assessment, suggested practices, monitoring and recording options, and references and further resources.

  Risk assessment diagrams are provided to assess the risk of potential environmental impacts occurring, and the good agricultural practices required to prevent or minimise the impact. This section provides information to help understand why the risk of impact varies. Some of the risk diagrams contain environmental indicators which are based on research, professional advice, legislative requirements and other guidelines.

- **Practical tools and resources**
  Review checklist
  The checklist provides a way of recording your progress through the guidelines and for identifying actions needed to address any environmental issues you uncover. By completing the checklist each year you can track your progress over time and build up a history of the actions you have taken and their effectiveness.

Process steps and inputs

Flow diagrams which detail the process steps and inputs for the major stages of field crop production, nursery production, field packing and shed packing. The diagrams show the range of steps that may occur for each process and the inputs and practices that may result in environmental impact.

Environmental impact identification table

The impact identification table details potential on-farm and off-farm environmental impacts from horticultural operations. The impacts are considered for each process step, making the link between activities and environmental 'hazards'.

Glossary

Definitions of terms not regularly used, or requiring further explanation.

List of further resources

References that may assist producers to find additional information regarding a specific issue.

Work sheets

An extra copy of the Review checklist. This is also a place where you can add examples of forms that you use to monitor and record activities relevant to environmental performance.

Regional natural resource management (NRM) issues

For natural resource management to be successful, it is important that management activities are coordinated between growers and other natural resource managers in their regions, such as Landcare groups, NRM groups and catchment management authorities. This gives the region a greater likelihood of achieving more holistic natural resource goals and reduces the risk of individual actions being fragmented and inefficient.

NRM groups and catchment authorities may have already developed environmental objectives or targets for your region. This information is useful because it:

- assists your activities to feed into the regional targets;
- may provide you with opportunities for financial assistance in achieving your own property goals; and
- can provide guidance on what the local environmental issues are. For instance, if salinity has been identified as an issue in your area this may prompt you to consider in greater detail whether your property might be at risk of developing salinity problems.

Information about NRM groups/catchment authorities in your region can be obtained from www.nrm.gov.au/index.html and selecting 'NRM Regions across Australia'.

Environmental impacts associated with fresh produce

Potential environmental impacts are changes that may occur in the environment as a result of horticulture production practices. Risk assessment is required to determine whether the potential environmental impact is likely to occur within a particular enterprise, and to determine the likely significance of the impact, based on the management of each practice.

Category	Hazard	Specific environmental impact
Land and soil	Soil erosion	Sedimentation of rivers/waterways Reduction of water quality – nutrients and agricultural chemicals entering rivers/waterways – eutrophication
	Soil structure	Compaction Increased run-off Soil erosion, sedimentation of rivers/waterways Nutrient depletion
	Salinity	Reduction of arable land Spread of saline water and land Adverse impact on flora and fauna – loss of biodiversity
	Soil acidity and alkalinity	Loss of productivity Reduction of arable land
	Sodicity	Reduction of arable land Soil erosion Soil waterlogging
	Soil degradation	Compaction Increased run-off Soil erosion, sedimentation of rivers/waterways Nutrient depletion
Water	Inefficient use of resource	Insufficient water supply/environmental flow Depletion of water table Adverse impact on flora and fauna – loss of biodiversity Rising water table and waterlogging Salinity Soil erosion Nutrient leaching Contamination of waterways
	Inappropriate water quality	Reduction of water quality - contamination by fertiliser, eutrophication - contamination by agricultural chemicals - contamination by fuels and oils - sedimentation
Chemicals	Inappropriate storage of chemicals	Contamination of surface/groundwater Contamination of drinking water Adverse affect on flora and fauna – loss of biodiversity
	Inappropriate application	Contamination of surface/groundwater Contamination of drinking water Adverse affect on flora and fauna – loss of biodiversity Soil contamination Adverse impact on other crops Adverse impact on neighbours
	Inappropriate disposal of agricultural chemicals, surplus agricultural chemicals, rinsates, chemical containers	Contamination of surface/groundwater Contamination of drinking water Adverse affect on flora and fauna – loss of biodiversity Soil contamination
	Spray drift	Disruption of Integrated Pest Management strategies Health risk for local residents Contamination of surface/groundwater Contamination of drinking water Adverse affect on flora and fauna – loss of biodiversity Adverse affect on surrounding crops

Category	Hazard	Specific environmental impact
Nutrients	Inappropriate use of resource	Soil acidification Adverse impact on flora and fauna – loss of biodiversity
	Misplacement of fertiliser	Reduction of water quality – eutrophication Adverse impact on flora and fauna – loss of biodiversity
Biodiversity	Loss of biodiversity	Clearing of land Reduction of wildlife corridors Loss of aquatic habitat Change in pest species present
Waste	Inappropriate disposal of waste	Contamination of soil and water Adverse affect on flora and fauna – loss of biodiversity Greenhouse gas emission – global warming and climate change Inconvenience to local residents
	Inefficient use of resources	Wasting non-renewable resources Greenhouses gas emission – global warming and climate change Waste disposal sites required (landfill)
Air	Dust	Sedimentation of waterways Soil erosion Inconvenience for local residents
	Smoke	Creation of greenhouse gases – global warming Inconvenience for local residents
	Greenhouse gases	Global warming Climate change
	Noise	Disturbance Inconvenience for local residents Adverse impact on fauna - loss of biodiversity
Energy	Inefficient use of resources	Creation of greenhouse gases – global warming Wasting non-renewable resources

Assessing and managing your enterprise

1 Land and soil management

Objective – to minimise soil degradation and loss from the property.

To achieve this objective, horticulturalists need to consider issues such as:

- a soil erosion caused by water,
- b soil erosion caused by wind,
- c soil structure,
- d salinity,
- e soil acidity and alkalinity, and
- f sodicity.

1a Soil erosion caused by water

Objective – to minimise the potential for water to erode soil on the property.

Soil erosion caused by water happens when water contacts exposed and/or unstable soils (soils with poor structure). Erosion can happen as a consequence of heavy rain or excess irrigation, or when drainage water from paddocks, roadways and areas around sheds and buildings moves across the land. In tree crops, shaded soil under the tree canopy can be eroded during intense rainfall events because there is little groundcover. In some regions, low-lying ground can be subjected to regular flooding. Waterways can also be subject to erosion, with negative impacts on downstream water quality (see Section 2b – Water quality).

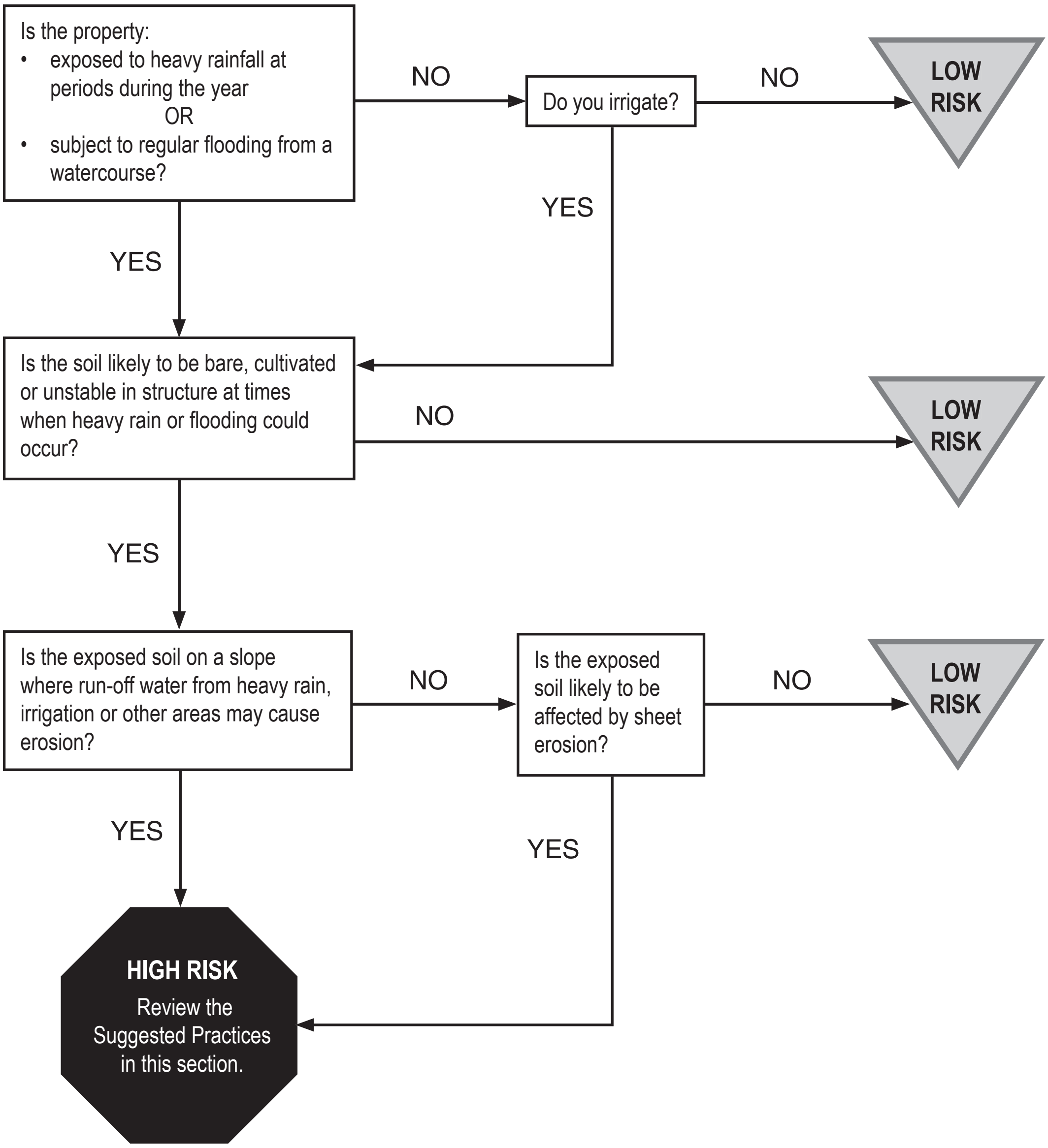
The likelihood of soil erosion by water and the control measures needed depend on vegetation cover, soil type and texture, soil stability (structure) and the type of horticultural activity.

Evidence of soil erosion caused by water may include:

- rills or gullies,
- turbid water in farm dams or leaving the property, and
- soil build up on fencelines or at the bottom of slopes.

To manage soil erosion caused by water, you need to identify sites on your property that are at risk, assess the level of risk and, if necessary, put in place control measures. There are a number of key strategies you can employ, including maintaining soil cover, controlling run-off water, improving soil structure and establishing sediment traps.

Risk assessment



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HIGH RISK – You need to take some action. Read the Suggested Practices for that topic.

Suggested practices

● Maintaining soil cover

Soil cover protects the soil from erosion by reducing the displacement (movement) of soil particles caused by rain or overhead irrigation droplets, and by slowing the movement of water across the site.

Types of soil cover include:

- grassed waterways on drainage and sump areas;
- inter-row groundcovers in orchards, vineyards and ground crops;
- green manure/cover crops planted between (in space and time) commercial crops;
- organic mulches, plastic, slashed inter-row material or crop residues spread over the exposed soil; and
- products such as PAM (polyacrylamide), PVA (polyvinyl acetate) or molasses which bind soil together.

Legal requirements are subject to change. Regularly check with Federal, State and Local authorities for updated requirements.

Managing soil cover

Control measures may include:

- avoiding soil tillage (where possible) during times of the year when heavy rainfall events are likely, especially in tropical areas;
- avoiding cultivation of light sandy soils subject to regular flooding;
- using minimum tillage systems that minimise mechanical disturbance of the soil;
- using permanent bed systems that improve soil structure and soil stability through maintaining or improving soil organic matter levels;
- planting green manure or cover crops during the period between commercial crops to cover the soil and increase soil organic matter levels for improved soil structure, stability and fertility;
- undersowing or planting in the inter-row area at the same time as commercial crops;
- leaving crop residues (where possible) on site until the site is next required;
- minimising the time soil is left exposed between harvest and planting of the next crop; and
- establishing permanent grass or vegetation cover on areas that are not cropped.

• Controlling run-off water

Controlling the direction of flow, volume and speed of run-off water on the site can minimise soil erosion. Long, gentle slopes are just as prone as short, steep slopes. Good planning and drainage design before planting can prevent problems later.

Control measures may include:

- utilising the natural contour lines (natural topography) of the property, where possible;
- cultivating rows across the slope of the land rather than up and down the slope, when practical and safe to do so;
- establishing cut-off drains or banks (also known as diversion banks/drains) to divert and prevent water from other areas coming on to the site;
- establishing contour drains/moulds/bunds to collect and slow run-off from site;
- establishing diversion drains to control excess water flow on and around exposed sites;
- establishing v-drains in inter-row areas to divert water to grassed waterways and away from exposed areas;
- establishing grassed irrigator runs and waterways to control run-off water collected by contour drains, diversion banks and roads;
- interrupting long slopes with a cut-off drain or grassed/mulched rip lines;
- establishing in-paddock structures such as sediment basins and sumps along drainage pathways;
- installing and maintaining barriers such as sediment netting, filter strips or secured straw bales in water drainage channels;
- mulching rip lines;
- positioning access roads on ridge lines or on the contour. If possible, on relatively flat ground, construct access roads so they are higher than surrounding cultivated land;
- ensuring all measures work with natural watercourses within and adjacent to the area being managed; and
- considering the likelihood of excess rain or potential flooding events and managing or avoiding associated run-off when establishing new horticultural sites, particularly where major groundworks are concerned.

• Improving soil structure

Adding organic matter increases soil resistance to erosion. Organic matter can either be left on the soil surface as a mulch or incorporated into the soil to improve soil organic matter levels and soil structure.

• Establishing sediment traps

Sediment traps or ponds (also called silt traps or ponds/sediment retention basins) aim to hold run-off water long enough to allow soil particles to settle. They can be small ponds or weirs, or large dams that capture and re-use run-off water. Artificially constructed wetland systems may be established to

Legal requirements are subject to change. Regularly check with Federal, State and Local authorities for updated requirements.

capture sediment and remove the nutrient in run-off waters.

Filter strips are areas of vegetation that catch sediment and nutrients in water that is flowing to a watercourse. Generally they run alongside watercourses or across a depression. They are not effective if the water is deep enough to flatten the vegetation and is not slowed down. Slopes of more than 10% are unsuitable for filter strips as the water moves across the ground too rapidly for sediment to be caught by vegetation.

Monitoring and recording

Erosion caused by water can be monitored by:

- visual inspection,
- assessing water turbidity, and
- assessing soil erosion losses.

Visual inspection

Immediately after a rainfall event, go and have a look at how run-off is flowing across the farm. Is erosion occurring? How dirty (turbid) is the water?

Inspect the property for signs of scouring (drainage lines, channels) or for silt accumulation around plants or other obstructions.

Photographs can be useful to record problem areas (e.g. drainage lines, rills, gullies, prone slopes) before and after control measures are implemented.

Assessing water turbidity

__Turbidity__ is a measure of water clarity or 'murkiness'. Soil particles in water increase the turbidity.

In addition to a visual inspection of water leaving the property or returning to farm dams, a turbidity tube can be made and used to gauge basic changes in water turbidity. Turbidity meters are also available for more precise assessments.

Turbidity tube

A turbidity tube is a length of clear pipe with a clear bottom. The general idea is to determine the depth at which you can no longer see through the water. This is an indicator of turbidity.

- Collect a water sample in a clean bucket without disturbing sediment from the bottom of the dam or stream.
- Assess the water sample as soon as possible after collecting.
- Place the turbidity tube on a white piece of paper or card that has a cross or other mark on it.
- Shake water sample and pour into the tube until the cross or mark on the card can no longer be seen when viewed from the top (i.e. looking down through the water).
- Record the height of the water in the tube.
- The lower the height of water, the greater the turbidity.
- This may indicate there is a large amount of sediment in your farm run-off and action may be required to stabilise soils or reduce run-off.

The tube and card need to be stored to prevent the tube from getting scratched and the mark on the card from fading.

Assessing soil erosion losses

Place a piece of 100x50 mm timber, or similar, on the ground and, over time, look at the amount of soil that accumulates behind it.

Pegs with depth markings can be placed in silt traps to measure the amount of accumulated silt.

Paddock records can also be useful to demonstrate groundcover/cropping history during times when high rainfall is usually expected.

References and further resources

Australian Soil Resource Information System – www.asris.csiro.au This website contains soil maps for all of Australia.

Bureau of Meterology – www.bom.gov.au

Carey, B, 2004, *Soil conservation measures – A design manual for Queensland* – www.nrm.qld.gov.au and search for 'Design manual', or – www.nrm.qld.gov.au/publications/land_management

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Natural Resources, Mines and Water, Queensland, *Land Manager's Monitoring Guide* – www.nrm.qld.gov.au/monitoring_guide/

New South Wales Department of Agriculture, *Cover crops for subtropical orchards*, Prime Note – www.dpi.nsw.gov.au

New South Wales Department of Agriculture Soil Sense publications – www.dpi.nsw.gov.au

Waterwatch – www.waterwatch.org.au – can assist with turbidity testing and further references.

1b Soil erosion caused by wind

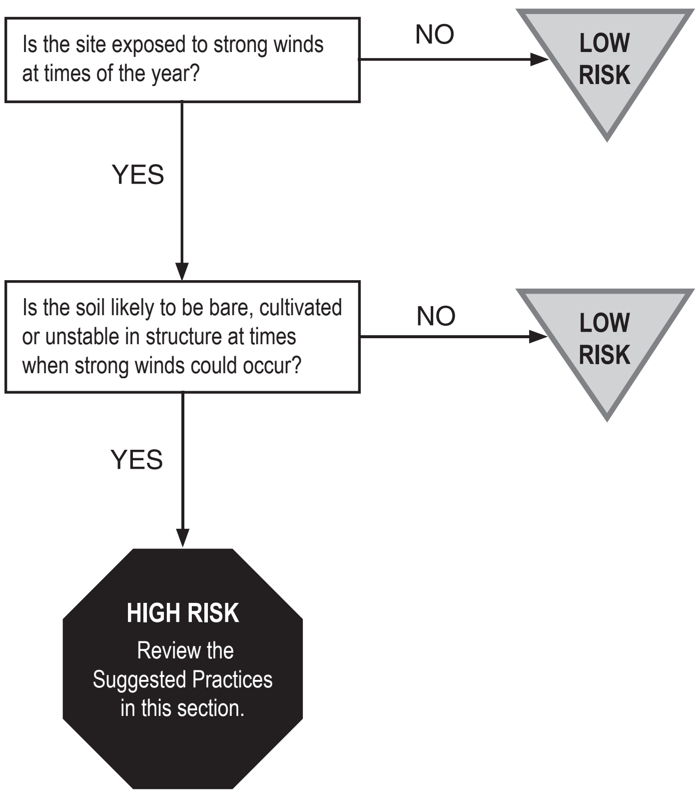
Objective – to minimise the potential for wind to erode soil on the property.

Soil erosion caused by wind happens when wind contacts exposed (uncovered) and unstable soils (soils with weak structure) at speeds that can physically move soil particles. Minimising the area of exposed soil and reducing the wind speed are the keys to minimising soil erosion. Once wind erosion starts, it is hard to control and repair. Prevention is best.

Evidence of soil erosion caused by wind may include:
- dust;
- rills or gullies on light or sandy soils;
- exposed subsoil and rocks (rocks appear to be 'rising to the top' of the paddock);
- exposed roots of trees and shrubs (long-lived vegetation); and
- soil and/or organic matter (such as twigs and grass) building up against the side of fences or hedges.

To manage soil erosion caused by wind, identify the sites on your property that are at risk, assess the level of risk and put control measures in place if needed. There are a number of key strategies you can employ, including maintaining soil cover, controlling wind speed and improving soil structure.

Risk assessment



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HIGH RISK – You need to take some action. Read the Suggested Practices for that topic.

Suggested practices

• Maintaining soil cover

Soil cover protects the soil from erosion by minimising soil exposure to the physical force of the wind. Types of soil covers include:

- grass or native vegetation on areas that are not cultivated;
- inter-row groundcovers in orchards, vineyards and ground crops;
- under-tree groundcovers and mulchers in orchards;
- green manure/cover crops planted between commercial crops; and
- organic mulches, plastic, slashed inter-row material or crop residues spread over the exposed soil.

Managing soil cover
Control measures may include:

- avoiding soil tillage (where possible) during times of the year when high winds are likely;
- planting green manure or cover crops during the period between commercial crops to cover the soil and increase soil organic matter levels for improved soil structure, stability and fertility;
- undersowing or planting between rows at the same time as commercial crops;
- using cover crops for germinating seedlings;
- leaving crop residues (where possible) on site until the site is next required;
- minimising the time soil is left exposed between harvest and planting of the next crop; and
- establishing permanent grass or vegetation cover on areas that are not cropped.

• Moderating wind speed

Controlling wind speed on the site can minimise soil erosion.

Constructing or planting a shelterbelt/windbreak will slow the velocity of wind across a site (shelterbelts/windbreaks should be designed to allow 30-50% of the wind to pass through). The protective effects from a shelterbelt/windbreak reduce with distance away from it (protection extends no more than 20 times the height of the shelterbelt/windbreak).

Vegetation shelterbelts/windbreaks also provide wildlife habitat, assist in minimising spray drift and reduce the visual and noise impacts of site activity and can have an influence in high water tables.

• Improving soil structure

Plenty of organic matter in the soil will strengthen soil structure and make it less prone to wind erosion.

Strategies to improve soil structure may include:

- using minimum-tillage systems that minimise mechanical disturbance of the soil and improve soil structure and soil stability by maintaining higher soil organic matter levels;
- using permanent bed systems that improve soil structure and soil stability by maintaining soil organic matter levels; and
- incorporating organic matter into the soil to build up soil organic matter levels.

• Other management strategies

Irrigation can be applied immediately prior to, or during, wind events to increase the cohesion between soil particles, thereby reducing erosion.

Cultivating so as to leave a rough, raised and very uneven surface can also reduce erosion.

Planning when setting up new sites, particularly where major ground works are concerned, should include consideration of the likelihood of wind extremes and managing or avoiding the periods when

Legal requirements are subject to change. Regularly check with Federal, State and Local authorities for updated requirements.

they are likely to occur. Using remnant vegetation or shelter belts within or adjacent to the new site can minimise soil erosion.

Monitoring and recording

Erosion caused by wind can be monitored by:
- visual inspection, or
- assessing soil erosion losses.

Visual inspection

Wind erosion can be visually assessed – have a look at an exposed site with light soils on a windy day! However, the effects of erosion are often subtle and require an extended period of time to become obvious. In this case it may not be possible to clearly distinguish between the causes of erosion, but an understanding of your own property, soil type and weather patterns should help you determine the most significant influences so that appropriate control measures can be instigated.

Visual signs of erosion include:
- rills or gullies;
- exposed subsoil;
- exposed rocks (rocks appear to be 'rising to the top' of the paddock);
- exposed roots;
- piles of organic matter such as twigs and grass forming 'debris dams'; and
- soil and organic matter caught in or building up against sides of fences.

Photographs are a good way to record changes over time.

Assessing soil erosion losses

Measuring wind erosion can be difficult because of its patchy nature.

Natural benchmarks

For longer-term monitoring in some situations, use natural benchmarks such as big rocks or trees – mark the soil height now, and then check the soil height over time to see if it changes.

Be careful when selecting a natural benchmark (for instance rocks may be moved by livestock or cultivation).

Alternatively, choose a natural benchmark that has a 'soil mark' and measure the distance between this soil mark and the current soil level to gauge the erosion that has taken place up until now.

Erosion pin

An erosion pin is a metal bar driven into the ground with a portion protruding for a known height (e.g. 5 cm). Monitor the distance between the top of the pin and the soil surface over time.

Erosion pipe

An erosion pipe is like an erosion pin except that it contains soil which will not be affected by erosion. Monitor the distance between the soil height in the pipe and that surrounding it.

Be careful where you site the pin or pipe so that results are not affected by ploughing or other soil cultivation activities.

(Details on monitoring soil erosion are taken from Doolittle, W.E, 2004, *Measuring erosion*. Available from http://uts.cc.utexas.edu/~wd/courses/373F/notes/lec17ero.html)

References and further resources

Australian Soil Resource Information System – www.asris.csiro.au – this website contains soil maps for all of Australia.

Hamlet, A.G (Ed) 2002, Soil Management – *A Guide for Tasmanian Farmers*, DPIWE Tasmania.

Doolittle, W.E, 2004, *Measuring erosion*. Available from http://uts.cc.utexas.edu/~wd/courses/373F/notes/lec17ero.html – this website includes details on monitoring soil erosion.

Natural Resources, Mines and Water, Queensland, *Landholders Monitoring Guide* – www.nrm.qld.gov.au/monitoring_guide/

1c Soil structure

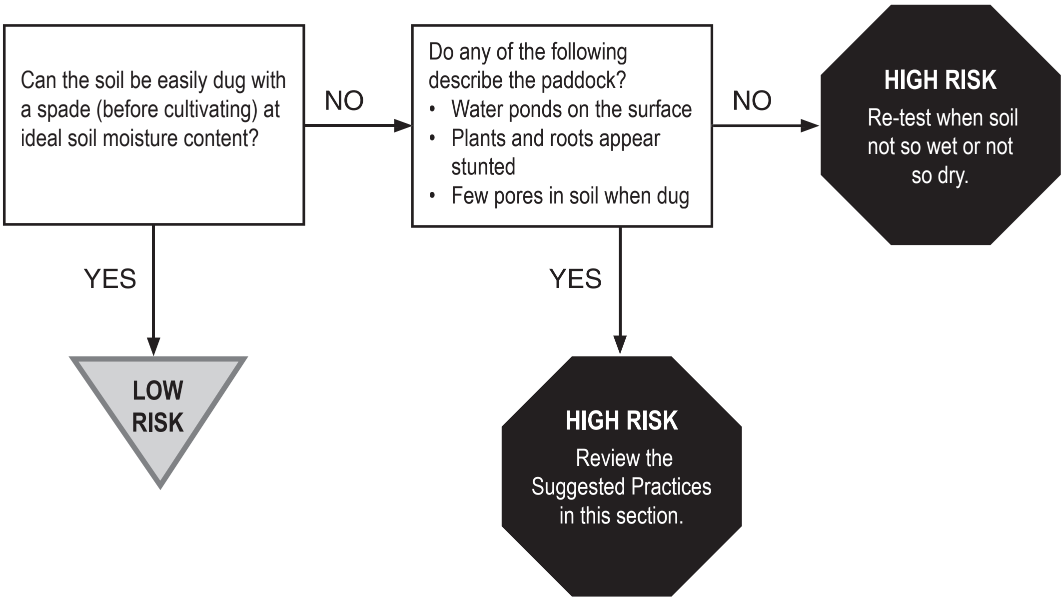
Objective – soil structure is suitable for root growth, water infiltration, aeration and drainage needs of the crop.

Deep well-structured soils grow the best crops. A well-structured soil has pores, channels and spaces between aggregates (clumps). Water can drain quickly, roots go through the soil easily and there is no hard crust on drying.

Degraded soil has a high proportion of small particles with few water stable aggregates. The reduction of pore size and continuity results in massive blocks that restrict root growth and plant productivity. Compacted soil requires more cultivation to prepare a seedbed and this additional cultivation causes further deterioration in soil structure.

To maintain and improve good soil structure you should establish an appropriate crop rotation, increase organic matter in the soil and follow good tillage practices.

Risk assessment



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Suggested practices

Cultivation method

Most tillage for fruit and vegetable crops occurs prior to planting to enable suitable contact between the soil and the planted material. This primary tillage is an important part of initial land preparation and cannot really be avoided. Secondary tillage operations should be minimised where possible.

Machinery can cause compaction, so the following points should be considered:

- minimise traffic in the paddock;
- keep trucks to headlands;
- use low weight spray rigs;
- consider the effects of axle load, tyre width and inflation pressure, aiming to maximise weight distribution; and
- make contractors aware of compaction issues.

Consider using a minimum-tillage approach such as tramlining or semi-permanent beds.

When choosing cultivation, consider the crop stage, soil moisture and soil condition. Rotary hoes are generally used to pulverise the soil for primary tillage. Along with disc cultivators, they should be used as sparingly as possible as their use leads to reduced soil organic carbon and soil compaction. Tyned and non-inverting implements are kinder on the soil structure.

Blunt tools can also add to compaction. Use sharp and correctly-adjusted tools to till the soil. Use implements that mainly apply an upward force to the soil.

Minimise the number of soil workings.

Avoid overworking with powered implements.

Consider using semi-permanent beds.

Cultivation timing

The soil moisture content during tillage has an important effect on soil structure. Where the water content is too great, the soil acts like plasticine, smearing and compacting with tillage and traffic. Don't go onto paddocks with machinery when the soil is wet. Similarly, soils can be too dry to work, requiring excessive amounts of energy to produce a seed bed.

Ideal moisture levels depend on soil type and texture. You can check by working some soil from the plough layer in your hands. If the soil is too wet it will work like plasticine, if it is too dry it will be hard to work and tend to shatter to dust.

*A **sodic soil** has an exchangeable sodium percentage (ESP) of more than 6. This means that sodium comprises more than 6% of the total exchangeable cations in the soil.*

Remedial action

If a hard pan or compaction layer is present, then additional cultivation may be needed depending on whether the cause is cultural or due to sodicity (see Section 1f – Sodicity). If the condition is not due to sodicity, cross-ripping under the correct soil moisture levels will help to shatter the pan, loosening and breaking clods that will break down further when exposed to the weather.

Deep ripping needs to be done early enough to allow weathering, or else try to leave your deepest working to last in the soil preparation sequence, because after ripping the soil is highly susceptible to recompaction.

The benefits of deep ripping can be short term (~1 year) unless actively-growing roots enter the fracture lines.

Legal requirements are subject to change. Regularly check with Federal, State and Local authorities for updated requirements.

Soils with shallow sodic subsoils should not be ripped. This can bring sodic soils to the surface and create problems with surface crusting (see Section 1f – Sodicity).

Increasing organic matter

Increasing organic matter through use of crop rotations and green manure crops promotes good soil structure. Stubbles and crop residues can also be returned to the soil.

You can also apply organic matter such as greenwaste compost.

Crop rotation

Using rotations and green manure crops will provide short-term soil structure benefits through better soil aggregation. This helps optimise the soil's water-holding capacity, ability to hold nutrients, workability and water infiltration.

Rotating crops also assists soil structure, with crops such as grasses and legumes increasing the spaces or pores through the soil. Deep-rooted crops can also recycle excess soluble nutrients like nitrate and sulphur from deeper in the soil and these crops add organic matter as the deep roots eventually break down. Roots help break up the soil and create pores to assist with movement of water through the soil.

Other organic amendments can be added to soils to boost organic matter levels. These include fowl manure, feedlot manure, fish emulsion, humic acid, composts and biosolids.

Monitoring and recording

Soil compaction can be assessed by determining how difficult it is to dig. The assessment should bear in mind any short-term tillage and effects of soil moisture.

Spade test

The following scale can be used:

Hand	Soil that can be dug easily by hand has a poor structure or is very sandy. Maintain and improve structure by increasing organic matter. Use minimum tillage for all crops.
Spade	Soil that can be dug easily using a spade has good or very good structure.
Standing on spade	If you have to stand on the spade, the soil may be compacted or have high clay content. Aim to break up compacted areas and improved drainage.
Jackhammer	This soil is highly compacted or has a very high clay content. Good management is required to improve the drainage. Consider long-term or permanent crops/pasture.

Record the result of spade test.

(Taken from *Spade Test for Soil Management*, Department of Primary Industry and Fisheries, Tasmania, 1997)

Penetrometer (screwdriver) test

A simple test of compaction is to see how far you can push a screwdriver into the soil using reasonable hand pressure. It is a way of simulating the difficulty that roots have pushing through the soil. Try it after decent rainfall or irrigation.

• Visual assessment

Soil compaction affects the ability of plant roots to penetrate the soil and root systems are often stunted. Dig up some plants and assess their root systems and also assess the overall vigour of the plants. Stunted or sharply-bent roots mean small, feeble, low-yielding plants that are prone to drought. It can be useful to compare roots from different areas, such as under fencelines where compaction may be less.

Take a closer look at the clods and aggregates. Many large clods mean the soil will need to be kept wetter to allow roots to penetrate. Sharp angular aggregates with smooth faces indicate poor structure. Well-structured soils have a range of aggregate sizes (2-10 mm), with irregular or rounded shapes and porous faces.

Look for areas where water ponds. Ponding is a way of measuring compaction and soil structure. Water lying around in the paddock means that there are few soil pores in and below the plough level. Soil compaction is one cause of this.

• Soil test

Organic matter content can be included on regular soil tests. Natural levels of organic matter in the soil depend on factors such as climate, site drainage and soil texture. A heavy soil will generally have higher levels of organic matter than light, sandy soils. Measured as organic carbon content, an approximate guide is as follows:

- very low (below 1%)
- low (1-2%)
- satisfactory (2-4%)
- high (above 4%)

References and further resources

Australian Institute of Agricultural Science and Department of Primary Industry and Fisheries, Tasmania, (1997) *Krasnozem Topsoil Structure*.

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Department of Primary Industries, Water and Environment, Tasmania, 1997 – *Spade Test for Soil Management*.

Hamlet, A.G (Ed) 2002, *Soil Management – A Guide for Tasmanian Farmers*, DPIWE Tasmania.

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1d Salinity

Objectives –

- **horticultural activities are managed to ensure soil or water salinity problems are not created or exacerbated.**
- **horticultural production does not contribute to local, catchment or regional salinity problems.**

Salinity refers to the presence of soluble salts in soil or water. These salts may be naturally occurring, coming from the parent material from which the soil was formed. Other sources of salt can be rainfall, overuse of mineral fertilisers or poultry manure, or the use of saline irrigation water. Saline irrigation water may result from salts percolating out of naturally salty soil into waterways or groundwater, or from seawater intrusion into coastal groundwater. Seawater intrusion is usually a result of excessive groundwater drawdown from irrigation, or lack of groundwater recharge due to drought. Primary salinity is naturally occurring, while secondary salinity is the result of human activity. In the context of these guidelines, salinity should be taken to mean secondary salinity.

Salinity can dramatically reduce agricultural productivity, as high salt levels can limit crop growth and even kill plants. Salinity makes it more difficult for plants to extract water from the soil. Salinity also has impacts beyond agriculture as it can affect infrastructure such as roads and buildings. Salinity reduces the diversity of native plants and animals and is linked to environmental degradation such as soil erosion, deteriorating water quality in streams, rivers and groundwater and loss of riparian vegetation.

The development and progress of salinity tends to be highly complex. Water table levels and potential salinity problems and discharge points may vary considerably. This will depend on the site conditions, groundwater processes and land management practices.

Rising water tables are one of the main causes of salinity. Crop and annual pasture plants use less water than perennial native vegetation, therefore allowing more water to travel down past the root zone and into the groundwater beneath the surface. This extra water makes the water table rise. As the water rises it dissolves the salts that are naturally in the soil, so the rising water becomes salty, contaminating the land and surface water. Rising water tables can also bring salt into the root zone, which may not be leached out of the soils by rainfall or irrigation. Evaporation from water tables within two metres of the soil surface also causes salt accumulation in the root zone and can dramatically affect plant productivity.

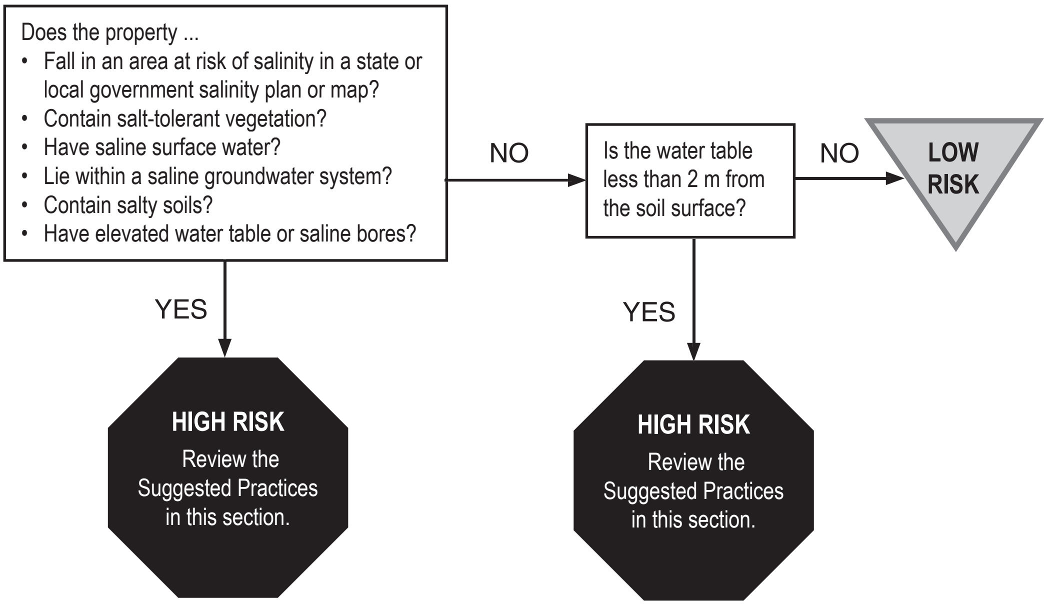
Undulating landscapes tend to have specific groundwater discharge points, resulting in discrete areas of salinity that can vary in severity and area. In contrast, rising water tables in flat landscapes tend to affect larger areas and salinity can be a more regional issue.

Salt movement and salinity outbreaks in landscapes dominated by sandy soils tend to be rapid (<10 years) and severe compared to landscapes with many metres of sub-surface clays. Salt movement in clay landscapes is buffered by the clay and may take decades, or even centuries, to flow through the system.

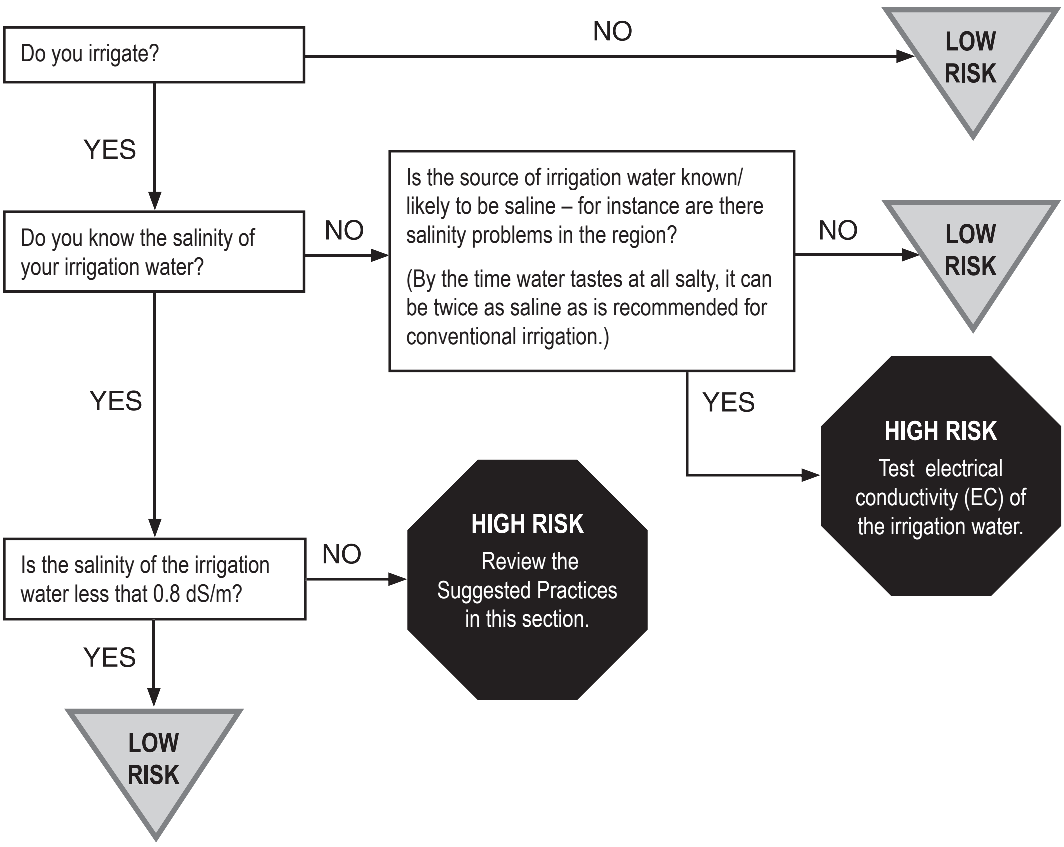
To manage salinity it is important to understand whether it is caused by rising groundwater, irrigating with saline water or saline soils. Sites on a property that are at risk need to be identified, the level of risk assessed and control measures put in place if needed. There are a number of key strategies in relation to managing salinity including careful site selection, understanding the source/cause of salinity, monitoring salt levels in irrigation water and adjusting irrigation strategies where necessary, and minimising rising water tables through appropriate drainage/use of vegetation.

Risk assessment

Groundwater and soil salinity



Irrigation water salinity



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HIGH RISK – You need to take some action. Read the Suggested practices for that topic.

Suggested practices

Always avoid salinity problems in preference to attempting rehabilitation. Key considerations in avoiding salinity include choosing the right site and then employing good soil/water management strategies, combined with diligent monitoring.

Site selection

A megalitre of irrigation water that has a salinity level of 1dS/m will deposit 640 kg of salt.

When choosing sites, consider the likelihood of salinity problems. Undulating landscapes tend to have specific groundwater discharge points, resulting in discrete areas of salinity that can vary in severity and area. In contrast, rising water tables in flat landscapes tend to affect larger areas and salinity can be a more regional issue.

Check for visual indicators of salinity problems, such as:
- salt-tolerant vegetation, and
- bare soil or salt scalds.

A soil survey or Electro Magnetic (EM) survey can help identify, assess and help manage saline soils and water.

Understanding the source

If salinity problems exist or are suspected, it is important to understand the source of the problem. Salinity can be due to saline irrigation water, groundwater salinity or soil salinity.

Irrigation water salinity

Salts dissolved in water can be easily measured by testing for electrical conductivity (EC). A small, hand-held meter is invaluable for checking the salinity of irrigation water and monitoring changes through the season. If irrigation water exceeds an EC of 0.8 dS/m (this is equivalent to 500 ppm or 500 kg of salt in 1 megalitre of water) a full chemical analysis, interpreted by a technical expert, should be undertaken and professional irrigation management advice sought. If salinity is present, depending on the actual EC level and the soil type, consider irrigating at night to avoid high evaporation rates which cause salts to concentrate. Avoid leaf contact (e.g. use drip and not overhead sprinkler), maintain low soil moisture deficit (making it easier to flush salts from the root zone), ensure good subsurface drainage and shandy/dilute saline water with less salty supplies or consider growing salt-tolerant crops. These practices will usually only be beneficial for a short time. It is important to consult a specialist for more site-specific assistance.

***dS/m** stands for deci-Siemens per metre and is a measure of electrical conductivity, and therefore a measure of salinity*

Some salinty benchmarks (in dS/m)

Distilled water = 0	Absolute limit for people = 2.5
Desirable limit for people = 0.83	Limit for mixing herbicides = 4.7
Tastes salty (depending on the ions present) = 1.7	Seawater = 55+

Legal requirements are subject to change. Regularly check with Federal, State and Local authorities for updated requirements.

Tolerance of plants to salinity in irrigation water:

Crop	EC_i**(dS/m) threshold for crops growing in		
	sand	loam	clay
Apple	2.0	1.2	1.7
Avocado	2.3	1.3	0.8
Beans	1.9	1.1	0.6
Beet	6.5	3.7	2.1
Broccoli	4.9	2.8	1.6
Carrot	2.2	1.2	0.7
Cucumber	4.2	2.4	1.4
Eggplant	3.2	1.8	1.1
Grape	3.3	1.9	1.1
Grapefruit	3.0	1.7	1.0
Lettuce	2.7	1.5	0.9
Olive	5.1	2.9	1.7
Onion	2.3	1.3	0.8
Orange	2.9	1.7	1.0
Pea	3.2	1.8	1.1
Peach	4.7	2.7	1.6
Pepper	2.8	1.6	0.9
Potato	3.2	1.8	1.1
Rockmelon	4.6	2.6	1.5
Tomato	3.5	2.0	1.2
Zucchini	7.3	4.2	2.4

(Source: *Australian and New Zealand Guidelines for Fresh and Marine Water Quality* – Volume 1: Chapter 4 – Primary Industries)

** EC_i is a measure of the salinity of the irrigation water. The threshold is the salinity level above which yield decline is likely to occur. The threshold is lower on soils with higher clay content because plants have to work harder to extract water from these soils to start with. Saline irrigation water makes it harder again.

Guidance is available on crop tolerance for water salinity, however this is highly dependent on soil types and the degree of associated waterlogging. Expert advice should be sought.

Groundwater salinity

To minimise the chances of salinity problems, the water table should be kept two metres or more below the soil surface. In some areas this is an issue that requires regional management, such as establishing spear points, tile drains or groundwater pumps to increase the depth of the water table.

The water table should also be monitored over time to check if it is stable or rising. If the water table is high (within 2 m) then artificial subsurface drainage may be needed. If water tables are not yet high but are rising, subsurface drainage may be needed in the future. Also work on improving irrigation efficiency.

Soil salinity

Salinity levels in the soil are measured in a 1:5 soil solution (1 part soil to 5 parts water). These are called EC 1:5 readings. A reading of <0.2dS/m is usually safe for horticultural crops. The heavier the soil texture (e.g. clay) the more sensitive the crop is. Thus EC 1:5 readings need to be adjusted for soil texture to reflect how happy the plant actually feels in the soil. The adjusted measurements are called 'saturation extract' or EC_{se}. For major horticultural projects, it is recommended that EC_{se} values are measured directly rather than the approximate conversions. A few laboratories in Australia provide this service.

In some cases, applying a 'leaching fraction' when irrigating may be necessary to flush salts through the soil profile. However for leaching to be effective, good drainage is needed and a plan for safe disposal of the saline drainage water must also be in place. Consider growing or changing to salt tolerant crops or varieties. Further advice should be sought from a specialist.

Legal requirements are subject to change. Regularly check with Federal, State and Local authorities for updated requirements.

Sometimes high soil salinity can be found when the water table is low and the salinity of the irrigation water is also low. In these instances check the leaching efficiency of the irrigation system. Also check your fertiliser program – certain fertilisers such as muriate of potash can have a strong influence on soil salinity.

High salinity can be found on the edge of wetted areas or in other dry spots. Also check for poor drainage of soil and seek expert advice. Careful management of the soil chemistry is needed when saline, sodic soils are drained.

Soil salinity tolerance of horticultural crops:

Crop	Soil salinity EC_{se} (in dS/m) of the saturation extract	
	Threshold	25% yield loss
Almond	1.5	2.8
Apple or pear	1.7	3.3
Apricot	1.6	2.6
Avocado	1.3	2.5
Beans	1.0	2.3
Broccoli	2.8	5.5
Cantaloupe	2.2	5.7
Capsicum	1.5	3.3
Carrot	1.0	2.8
Cucumber	2.5	4.4
Grape	1.5	4.1
Lemon	1.7	3.3
Lettuce	1.3	3.2
Olive or fig	2.7	5.5
Onion	1.2	2.8
Orange	1.7	3.2
Peach	1.7	2.9
Potato	1.7	3.8
Strawberry	1.0	1.8
Sweetcorn	1.7	3.8
Tomato	2.5	5.0

(Source: Salt Action Salinity Calculator for Horticulture, 1999)

These values are a guide only and can vary with soil type, leaching potential, irrigation method and plant age.

The term leaching fraction refers to the application of water to the point where water percolates down a soil profile.

Irrigation management

In areas affected – or at risk of being affected – by salinity irrigation requires careful management. It is a good idea to seek professional advice before developing an irrigation system in these situations.

Applying a leaching fraction can flush salts out of the topsoil. Rainfall may act as a leaching fraction. However, excessive leaching fractions can worsen the process of salinisation by causing the water table to rise, so they need to be carefully managed.

Monitoring the level of soil moisture provides a means of checking water table depth as well as efficiency of irrigation (see Section 2a – Irrigation efficiency).

Legal requirements are subject to change. Regularly check with Federal, State and Local authorities for updated requirements.

Improving drainage

Improve drainage in saline areas, particularly if salinity problems are associated with a rising water table and saline groundwater. If soils are waterlogged, removing excess water can help leach of salt from the root zone to lower levels in the soil profile. Consideration must be given to management of the drainage water.

Cut-off drains can divert and remove surface water that would otherwise become groundwater recharge. Surface drains should be stabilised with fencing and vegetation cover.

Raised beds with adjoining furrow drains can improve surface drainage and salt leaching.

Sub-surface drainage can reduce waterlogging and increase the leaching of salt.

Care is needed when considering drainage options as drains in dispersive soils can lead to soil instability and severe erosion.

• Vegetation cover

Vegetation can assist in preventing and managing salinity, particularly salinity associated with rising water tables.

Deep-rooted plants can assist in preventing rising water tables, by utilising water deep in the soil profile.

Maintaining vigorous plants will help use rainfall, preventing excess water soaking through the soil surface.

If salinity problems already exist, salt-tolerant tree species can be established to assist with water utilisation and gradual lowering of the water table.

Monitoring and recording

If you are beginning a new project or irrigating a new area, undertake the required investigation to determine the risk of salinity problems arising or to find existing problems.

If salinity problems exist or there is a risk of them developing, a monitoring program should be developed based on a salinity survey and specialist advice. The program needs to be tailored to suit the specific site.

From then on it is a matter of monitoring in areas where salinity issues occur. It is recommended you measure and record:

- soil salinity (electrical conductivity, chemical composition of the salts and EM survey);
- trends in the salinity of irrigation water and groundwater;
- trends in the depth of the water table;
- salinity (sodium and chloride) in leaf samples; and
- photographic points to track changes in scald area and severity.

A low-cost approach to monitoring for salinity is detailed over the following pages. This may not be appropriate for your situation, particularly if dealing with high-value perennial crops where a more detailed analysis of the salinity risk would be warranted.

• Monitoring the water table

Equipment needed – a small 50 mm drilling rig (borrow or hire), a few lengths of 40 mm diameter PVC pipe and a bundle of steel posts.

Select suitable sites for monitoring stations
If you don’t have any visible sign of salt-affected land, choose a site that is convenient for monitoring (i.e. not in the middle of land you will be regularly working up) and that could be at risk of salinity.

If you have a salt scald, choose a monitoring station where the boundary is suspected of spreading, and if possible where the boundary is easy to identify. Two or three monitoring stations for each area of salt-affected land should be sufficient. For each monitoring site, mark the boundary of the affected area with steel posts 10-20 m apart, exactly on the salt boundary, so that you will easily see any change in the boundary over time.

Establish the monitoring stations

At each monitoring station, drill holes (about 50 mm in diameter) with a hand or power auger to a depth of 2 m. If you have salt-affected land, locate the holes across the salinity boundary so that at least one hole is in the unaffected area, one is in the obviously affected area and one is on the boundary.

Use 3 m lengths of 40 mm PVC pipe (Class 6) to line the holes. Cut slots in the bottom metre with a fine-bladed hacksaw. When the pipe is in the hole, pack clay or cement grout around it at ground level to prevent inflow of rainwater. Keep rain out of the top with an upturned jam tin or old bucket. Identify the hole by a number on the top of the pipe. Prevent stock rubbing against the pipe by driving a steel post into the ground next to it or cutting the pipe off short, 20-30 cm above ground level.

Determining the depth of the water table

After establishing the monitoring sites, leave the holes for at least three weeks before measuring the depth to the water table from the top of the pipe. Subtract the height of the pipe above the ground surface to calculate the depth to the water table below the ground surface. Use a metric tape measure with a small wash-basin plug wired on the end to detect the water surface by sound.

If no water is detected in a 2 m deep hole, it is unlikely that the land is in immediate danger of salt encroachment. Capillary rise (wick action) of saline water to the soil surface only operates from water tables that are 2 m deep or shallower in most soil types.

If the water table is 1.5-2 m below ground level, the soil surface must be considered at risk. If the depth to the water table is less than 1.5 m there may well be indications of salt on the surface.

With the water table at 1 m or less, salting is practically inevitable. In the worst cases, the water table level in the pipe may rise above ground level, indicating upwards pressure in the water table.

Soil profile sampling

Take soil samples from near each hole during dry months. Sampling should be conducted down the soil profile, ideally to a depth of at least 2 m.

Label each sample clearly with the number of the hole and depth. Get the soil samples analysed for electrical conductivity. Sites should be sampled every six months to three years depending on the results and risk of rising water table.

Take water samples

Using a weighted dipper on the end of a piece of cord (or a submersible pump), take a sample of groundwater. Have this sample analysed for electrical conductivity.

Long-term monitoring

To detect whether the water tables are rising, falling or stationary over a period of years, check water table depths regularly and record or graph them. The most suitable time for measuring depths is in dry months, when the risk of capillary rise is greatest. It is a good idea to take measurements across the seasons to establish the range of water table heights.

Annual checking of the saltland boundary between the steel posts will also indicate whether the problem is getting worse, is stable or is retreating. Take photographs to record changes.

Soil sampling near the holes every three years or so will also confirm any changes in the soil salinity suggested by the vegetation. Take the samples at the same time of year but not within three weeks of heavy rain.

Make a note each year of the vegetation type and density near each hole. It is likely to vary with the degree of salinisation. If the site is being cropped, note the relative health of the crop across the salinity boundary. Photographs are a particularly useful record.

Interpretation of results

You have definite evidence of a worsening situation and of its rate of change if, over a period of years:

- the water table levels in spring and summer are rising;
- the boundary of salt-affected vegetation is moving outwards; or
- topsoil salinity levels are increasing.

However, you have evidence of a stable situation under the present climatic and management regime if the water table levels, boundary of salt-affected vegetation and topsoil salinities are not changing.

● Monitoring salt levels in irrigation water

A hand held conductivity meter can be used to measure salinity in soil and water samples.

● Monitoring irrigation and leaching

There are many soil moisture monitoring tools available. Capacitance probes are amongst the most useful for indicating soil moisture levels.

References and further resources

Australian Soil Resource Information System – www.asris.csiro.au – this website contains soil maps for all of Australia.

Department of Agriculture, Western Australia, 2001, *A simple way to monitor your saltland*. Farmnote 35/91.

Department of Environment and Heritage, *Water Quality Guidelines* –
www.deh.gov.au/water/quality/nwqms/pubs/wqg-ch4.pdf

Department of Primary Industries, Water and the Environment, Tasmania, *Saltpak* (simple field test kit)

Hamlet, A.G (Ed) 2002, *Soil Management – A Guide for Tasmanian Farmers*, DPIWE Tasmania

National Dryland Salinity Program – www.ndsp.gov.au/

State of the Environment Tasmania 2003, Resource Planning and Development Commission
– www.rpdc.tas.gov.au/soer/lan/2/issue/27/ataglance.php

1e Soil acidity and alkalinity

Objective – soil pH is maintained within the optimum range for crop production.

Soils can be naturally acid or alkaline. Soil pH may also change with irrigation, fertiliser and crop management practices. As soil pH changes, the availability of soil nutrients may also change. Therefore it is important to monitor soil pH changes over time.

Soil acidity

Soil acidification is a major land degradation issue, which can lead to reduced availability of nutrients, lower yields and fewer crop options. Soil acidity can be naturally occurring and can be made worse by prolonged and heavy use of nitrogen fertilisers like sulphate of ammonia and MAP (monoammonium phosphate). It can also be exacerbated by the removal of hay and alkaline materials.

The speed with which soil becomes acidic depends on many factors including soil type, soil texture (sandy soils become acidic more easily), organic matter, cation exchange capacity, the amount of crop product removed and the type of fertiliser used.

Older and more highly-weathered soils are likely to have become acidic due to the natural processes of time and weathering. Calcium and, in particular, magnesium can be leached out of the soil profile under these conditions, contributing to acidity.

Acid sulphate soils are formed when seawater or sulphate-rich water mixes, in the absence of oxygen, with land sediments containing iron oxide and organic matter. Acid sulphate soils are commonly found less than 5 m above sea level. Mangroves, salt marshes, floodplains, swamps, wetlands, estuaries and brackish or tidal lakes are ideal areas for acid sulphate soil formation.

The presence of acid sulphate soil may not be obvious on the soil surface as it is often buried beneath layers of more recently deposited soils and sediment.

When exposed to air due to drainage or disturbance, these soils produce sulphuric acid which in turn can release toxic quantities of iron, aluminium and heavy metals.

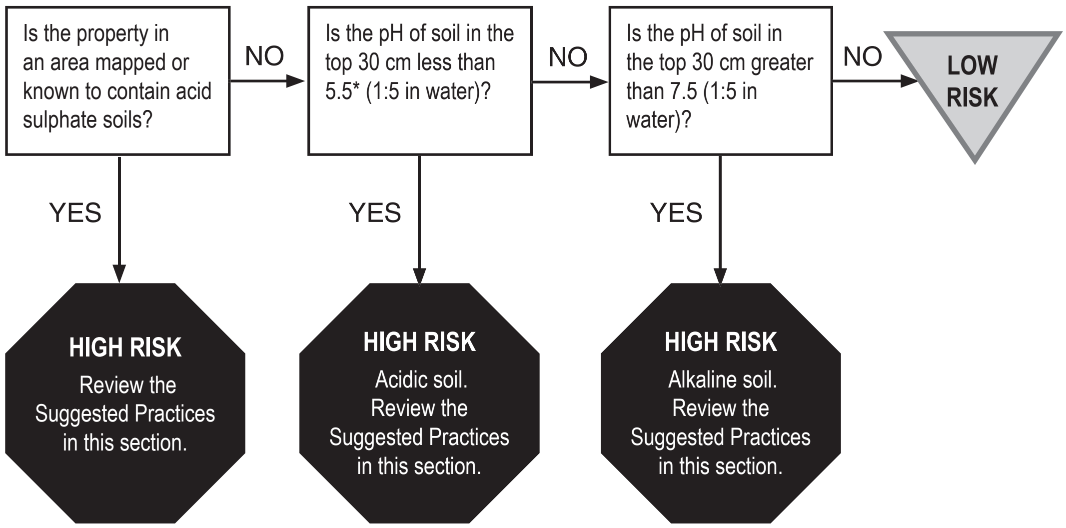
Soil alkalinity

Alkaline soils have a pH greater than about 7.5, or a high sodium content or both.

Alkaline soils may be deficient in zinc, copper, boron and manganese. Soils with an extremely alkaline pH, (>9) are likely to have high levels of sodium.

Some soils in the semi-arid and arid regions have naturally high pH caused by significant quantities of free calcium carbonate. Irrigated well/bore water may also contain significant quantities of calcium carbonate.

Risk Assessment



* There are some exceptions to this limit, a few plants on some soils grow best below pH 5.5.

LOW RISK – You probably don't have a significant problem in this area. You may like to read the Suggested Practices section to check your understanding of the issue.
HIGH RISK – You need to take some action. Read the Suggested practices for that topic.

Suggested practices

● Soil acidity

Lime or dolomite is usually added to maintain soil pH within a desirable range and can reverse the acidifying process in surface soils. Soil testing can help determine the correct rate to apply. Over-application can take years to remedy and can decrease uptake of nutrients by plants. It is usually easier to apply lime before planting. Thorough incorporation improves results, although incorporating lime into subsoil layers is difficult.

Not all soils can be maintained at pH 5.5 or above. Unless acidic soils are already cultivated and acid tolerant crops are to be grown, consider leaving them in their natural state, as drainage and cultivation can cause extreme acidification. If this occurs, liming is often expensive and often fails to achieve a lasting increase in pH.

Nitrogen leaching is a common form of soil acidification; reducing nitrogen, reducing leaching or using less acidifying forms of nitrogen can assist in reducing soil acidification. In some fertilisers the conversion from the applied form to one the plant can take up is a process that acidifies the soil. The acidification potential of different fertilisers is:

- severely acidifying – ammonium sulphate and monoammonium phosphate (MAP);
- moderately acidifying – diammonium phosphate (DAP);
- slightly acidifying – urea and ammonium nitrate; and
- non-acidifying – potassium nitrate, calcium nitrate and composted poultry manure.

Nitrates are highly mobile under the influence of high rainfall or over-irrigation and will readily leach in permeable soils. This process can cause further soil acidification and contamination of surface and groundwaters.

Legal requirements are subject to change. Regularly check with Federal, State and Local authorities for updated requirements.

Legumes or nitrifying crops can also contribute to soil acidity.

Soil acidity can also develop under drip irrigation where soils are highly leached.

Efficient nitrogen application includes applying smaller amounts of fertiliser more often. Fertigation (that is, applying fertilisers through irrigation systems) is one technique that can help match fertiliser application more effectively with crop demand and also allows for use of soluble fertilisers like potassium nitrate and calcium nitrate. Organic matter can help to buffer soil from pH changes.

Acid sulphate soils should not be drained, cleared or exposed. This will prevent mobilising the acids and toxic elements in the profile.

● Soil alkalinity

Alkaline soils need to become more acidic. One way of achieving this is to use fertilisers such as crushed sulphur and some ammonium-based nitrogen fertilisers.

Elemental sulphur combines with oxygen and water to become sulphuric acid. This process can take some time and its effect on soil pH will depend on how much free calcium carbonate there is as this acts as a buffer.

Monitoring and recording

A check of the soil pH is an ideal way of monitoring the change in acidity of soils over time. It is important that pH is determined in soil samples taken to a depth of at least 60-80cm to represent the root zone, and because surface lime applications often only increase pH to the depth the lime was incorporated. When collecting samples, be careful to separate the 0-15 cm and 15-30 cm samples from the deeper layers so that the acidity profile can be identified.

You can also measure pH with a simple test kit available from rural merchandise stores. The kit uses colour to indicate the pH level and is easy to use. It measures pH in water and not calcium chloride, so the results may be different from laboratory tests conducted by your local provider.

Soil water extraction tubes can be used to collect soil water samples at different depths for analysis of pH as well as other factors such as salinity and nitrates.

References and further resources

Australian Soil Resource Information System – www.asris.csiro.au . This website contains soil maps for all of Australia.

Soil acidity:

Australian Government Agricultural Portal – www.agriculture.gov.au and go to Resource Management/Soil/Soil Acidity

Department of Primary Industries, Victoria – www.dpi.vic.gov.au and go to Agriculture & Food/Soil & Water/Soil acidification

NSW Department of Agriculture – www.agric.nsw.gov.au/reader/soil-acid/ss792-acidity.htm

Acid sulphate soils:

State of the Environment Tasmania 2003, Resource Planning and Development Commission – www.rpdc.tas.gov.au/soer/lan/2/issue/91/ataglance.php

Natural Resources, Mines and Water, Queensland – www.nrm.qld.gov.au/land/ass/index.html

Soil alkalinity:

Cliff Snyder, Soil pH Management – www.agcentral.com/imcdemo/04pH/04-05.htm

Natural Resources, Mines and Water, Queensland www.nrm.qld.gov.au/factsheets/pdf/land/l47.pdf

If Sodicity

Objective – soil permeability is adequate for water infiltration and drainage needs of the crop and erosion of sodic soils is minimised.

Sodic soils are those where the amount of sodium held on to the clay particles is 6% or more of the total cation exchange capacity.

Sodic soils have an unstable structure and are poor places for plants to grow.

Following rain or irrigation with fresh water, clay particles in sodic soils force each other away, because of the sodium bound to the clay. This causes the soil to disperse, leaving a cloudy suspension.

Soil sodicity and soil salinity are often related because both involve sodium – a metal element widespread in Australian soils. Sodicity may be the more obscure problem, but it is a more widespread form of land degradation. It affects nearly a third of all soils in Australia (including one-third of all agricultural soils) and can cause poor water infiltration, low water storage, toxicity, surface crusting or sealing and waterlogging.

Many duplex soils (sandy topsoil over clay) in Australia have sodic clay subsoils. The structure of the subsoil clay is described as prismatic or columnar, which is hostile to plant roots. Tunnel erosion is also a risk on slopes with sodic clay subsoils.

The impacts of sodic soils extend to water catchments, infrastructure facilities and the environment. Run-off from sodic soils carries clay particles into waterways and reservoirs causing water turbidity, or cloudiness.

Risk assessment

Soil can be described as:
- subject to waterlogging?
- poor water infiltration?
- subject to surface crusting?
- severe erosion, including tunnelling?
- "spewy"?
- exposed subsoils have dribble patterns?

NO → **LOW RISK**

YES ↓

Test soil:
- Field test – take some soil crumbs and assess dispersion in fresh water.
- Laboratory test – collect samples for laboratory test of ESP (exchangeable sodium percentage) and EC (electrical conductivity.

NO not sodic → **HIGH RISK** Seek other diagnosis of soil problems (e.g. waterlogging).

YES sodic ↓ **HIGH RISK** Sodic soil. Review the Suggested Practices in this section.

LOW RISK – You probably don't have a significant problem in this area. You may like to read the Suggested Practices section to check your understanding of the issue.
HIGH RISK – You need to take some action. Read the Suggested Practices for that topic.

Suggested practices

Improving sodic soils is not straightforward. Good soil management practices will generate as much benefit as high-input, costly remedial action, especially if the soil is in reasonable condition to begin with. Practices such as minimising tillage and compaction, returning large amounts of organic matter to the soil and improving surface drainage should be the first consideration before undertaking specific remedial action.

Once basic good soil management practices are adopted then attention can be turned to the sodicity problem itself. If sodic soils are identified or suspected seek professional advice.

Calcium in the form of gypsum can be added to sodic soils to improve their structure. Gypsum may also be applied to the soil via the subsurface drip irrigation system.

Gypsum improves soils in two ways. The first is a short-term benefit. The calcium salts in the gypsum increase the salt level in the soil solution around the clay particles. This prevents dispersion of sodic clays and promotes aggregation.

The second effect is a longer-term one. Sodium ions held on the clay particles are swapped with the calcium ions from the gypsum. This helps reclaim the soil and allows the displaced sodium ions to be leached out below the root zone.

The gypsum can be applied to riplines to help stabilise fracture lines, or broadcast and either incorporated or left on the surface. The best option depends on the nature, depth and extent of soil sodicity. Other factors to consider are soil pH, soil salinity, irrigation water quality, drainage, irrigation systems and the horticultural enterprise being undertaken. Because there are many factors to consider when dealing with sodic soils, it is advisable to seek professional advice.

Lime (calcium carbonate) can also be used if the soil is not alkaline. However lime does not have the short-term benefits of gypsum.

Generally sodic soils take many years to improve using lime and gypsum. In the meantime it is important to manage these soils appropriately:

- Minimise tillage and avoid aggressive, deep working.
- Maximise returns or additions of stubble and organic manures to stabilise structure and maintain permeability.
- Install surface drains and cutoff drains to minimise waterlogging.
- Consider raised beds.
- Sodic soils can be irrigated with slightly saline water. Fresh water will maximise dispersion. Seek professional advice, as this can have negative effects on plant health due to increase in sodium and chlorine levels.
- Avoid deep ripping – unless soils are stabilised with gypsum, the fracture lines will collapse during the first full saturation, resulting in a more compacted and impermeable state than prior to ripping.

Technical advice should be sought to identify the suite of management options that are relevant and practical for the management of sodic soils in your particular situation.

Monitoring and recording

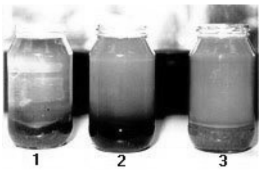
Monitoring of soil physical properties and sodium levels is required to check the results of your management strategies.

Legal requirements are subject to change. Regularly check with Federal, State and Local authorities for updated requirements.

Test the surface and the subsoil separately to determine the distribution of any sodicity problem.

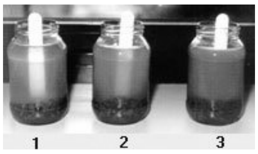
- Collect samples from both the surface and the subsoil using a 5 cm soil auger or similar. Place the samples in clean buckets, one bucket for the subsoil and one for the surface soil.
- Collect samples randomly from a minimum of five locations over a uniform 1-2 ha representative area of the paddock.

- If it isn't clear where the subsoil begins, take a sample from the top 10 cm of the soil profile. Then take a second sample from somewhere deeper in the profile, within the range of 20-60 cm below the surface.
- Spread the soil from each bucket into a thin layer on a clean plastic sheet. Place in a well-ventilated location to air-dry, which may take several days.
- You need pieces of soil approximately 1 cm in diameter for this test. If necessary, break the air-dried soil into pieces and then mix thoroughly.
- From each surface and subsoil sample weigh 100 gm of soil into a clean 600 ml glass jar with lid.
- Measure out 500 ml rainwater or distilled water to give a 1:5 ratio of soil to water.
- Gently pour this water down the side, without disturbing the soil at the bottom.
- Invert the jar once, slowly and gently, and then return to its original position (avoid any shaking). Then let stand for four hours, with no vibrations or bumping.
- Check the suspension above the sediment at the bottom of the jar. Place a white plastic spoon or spatula in the solution (without stirring) to assist in determining the level of sodicity. Score the cloudiness using the following scale:



Estimating turbidity (soil sodicity) in a 1:5 soil/water suspension:

1 Clear or almost clear – not sodic
2 Partly cloudy – medium sodicity
3 Very cloudy – high sodicity



Estimating turbidity using spatula visibility:

1 Plastic spatula visible – not sodic
2 Plastic spatula partly visible – medium sodicity
3 Plastic spatula not visible – high sodicity

Make up another soil suspension and repeat the process if unsure. Record the results.

A laboratory test for ESP (Exchangeable Sodium Percentage) and salinity of both surface and subsoil will provide the necessary information to decide management options.

(Source of salinity monitoring information is the Australian Academy of Science, 1999, *Sodicity – a dirty word in Australia*, Activity 1, A field test for sodicity, Australian Academy of Science website – www.science.org.au and select Nova, then select Physical Sciences and scroll down to *Sodicity – A dirty word in Australia*).

References and further resources

Australian Soil Resource Information System www.asris.csiro.au . This website contains soil maps for all of Australia.

Department of Primary Industries, Victoria – www.dpi.vic.gov.au and go to Agriculture & Food/ Factsheets/Soil & Water/Groundwater/Effects of irrigating with saline water on soil structure in the Shepparton Irrigation Region

NSW Department of Agriculture – www.agric.nsw.gov.au/reader/soil-sodic
There are also other relevant fact sheets under the soil management and irrigation section of this website.

Nova, *Sodicity – a dirty word in Australia* – www.science.org.au/nova/035/035key.htm

2 Water management

Objective – to maximise water use efficiency without compromising water quality on-farm and downstream.

2a Irrigation efficiency

Objectives –
- **uniform application of water to match crop needs.**
- **drainage impacts are managed in accordance with environmental, community and regulatory standards.**

Water is a valuable resource and in many areas is becoming increasingly scarce. Good irrigation management is essential to maximise yields and control product quality.

Availability of water is increasingly subject to government regulations. These are designed to ensure waterways and groundwater extractions are at sustainable levels and protect the health of aquatic environments.

Water management considers both the crop's water demand and the amount of water available. It also involves management of irrigation to maximise efficient use of water applied.

Drainage water and run-off also need to be managed to avoid any impact, such as nutrient pollution, on groundwater or waterways and wetlands.

Irrigation efficiency is a term that helps us define the proportion of irrigation water that is actually taken up and used by the crop. Improvement in irrigation efficiency is normally associated with water savings, production gains and better long-term environmental management.

Irrigation efficiency is determined by irrigation management factors such as:
- ensuring irrigation systems are operating to design specification and applying water as evenly as possible;
- ability to time, or schedule irrigation, based upon crop water needs; and
- clear understanding of soils' water holding, infiltration and drainage capacity.

To manage irrigation efficiently a number of management practices need to be considered, starting with an understanding of water availability and crop requirements.

Efficient irrigation management practices
There are nine basic steps involved in the efficient management of irrigation:

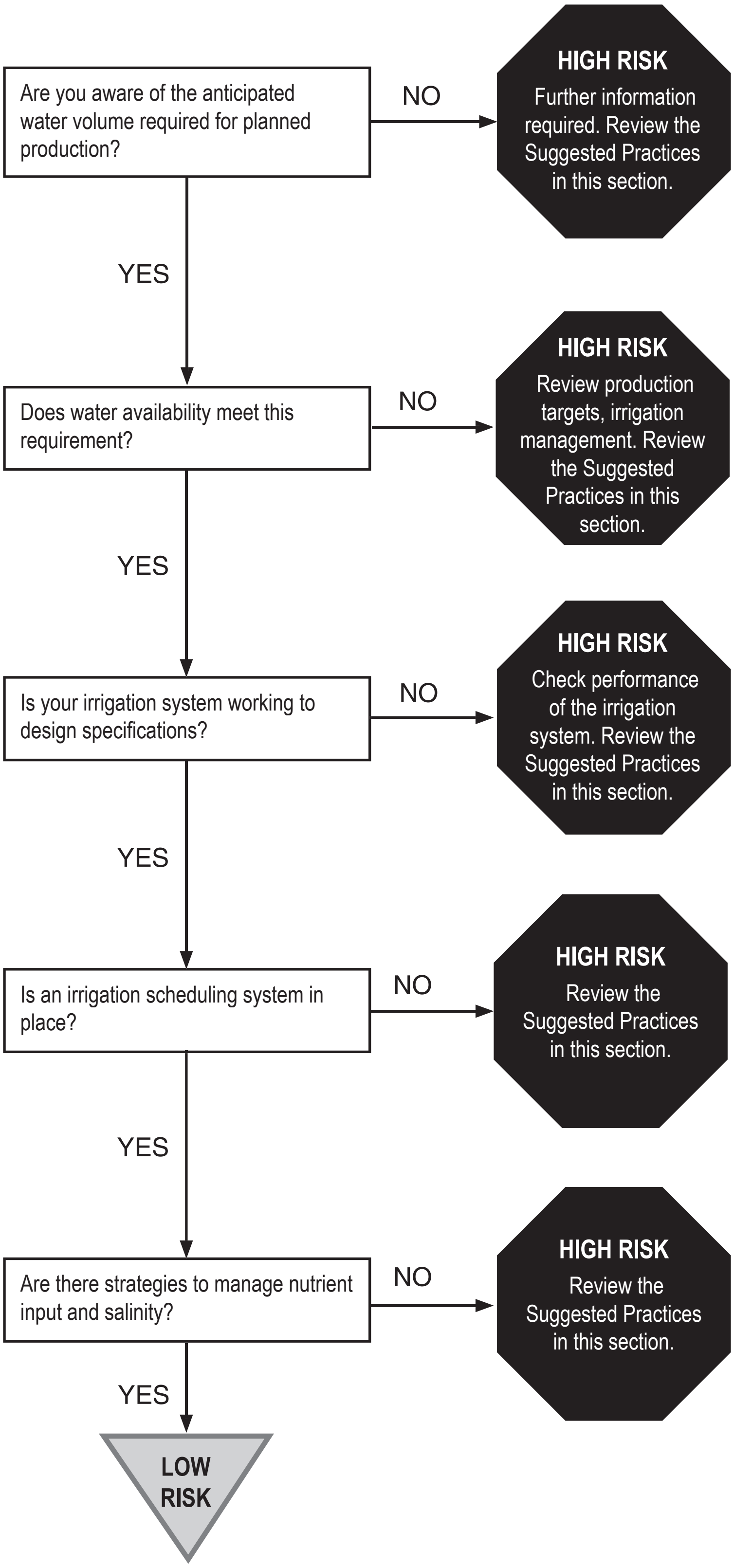
Identify
Define property goals and implications for water management

Plan
Know your soils
Design the most suitable irrigation system
Develop a farm water budget
Know your water supply/ies

Do
Determine a basic irrigation schedule
Implement strategies to manage nutrient input and salinity

Monitoring and recording
Monitor, record and evaluate
Check irrigation system performance

Risk assessment



LOW RISK – You probably don't have a significant problem in this area. You may like to read the Suggested Practices section to check your understanding of the issue.
HIGH RISK – You need to take some action. Read the Suggested Practices for that topic.

Suggested practices

● Identify your goals

Your goals will largely depend on the crop(s) you are growing and desired yield and quality. The property goal can be made up of a series of block or paddock goals. Once the goal is defined, you can identify the right irrigation management strategies to help meet your goal, e.g. growing 150 tonnes of Class A onions for the export market; growing 200 tonnes of processing potatoes; or establishing 2 ha of cherry trees and producing 20 tonnes of processing peaches from existing orchard.

The goal may also be influenced by average annual rainfall, capacity of the irrigation water source, regulatory restrictions on water storage or access to surface and underground water. A fairly accurate estimate of expected crop water use will assist in balancing property water supply with yield and quality targets.

● Know your soils

A soil survey is a fairly comprehensive analysis of soil types and their distribution across your property. Soil surveys establish a better understanding of your soil's ability to hold water and any potential physical and chemical limitations to growing your crops in that soil.

Soil surveys assist in determining if the land is suitable for developing particular crop types and help identify the irrigation system types that may be most suitable, manageable and efficient.

Soil surveys are also useful for identifying:

- soil structural issues that may result in limited drainage, surface run-off, soil structure decline and root growth problems; and
- soil chemical and nutritional characteristics that may directly effect plant growth or result in long-term soil quality decline (i.e. soil acidity, salinity and sodicity).

The types of measurement often referred to in a farm soil survey are:

- Readily Available Water (RAW) – this is the water content value most relevant to irrigators. As the name suggests, Readily Available Water is the water component that can be readily used by the crop under ideal growing conditions. It is not the total soil water content. Ideally irrigation should replace water that has been removed by growing crops (there are exceptions to this generalisation but it stands as a sound 'rule of thumb').
- the infiltration rate of soil – another valuable parameter which assists with better matching the application rate of the irrigation system with the soil's capacity to absorb this water without wastage or run-off.

Readily Available Water (RAW)

RAW is determined by soil texture and the rooting depth of the crop. The table below helps you estimate how many millimetres of readily available water* would be held in a metre of topsoil.

Readily available water for different soil types:

Soil texture	Readily available water (mm/m) between – 8kPa and	
	-40Kpa	-60Kpa
Sand	35	35
Loamy sand	50	55
Sandy loam	60	65
Loam	65	75
Sandy clay loam	60	70
Clay loam	55	65
Clay	45	55

Legal requirements are subject to change. Regularly check with Federal, State and Local authorities for updated requirements.

* Readily Available Water, as referred to in this table, is the water available between the soil being at full point (-8kPa) and dried to a tensiometer or gypsum block reading of –40kPa and –60 kPa. More information can be found at www.growcom.com.au/WaterForProfit_fs.html and going to *How much water is in my soil* and *Soil water and texture*.

Infiltration rate

Infiltration rate is the speed at which water can move through a soil. Infiltration rate is related to soil texture, bulk density, organic matter, surface soil stability and groundcover.

The infiltration rate of a soil determines the maximum rate at which irrigation should be applied. Applying irrigation at a higher rate results in surface run-off. The table below provides indicative irrigation rates.

Average infiltration rates for some soil types: *

Soil texture	Suggested application rate (mm/hr) Average soil structure	Suggested application rate (mm/hr) Well-structured soil	Infiltration rate range (mm/hr)
Sand	50		20-250
Sandy loam	20	45	10-80
Loam	20	45	1-20
Clay loam	20	40	2-15
Light clay	2	5	0.3-5
Medium – heavy clay	0.5	5	0.1-8

(* Taken from Wise Watering Irrigation Management Course 2001.)

Understanding soil characteristics across the property is vital for determining irrigation frequency and depth of application. It also allows soils with similar characteristics to be grouped into the same irrigation management area, based on the amount and rate at which irrigation water can be applied. It can be used to select representative sites to monitor soil moisture.

Design irrigation systems

Crop production will suffer if the irrigation design or the irrigation method does not suit your property goals or the soil type. One of the key aspects of design is to match irrigation delivery with water demand.

Consideration should be given to issues such as crop type, variety, harvest dates, soil type, topography and exposure to drying winds. Poor designs reduce irrigation efficiency, cause uneven water application and uneven crop yield and quality. Efficient fertiliser application, particularly fertigation, depends on uniform water application.

Different irrigation system options include:
- drip irrigation (both surface and sub surface buried tape);
- micro-sprinklers;
- capillary bed (for containers);
- sprinkler irrigation;
- travelling gun irrigation;
- centre pivot and linear move irrigation; and
- surface (flood or furrow) irrigation.

Legal requirements are subject to change. Regularly check with Federal, State and Local authorities for updated requirements.

In general, pressurised irrigation systems are a more efficient form of water delivery than surface flood or furrow irrigation. Growers in many irrigation regions are moving away from flood/furrow irrigation systems and changing to pressurised systems that enable more accurate and manageable water delivery. Whatever irrigation method is chosen, the system must be designed to accurately match soil type and plant water demand and protect the environment.

The table below gives some range of expected irrigation application system efficiencies.

Expected irrigation application system efficiencies:

System	% Efficiency
Rain gun (cannon, travelling irrigator)	50 – 75
Fixed sprinkler	65 - 85
Linear move	75 - 90
Centre pivot	75 – 90
Drip	80 - 90

There are many factors in determining the most suitable irrigation system. Factors to consider include:

- soil types and variation
- Readily Available Water (RAW)
- yearly water allocation
- maximum extractable or stored water supply
- markets/end use of crop
- the need for frost protection
- the option of a cover crop
- maintenance and longevity of system
- recycle structure
- cost to install and maintain system
- long-term reliable extractable or stored water supply
- topography
- maximum crop water demand
- water quality
- fertigation
- allowances for leaching fraction
- the need for crop cooling
- potential pests and diseases
- average annual rainfall
- microclimate variation
- climate

Using experienced irrigation designers and installers for your crop is important. The Irrigation Association of Australia has a list of certified irrigation designers. See www.irrigation.org.au for more information.

● Developing a farm water budget

A farm water budget is about making sure you have enough water to meet the property goals. Water budgeting helps determine the amount of water you expect to use over the season and attempts to match this with intended irrigated crop area so that the horticultural business can check that planned irrigation needs are within water entitlements.

Water requirements need to be budgeted using measurements of crop water demand at different times of the year, the irrigation system and knowledge of the soil water holding capacity. Individual farm data is best, but in some districts average crop water demands have been calculated and are available from agronomists and irrigation specialists.

Farm water budgets can be refined to crop-specific water budgets and irrigation schedules. There are two main types of irrigation schedule, indirect and direct. These are discussed further below (see 'Determine a basic irrigation schedule' later in this section).

An example of a water budget:

Property name:
Year:
Intended crops:

Crop	Variety	Crop area (ha)	Water requirements / ha	Water requirements for crop
Total water requirement for property				
TOTAL water allocation for property				
Sufficient water available to grow intended crops?				

Legal requirements are subject to change. Regularly check with Federal, State and Local authorities for updated requirements.

Know your water supply

Understanding your crop water requirements and reliability of water supply is crucial.

The availability of water will affect the choice of crop type, the irrigation system and your irrigation management strategy. For example, drip systems (above ground or sub-surface) require a water supply that allows irrigation at short notice (e.g. within 24 hours) particularly during hot weather. Check with your state water agency to ensure the necessary licences/permits are obtained. In some districts with water allocation schemes, delays in ordering and then receiving water may limit your ability to adopt these practices. On-farm storage will reduce this problem, however, it is advisable to check whether licences/permits are required to construct dams. Interference with a waterway or obstruction of flow may require a licence/permit.

Comparing your crop water requirements against the quantity of water supply available will determine if you have sufficient water. Water may be limiting on an annual basis or sometimes in peak demand periods. If water supplies are limiting or uncertain, more efficient irrigation techniques and drought management strategies need to be considered.

Determine a basic irrigation schedule

Irrigation scheduling includes determining when and how much to irrigate. Growers have traditionally relied on their knowledge and experience to schedule irrigation. However many growers are now using other measures such as soil moisture monitoring, to fine-tune their irrigation scheduling. Irrigation scheduling can be done by indirect or direct means.

A correct irrigation schedule can optimise yield and crop quality, and reduce the amount of water used. In turn, pumping and water costs may be reduced and drainage minimised. Applying the right amount of water will also avoid leaching of nutrients beyond the root zone. This careful irrigation management helps to achieve production targets and has environmental benefits.

Indirect irrigation scheduling

Crop water demand can be determined by estimating the total loss of water from the crop based upon information such as local evaporation and expected crop water loss through the leaf surface referred to as ‘evapotranspiration’ (ET). Refer to Water for Profit – ‘Estimating crop water use based upon evaporative measurements’ for more information (see References).

The Bureau of Meteorology web site provides maps of average monthly evaporation for Australia for each month of the year. The January map shows that virtually all of Australia’s horticultural regions experience an average evaporation of less than 250 mm during that month (~8mm per day). A monthly evaporation of 250 mm represents a monthly water demand of 2.5 ML per hectare.

Some growers use software to develop a daily water budget. An example is shown below. This uses crop coefficients or crop factors to convert daily evaporation readings into estimated crop water use. Refer to *Water for Profit* information sheets for more information (see References).

Legal requirements are subject to change. Regularly check with Federal, State and Local authorities for updated requirements.

IRRIGATION SCHEDULING SPREADSHEET

SITE: SHEPPARTON

YEAR: 2003/04

Volume applied to this crop: 42 ML

Total hectares as entered: 30
Total volume used for year: 42

CROP = PEACHES

Hectares 30

Crop Factor	Effective rainfall
0.9	0.8

* Enter data in white squares
* Irrigate when soil moisture deficit is greater than 50 mm

Date	Evaporation (mm)	Rainfall (mm)	Potential ET (mm)	Effective Rainfall (mm)	Irrigation Applied (mm)	Soil moisture deficit (mm)
23 Nov	5.5		4.95	0	40	0
24 Nov	4.5		4.05	0		4.05
25 Nov	2	10	1.8	8		-2.15
26 Nov	8.8		7.92	0		5.77
27 Nov	6.8		6.12	0		11.89
28 Nov	5.9		5.31	0		17.2
29 Nov	2.5		2.25	0		19.45
30 Nov	5.5		4.95	0		24.4
1 Dec	9.9		8.91	0		33.31
2 Dec	9.9		8.91	0		42.22
3 Dec	7.1		6.39	0	50	-1.39
4 Dec	5.5		4.95	0		3.56
5 Dec	9.9		8.91	0		12.47
6 Dec	10.1		9.09	0		21.56
7 Dec	12.1		10.89	0		32.45
8 Dec	9.9		8.91	0		41.36
9 Dec	9.7		8.73	0	50	0.09
10 Dec	8.8		7.92	0		8.01
11 Dec	1.1	50	0.99	40		.31

Direct irrigation scheduling

Direct irrigation scheduling is achieved by measuring soil moisture. Soil moisture monitoring tools can provide information that can be used to check and improve irrigation scheduling. Such tools can help estimate the size of the wetting pattern (particularly depth), the level of plant stress and the additional moisture provided by rainfall. Monitoring soil moisture allows the initial estimates of how much and when to irrigate to be adjusted to suit a specific irrigation system and soil type.

Soil moisture monitoring tools normally measure soil water content or soil water tension.

Examples include tensiometers and resistance blocks (e.g. gypsum blocks) for measuring soil water tension, and neutron probes and capacitance probes for measuring soil water content.

Modern soil moisture systems track and graph soil moisture over time and can be used to help plan future irrigation dates. How much water to apply (hours) per irrigation to fully refill the soil can be calculated from the amount of water held in the soil and the system application rates.

The operational and maintenance requirements/costs of each system should be evaluated before making a decision. The nature of the crop may also have a bearing, for example annual crops require a more mobile system.

Regardless of the type of tools used, applying the right amount of water at the right time depends on:

- knowing crop water requirements, and stage of growth;
- consideration of effects of weather;
- water availability in the root zone (root zone RAW);
- wetting pattern (for micro-irrigation);

Legal requirements are subject to change. Regularly check with Federal, State and Local authorities for updated requirements.

- irrigation system efficiency; and
- any leaching requirement (for managing high salinity).

Measuring if the volume of irrigation is adequate or excessive can also be achieved using 'wetting-front' detector-type sensors such as the CSIRO FullSTOP™. For more information refer to *Insights in Irrigation, Soil Moisture Monitoring* (see References).

● Implement strategies to manage nutrient input and salinity

Manage nutrient inputs
For nutrients to reach the crop roots and to avoid losses from over irrigation, fertiliser should be applied when soils are close to field capacity, i.e. late in the irrigation run. Over-irrigation or application of a leaching fraction will wash the nutrients past the root zone. For more information see Section 4 – Nutrient management.

Manage salinity
Soil salinity can potentially reduce production by up to 100% due to reduced plant growth. This is because soil salinity makes it difficult for crops to obtain water and nutrients from the soil. Affected plants show similar symptoms to under-watering or can show visual symptoms such as burning on leaves. Soil salinity can also affect the biological health of the soil which can have serious long-term effects on soil fertility. Soil salinity testing should be done regularly to monitor root-zone salinity.

There are a number of possible causes for high soil salinity (saline irrigation water, high water table, poor drainage, inadequate leaching). For more information see Section 1d – Salinity.

Monitoring and recording

● Monitor, record and evaluate

Monitoring, measuring and recording activities are essential for the overall management of the property. A range of factors should be monitored and evaluated but the following are important:

Monitor crop performance
Keeping records of crop productivity is important to understand the effects of different irrigation practices. Measuring and recording yield, quality and maturity for each crop allows yearly comparisons and evolution against the goal of the property, and helps to refine management decisions.

Document water budget
Record irrigation schedules, amount of water applied, rainfall, soil moisture and crop evapotranspiration.

Assessment of economic yield
One measure of irrigation efficiency is through assessment of economic yield. This can be expressed in gross income per megalitre ($/ML) and/or production water use efficiency (tonnes of produce/ML). While no definitive figures exist for these criteria, historical on-farm or district comparisons will provide useful benchmarks.

Monitor water quality
Monitoring the quality of your drainage water can give an indication of nutrient loss. See Section 2b – Water Quality.

● Check irrigation system performance

You need to regularly check and maintain your irrigation system to make sure it is operating correctly and delivering what it should. If the system is not operating at maximum efficiency, irrigation scheduling and management strategies, such as controlling salinity, will not be effective.

Checks that should be undertaken include:

- visual inspection of irrigation system and crop performance;
- discharge or flow rate variation;
- uniformity of water distribution;
- pressure variation;
- presence of cuts, blockages, leaks in dripper lines;
- sprinkler/dripper malfunction;
- filters; and
- pumps.

It is also important to measure output uniformity or distribution uniformity. Uneven distribution causes areas of over/under irrigation and has consequences for crop yield and quality. The manufacturer's specifications should be referred to when assessing distribution uniformity and should be within the range specified in the table showing expected irrigation application system efficiencies table earlier in this section.

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2b Water quality

Objective – water quality is suitable for its intended use on the property and does not negatively impact downstream water quality.

There are two aspects of water quality that need to be considered. The first is to make sure that the quality of water being used is suitable for the intended purpose (e.g. irrigation, agricultural sprays, packing sheds), and the second is to make sure that your operation is protecting the quality of water leaving your farm so it does not negatively impact on downstream users and the environment.

If you are sourcing water from rivers or streams then upstream farms and businesses may impact on you.

Problems caused by using poor quality water on-farm include:
- salinity (high total soluble salt content);
- sodicity (high sodium content);
- toxicity (high concentration of specific salts in the soil);
- blue-green algae, which may be toxic;
- clogging of irrigation equipment; and
- corrosion of pipes and other equipment.

One of the factors that needs to be considered is the proportion of dissolved minerals and salts in your irrigation water.

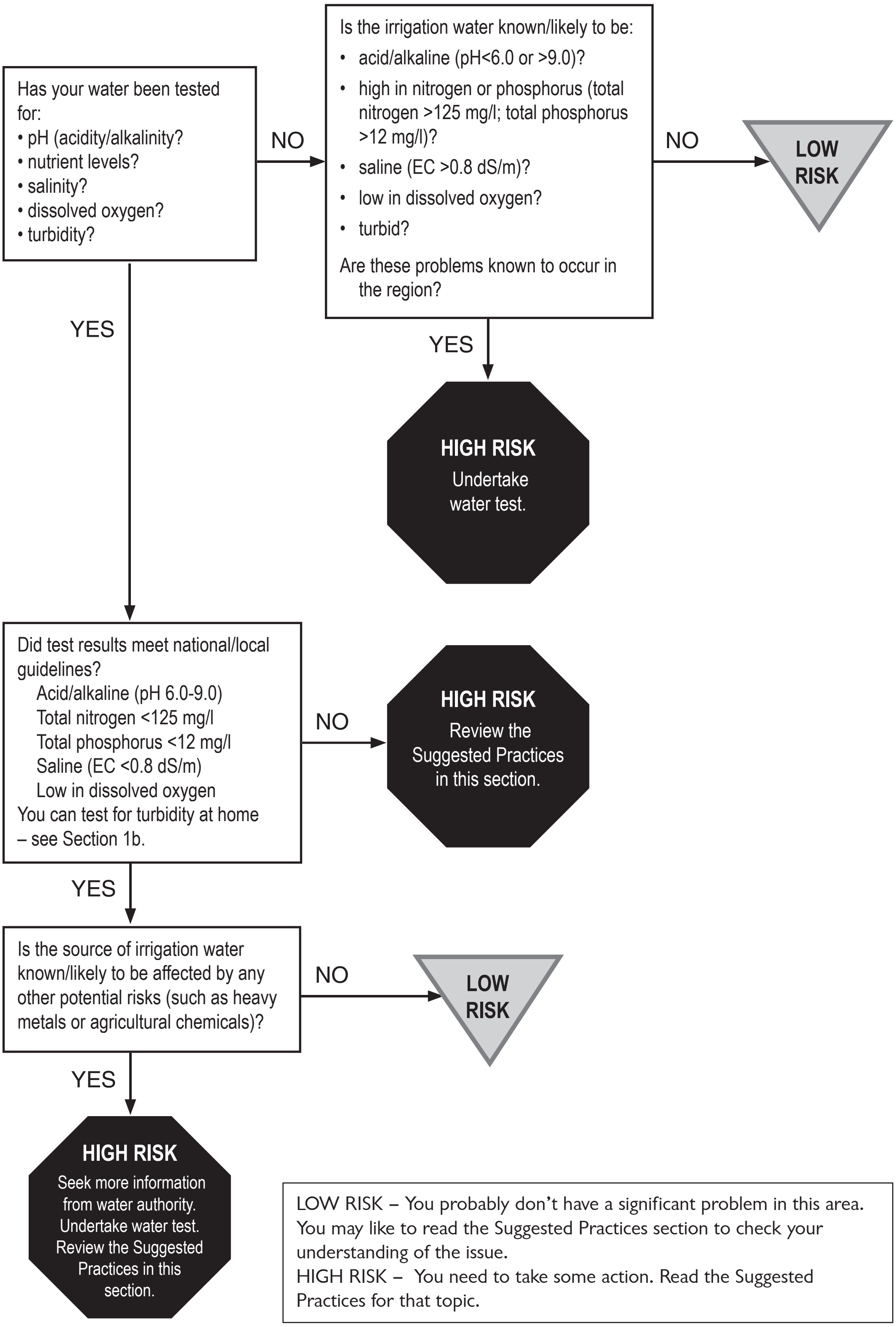
All groundwater and stream waters contain dissolved minerals. When irrigation water is used, the mineral salts are either taken up by the crop, left in the soil after the crop has used the water, leached down past the root zone, or washed out with run-off. Most of these salts are beneficial, but in some cases they may be harmful to the crops and to the long-term sustainability of the property. See Section 1d – Salinity.

Other chemical contaminants of water may include heavy metals, and agricultural or industrial chemicals.

The potential impact of poor quality water leaving the farm includes:
- harm to aquatic species in waterways from water eutrophication due to nutrient and organic matter pollution, and from chemical pollution;
- sedimentation of waterways and marine environments, causing disruption and damage to these ecosystems; and
- high nutrient levels in waterways contributing to blue-green algae outbreaks.

Risk Assessment

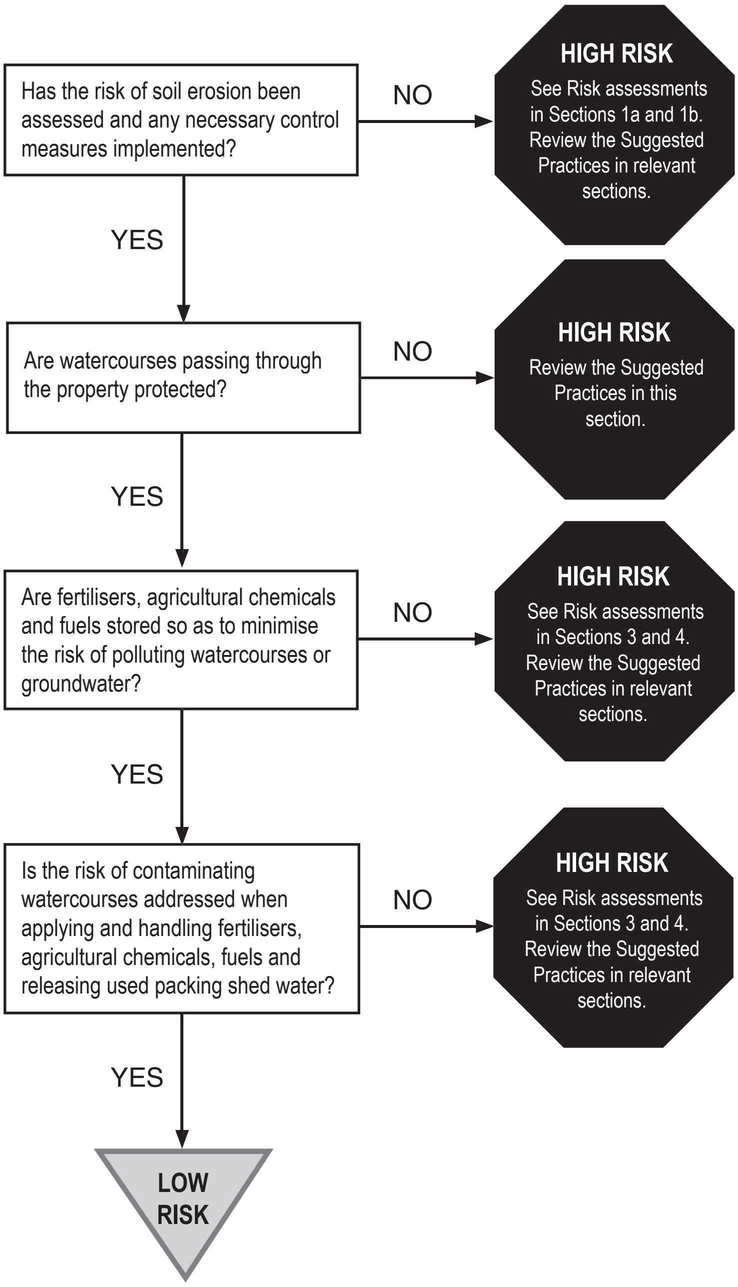
Irrigation water quality



LOW RISK – You probably don't have a significant problem in this area. You may like to read the Suggested Practices section to check your understanding of the issue.
HIGH RISK – You need to take some action. Read the Suggested Practices for that topic.

Guideline values should be taken from ANZECC 2000 Australian and New Zealand Guidelines for Fresh and Marine Water Quality National Water Quality Management Strategy, Australian and New Zealand Environment Conservation Council, Agriculture and Resource Management Council of Australia and New Zealand. This source provides detailed information on the water quality required for irrigation.

Downstream water quality



LOW RISK – You probably don't have a significant problem in this area. You may like to read the Suggested Practices section to check your understanding of the issue.
HIGH RISK – You need to take some action. Read the Suggested Practices for that topic.

Suggested practices

- **Check water source quality**

This should be a priority when considering new enterprises. Good data is often available from your water supply authority/company/State government agency.

Where use of saline water is unavoidable, regularly check salinity to plan suitable irrigation management options.

Legal requirements are subject to change. Regularly check with Federal, State and Local authorities for updated requirements.

It is important to remember that water quality can change from month to month and summer flows in a river system can have quite different water quality to winter/spring periods.

Check quality of water leaving the farm

It is also worth checking the drainage and run-off water leaving your own property. How does it compare with the water upstream or your neighbours? If the water is high in nutrients and turbidity (water cloudiness) then you should consider how fertiliser management, soil erosion, protecting watercourses and agricultural chemical management could be improved. See 1a – Soil erosion caused by water; 1b – Soil erosion caused by wind; 3 – Chemical management; and 4 – Nutrient management.

Your water authority, local catchment authority or Landcare group can usually provide access to water testing laboratories and information on run-off water quality targets.

Protect water quality

Water quality is impacted by activities both on and off farm. It is important to be aware of on-farm activities that can negatively affect water quality as this may impact the suitability of the water for use on the farm as well as having significant environmental impacts. Farm activities may affect water quality by increasing levels of salts, nutrients, suspended sediment, chemicals or organic matter.

Protect watercourses

Watercourses such as rivers, creeks and streams as well as their riparian areas (areas on or near creek and river banks) should be protected. Areas that have significant protected riparian zones have the ability to capture and filter soil sediment and soluble nutrients, improving water quality before it leaves the farm. A strip of undisturbed vegetation should be left to protect waterways.

Revegetate riparian areas with a mixture of native grasses, shrubs and/or trees to provide a buffer and stabilise waterway banks. In some regions there are legislated separation distances (for example 100 m) between sources of groundwater or surface water and obvious pollution sources such as fertiliser or agricultural chemical storage, packing sheds and workshops. It is advisable to check with the relevant government agency.

In known drainage lines or areas where run-off enters waterways install filter strips or buffer strips to minimise sediment and nutrient entering waterways. Seek information regarding design of the buffer strips, particularly in relation to the most appropriate vegetation and width of strip. Fencing waterways to keep stock out and providing off-stream drinking points also help protect watercourses.

Financial assistance may be available to fence riparian zones. Contact local Landcare, catchment authority or government representatives.

Soil erosion

Soil erosion is an important issue for both soil protection and water quality protection. High turbidity of run-off indicates soil loss is occurring. This is most common after intense rainfall, particularly after a dry spell. Buffer zones or grassed areas can be established to filter run-off and storm water. Often nutrients, especially phosphorus, and farm chemicals are carried attached to soil particles. Controlling soil erosion will help to retain nutrients and reduce nutrient pollution downstream.

Legal requirements are subject to change. Regularly check with Federal, State and Local authorities for updated requirements.

See Section 1a – Soil eriosion caused by water, and 1b – soil erosion caused by wind, for more details.

Nutrient management

Nutrient management is important to ensure that the nutrients applied are either used by the crop (some of which will be exported off-farm in the harvested product) or safely stored in the soil for the next crop.

Fertiliser or nutrients can be applied through fertiliser or nutrient rich water (e.g. recycled water can have significant concentrations of nitrogen and phosphorus). All nutrient sources should be considered when deciding crop nutrient requirements (nutrient budgeting).

Inaccurate or over-application of fertilisers can contaminate ground and surface water. This can result in the enrichment of water with nitrogen or phosphorus (eutrophication) causing rapid growth of algae and aquatic plants. This disturbs the balance of organisms present in water and the quality of the water within waterways. Nitrogen leaching can also cause soil acidity problems.

There are no blanket answers to reduce nutrient loss. Each farm is different and will require a different response.

A property is more likely to be susceptible to nutrient loss where:

- soil types are very heavy and there is surface run-off (worse when surface is cultivated);
- soil types are sandy and there is high leaching;
- high fertiliser inputs are used;
- crops have high irrigation requirement (more irrigations mean more chances to wash nutrients out);
- a flood or furrow irrigation system is used;
- the property is located in a high rainfall area;
- the cultivated area is located close to a watercourse;
- water is not well managed; and
- time of nutrient application is not well managed.

Underlying most of the best practices is the need to keep nutrients in the plant root zone and to manage water to minimise irrigation run-off via the surface or into the groundwater.

Good nutrient management involves:

- deciding what nutrients are needed, e.g. budget nutrients removed in the crop versus nutrients added in fertiliser applications;
- applying fertilisers the right way;
- minimising nutrient leaching to groundwater, especially nitrogen, by applying lighter than normal irrigation after fertiliser application or fertigating with lighter irrigations than normal;
- ensuring any in-line fertiliser injection systems have back flow prevention measures;
- storing fertilisers properly; and
- reducing possible harm to the environment by ensuring broadcast application of fertilisers involves leaving a buffer (no fertiliser) zone between the crop and sensitive areas such as watercourses and native vegetation.

For more information on selection and application of fertilisers see Section 4 – Nutrient management.

Correct storage and application of fertilisers will reduce environmental harm. Controlling soil erosion and reducing run-off and sediment loss will assist with loss of nutrients from target areas.

● Agricultural chemical management

Agricultural chemicals can contaminate waterways through inappropriate application and storage.

Agricultural chemicals should not be applied where they could drift onto water, unless they are specifically approved for use in or near water. Make sure there is a margin between where the spray falls and the bank of any watercourse. For some chemicals, a minimum width for the no-spray zone is specified on the label. See also Section 3 – Chemical management, for information on spray drift minimisation.

Legal requirements are subject to change. Regularly check with Federal, State and Local authorities for updated requirements.

Storage of agricultural chemicals, disposal of waste agricultural chemicals and empty containers must be undertaken with care. See Section 3 – Chemical management.

Prevent pollution from fuels and oils

Oil and fuel spills can pollute waterways and soils, and are a major threat to flora and fauna. State legislation and environmental protection authorities treat the matter very seriously. Theft, vandalism and accidental damage by moving vehicles can cause oil spills and should be guarded against. For more information see Section 3 – Chemical management.

Packaging shed water

Some packing sheds use large amounts of water as part of the packing process. Steps should be taken to ensure used water is safe to release back into waterways. This can be achieved through regular monitoring and if necessary filtering or treating water to remove organic material and chemicals. Organic material in water affects the amount of oxygen available and can have significant impact on fish and other aquatic life.

Organic matter

Septic tanks, and manure storage and waste produce dumping areas should be located well away from waterways and from water sources such as bores and dams. Run-off containing leachates from manure storage heaps and dumped piles of waste produce should be contained to prevent entry into waterways.

Ensure sewerage and septic systems are regularly maintained to prevent leakages into surface or groundwater.

Monitoring and recording

Where there is a risk of poor quality irrigation water, testing should be undertaken regularly and at times of greatest risk. For instance, water should be tested for agricultural chemicals (on farm and off farm) when spraying has taken place near the water body. Copies of water tests should be maintained to track changes over time.

Testing parameters will vary with each situation, however the most common tests will be for pH, pesticides (as above), key nutrients (nitrates and phosphates), EC (electrical conductivity) to test salinity, and biological oxygen deficit (BOD) to test for organic matter presence and its potential effect on aquatic species. Accredited commercial testing laboratories are available Australia-wide. Check with your local council or State natural resources or primary industries department for further information.
A regular nutrient stocktake is a cost-effective way of checking fertiliser stocks, storage facilities, purchases and usage. The record should include storage location, type and amount of fertiliser. You may wish to also include details of dates into and out of store, and link usage to the fertiliser application records. A regular chemical stocktake should also be done.

The farm map should indicate fertiliser and chemical storage locations and nearest watercourses.

Records of weather conditions when applying agricultural chemicals can be used to substantiate minimisation of spray drift.

Records for disposal of unregistered chemicals and chemical containers can also be useful.

Monitoring the use of fuel and oils can detect potential threats to water quality caused by wastage, spills or leaks.

Monitoring any drainage lines for run-off water quality (e.g. nitrate test strips and turbidity tests) is also recommended. This can indicate areas and location of nutrient and soil loss. Many regions have access to this equipment through a local community 'Waterwatch' group.

References and further resources

Department of the Environment and Heritage, *Water Quality Targets* – www.deh.gov.au/water/quality/targets/index.php

Department of Primary Industries, Water and the Environment, Tasmania, *Water Quality Monitoring* – www.dpiwe.tas.gov.au/inter.nsf/WebPages/LBUN-4YH4AK?open

Landcare Australia – www.landcareonline.com/

National Water Quality Management Strategy (NWQMS) (includes ANZECC guidelines) – www.deh.gov.au/water/quality/nwqms/

Waterwatch Australia – www.waterwatch.org.au/
Monitoring Water Quality – www.waterwatch.org.au/monitoring.html

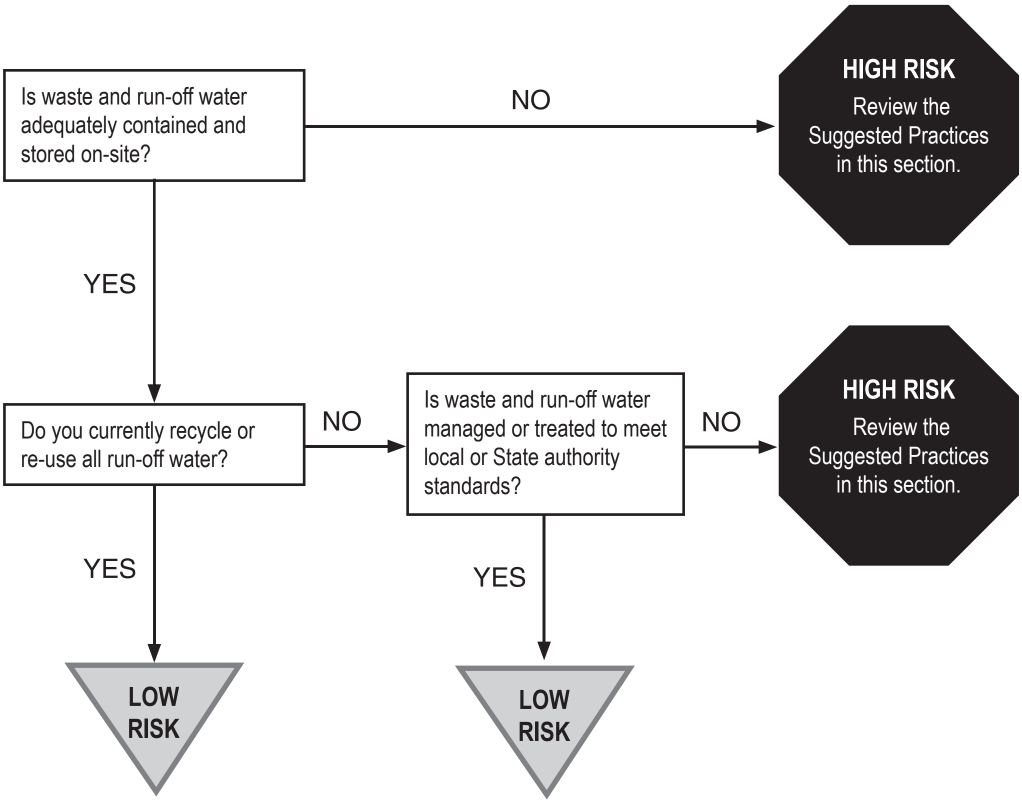
Waterwatch Tasmania, *Water Quality* – www.tas.waterwatch.org.au/quality.htm

2c Managing wastewater

Objective – to manage wastewater and run-off appropriately to minimise or eliminate potential negative environmental impacts.

Appropriately managing all waste and run-off water from production areas is important to minimise the release of polluted waste water into the environment. This is particularly so for containerised nursery operations, where leaching of irrigation water (and rainfall) from containers, and consequent nutrient losses in run-off water, is difficult to avoid. Collecting and recycling it as irrigation water or re-using it in non-production areas such as lawns, gardens and windbreaks also saves on water and fertiliser use, further reducing costs. Wastewater from packing sheds is also addressed in Section 2b – Water quality and managing water from chemical dips is addressed in Section 3 – Chemical management.

Risk assessment



LOW RISK – You probably don't have a significant problem in this area. You may like to read the Suggested Practices section to check your understanding of the issue.
HIGH RISK – You need to take some action. Read the Suggested Practices for that topic.

Suggested practices

An effective re-cycling/re-use system involves the following activities:

- Intercept and divert water from outside your property away from the production area. This reduces the volume of water to be managed and stored, and prevents pollutants and diseases being carried through the nursery.
- Seal production areas to minimise infiltration of water into the soil and to direct run-off water to drains. In nurseries, 200 µm thick plastic is commonly laid with at least 75 mm depth of 10-25 mm diameter gravel on top. Other options are concrete or bitumen. Level the growing beds to a minimum grade of 1:70 to ensure movement of run-off water to drains.
- Plan layout for drainage and prepare drains to collect run-off water and deliver to a collection dam or tank. Follow local authority or industry guidelines for designing drainage and storage capacity.
- Set up filters and treatment systems to remove sediment, litter and undesirable chemicals from run-off water.
- Collect run-off water into storage dams/tanks. Storage dams/tanks need to be specially constructed for holding run-off water. Natural wetlands on your property should not be considered as storage for run-off water due to potential pollutants in the water affecting the wetland. Follow local authority or industry guidelines for storage capacity and construction.
- Disinfect run-off water to remove pathogens before recycling or reusing (see NIASA Best Management Practice Guidelines section 1.1.1).

A useful reference that provides detailed information about setting up a recycling/re-use system is *Managing water in plant nurseries – a guide to irrigation, drainage, and water recycling in containerised plant nurseries*, 2nd edition, by NSW Agriculture.

Monitoring and recording

Regularly monitor run-off water to determine effectiveness of treatments.

Monitor:
- pH,
- nutrient levels (particularly nitrates), and
- electrical conductivity (EC) which is an indicator of total salts in the water.

Keep a record of run-off water monitoring results.

References and further resources

Badgery-Parker, J, (2003) *Managing wastewater with a wetland*. NSW Agriculture

NIASA Best Management Practice Guidelines, Chapter 'Nursery industry water management – best practice guidelines', NGIA, Sydney.

NSW Agriculture (2000) *Managing water in plant nurseries – a guide to irrigation, drainage, and water recycling in containerised plant nurseries*, 2nd edition.

The Nursery Papers 2003:7 – *Designing a nursery reed bed*.

The Nursery Papers, 1996:4 – *Monitoring and managing recycled water quality in nurseries*.

Rolfe, C and McPhee, G (1999) *WaterWork: A competency-based homestudy and workshop package*, version 2.1 on CD-ROM, produced by Australian Horticultural Training, published by Nursery & Garden Industry Australia and NSW Agriculture.

Legal requirements are subject to change. Regularly check with Federal, State and Local authorities for updated requirements.

3 Chemical management

Objective – agricultural chemicals are used in accordance with label or permit instructions; and all chemicals, including fuels and oils, are stored, handled, applied and disposed of in a manner that minimises environmental impacts.

Agricultural chemicals are by nature potentially dangerous to humans, flora and fauna and ecosystems.

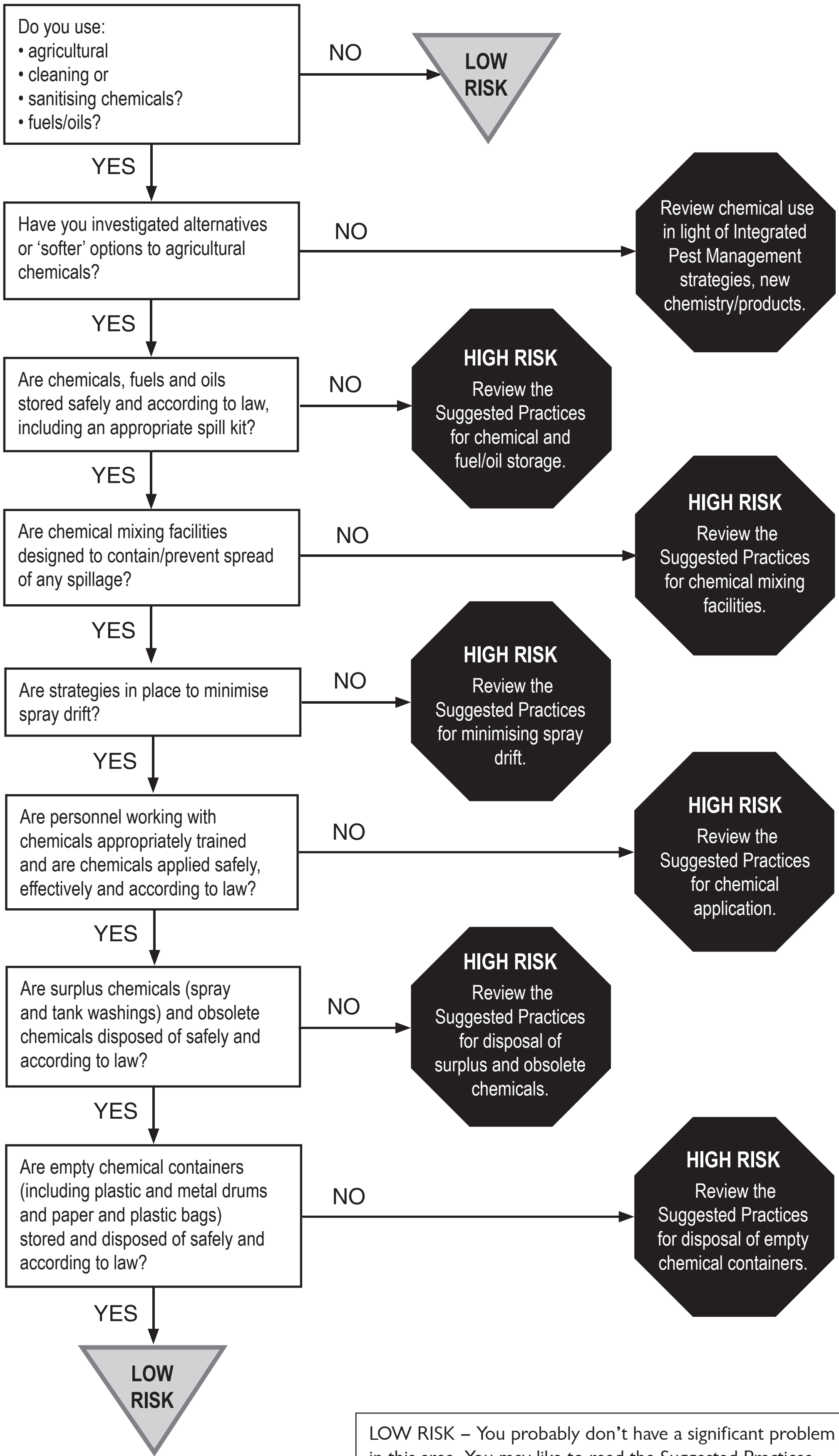
Pesticides can have serious effects on natural ecosystems if they move off-site via water, air or soil. Of particular concern is the effect of pesticide residues on sensitive neighbouring or downstream ecosystems such as wetlands, freshwater and marine habitats, and national parks and reserves.

Spray drift, in particular, is a potential source of friction between farmers and their neighbours. Spray drift can also cause much damage to wildlife. Liability for damage, illness or injury caused by spray drift is also becoming a serious issue.

Chemicals other than pesticides are widely used for cleaning and sanitising around growing and production sites and for treating water. Care needs to be taken to ensure these chemicals do not enter waterways and drains or accidentally spill on to soils and vegetation.

To minimise harm to the environment, all aspects of chemical use, from justification of the need for chemical intervention to storage, handling and disposal of empty containers, need to be considered.

Risk assessment
Use of chemicals



LOW RISK – You probably don't have a significant problem in this area. You may like to read the Suggested Practices section to check your understanding of the issue.
HIGH RISK – You need to take some action. Read the Suggested Practices for that topic.

Spray drift

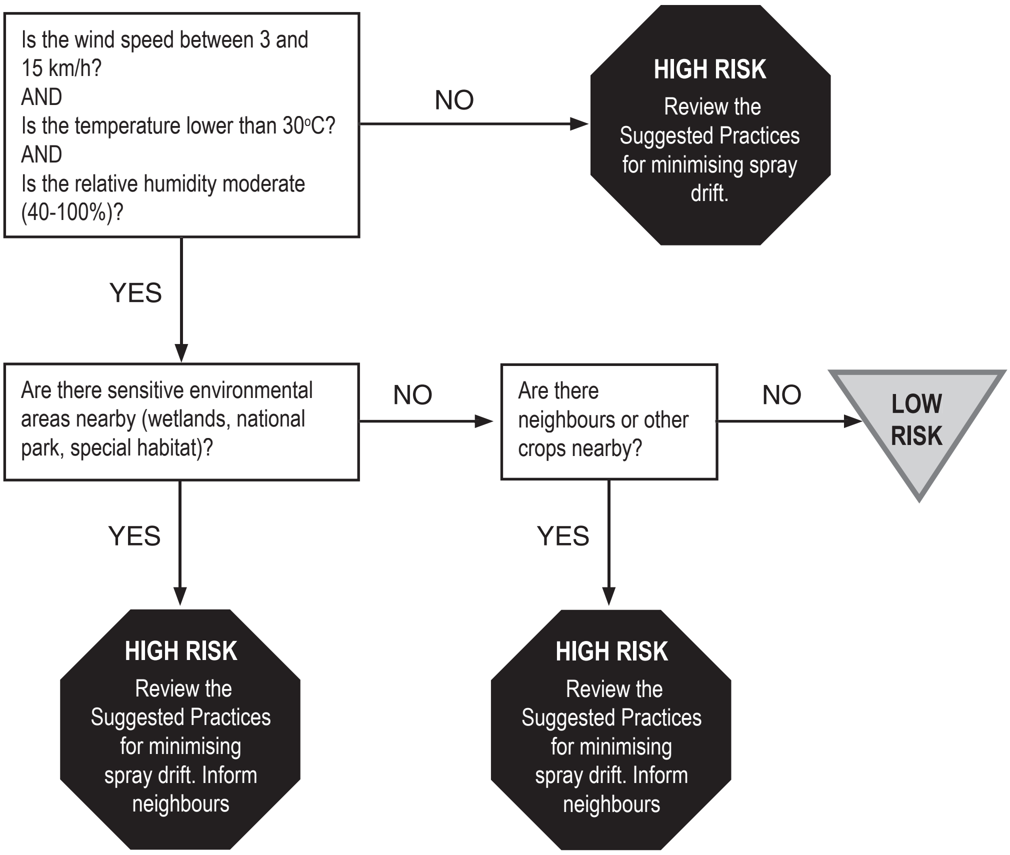
Spray drift is a potential source of friction between farmers and their neighbours. Spray drift can also harm wildlife. Liability for damage, illness or injury caused by spray drift is becoming a serious issue.

Spray drift is caused by a combination of factors, including:

- wind speed;
- instable local atmospheric conditions;
- wrong nozzles or pressure choice affecting spray quality;
- vehicle speed;
- boom height; and
- poor equipment maintenance, including incorrect equipment setting.

Risk assessment

Spray drift



LOW RISK – You probably don't have a significant problem in this area. You may like to read the Suggested Practices section to check your understanding of the issue.
HIGH RISK – You need to take some action. Read the Suggested Practices for that topic.

Suggested practices

Minimise application

Pesticides are only one strategy for controlling pest insects, diseases and weeds.

Integrated Pest Management (IPM) involves a range of strategies:

- Training in recognition of the pests and diseases that can attack your particular crops, their symptoms of attack and life cycles.
- Regular monitoring of crops for pests, diseases and weeds.
- Only using pesticides if pest numbers exceed threshold levels, and consider using:
  - environmentally friendly pesticides, such as oils, soaps and biological control agents such as bacillus formulations;
  - narrow-spectrum pesticides instead of broad-spectrum pesticides;
  - spot applications of pesticide instead of blanket sprays;
  - strategic application when the pest or disease is most vulnerable; and
  - resistance minimisation strategies.
- Practising good hygiene to limit disease in particular.
- Having an all-year-round weed management program in place, both in and around the growing area – weeds can harbour pests and diseases and act as a constant source of reinfestation (although weeds may also be a refuge for natural predators).
- Maintaining good soil health, including an open, well aerated structure, high organic matter levels and a diverse and active soil biology, which in turn promotes healthy crops which are more resistant to disease and pests.
- Encouraging natural predators. See Section 5 – Biodiversity.

Further information about IPM is available from State departments of agriculture/primary industries.

Laws relating to chemical storage and use change frequently. Check with your State authority for the most up-to-date information.

Safe storage

Agricultural chemicals can contaminate watercourses if not stored appropriately. Any new chemical storage should meet the highest standards of design and construction. Existing chemical sheds may need to be improved.

Chemical sheds should not be built where there is a risk of polluting watercourses or groundwater, or in areas subject to flooding.

All farm chemicals must be stored in a secure storage area that meets local regulations/ legislation. Farm chemical safety and handling training courses address chemical storage issues as do Managing Farm Safety courses. It is recommended that growers obtain specific local advice as each state and, in some cases, each local government area, may have particular requirements.

In general, when storing agricultural chemicals use the following guidelines:

- Store pesticides and chemicals away from residences and other occupied buildings.
- Store pesticides and chemicals in a lockable, weatherproof, fireproof, well-ventilated area away from production facilities, waterways, water supplies and flood-prone areas.
- Keep the storage area clear of extraneous or combustible waste materials and control ignition sources.
- Ensure adequate lighting for a safe working environment.
- The floor should be impermeable and easy to clean, and the storage area should be able to contain spills. Spilt liquid can be contained by bunding (an embankment or wall).
- Maintain a chemical spill cleanup kit near the area (see *Dealing with spills* later in this section).
- Store pesticides and chemicals in their original containers.
- Store pesticides separate from fertilisers and chlorine.
- Store liquid pesticides and chemicals below powders.
- Maintain an up-to-date inventory of stored pesticides.

Legal requirements are subject to change. Regularly check with Federal, State and Local authorities for updated requirements.

- Store only enough pesticide on site to meet short/medium-term needs.
- Regularly check pesticide and chemical containers for any leakage or damage.
- Running water should be available.
- Chemical storage areas should be appropriately signed for the size and nature of the storage, including a 'No Smoking' sign.
- Consider a central storage point based with a local spray contractor or at the airstrip.
- Keep current Material Safety Data Sheets for all chemicals in use.

For more information on appropriate signage for chemical sheds refer to Workplace Health and Safety agency in your State.

All States have strict regulations concerning storage of pesticides on farm and business sites, including occupational health and safety requirements. Check with your local authority to ensure you conform to these regulations.

Safe transport

Ensure chemical containers are leak-proof and adequately secured when transporting on farm or between farms.

Observe safe handling practices when transporting pesticides and chemicals.

Dealing with spills

It is a good idea to have an emergency plan in place to deal with spills of different groups of chemicals so you are prepared if it ever happens.

Know how to deal with spills and have spill kits close to storage and mixing areas. Spill kits should include:

- a shovel;
- dustless absorbent material, such as 'kitty litter', activated charcoal, vermiculite, hydrated lime, clay or earth and dry sand (avoid using sawdust or other combustible materials); and
- containers to hold the absorbent material or other leaking containers.

Wear protective clothing, including gloves, respirator, boots and eye protection when dealing with spills.

Properly dispose of the chemical-drenched absorbent clean-up material.

Use hydrated lime or bleach to decontaminate spill surfaces, but never use these two materials together.

Report the spill to authorities if it is large or if it enters waterways.

Mixing and application

Responsible use of pesticides and chemicals

Ensure at least one person in the business has completed an accredited chemical user's training course (similar or equivalent to ChemCert) and ensure all staff that apply pesticides have adequate training.

NSW requires all people who apply chemicals in the business to have accredited training.

Regularly calibrate and maintain pesticide application equipment.

Only use pesticides that are registered or permitted by the Australian Pesticides and Veterinary Medicines Authority (APVMA) or otherwise authorised for use in your State for the particular:

- crop,
- application timing,
- method of application, and/or
- tank mix.

Obtain and keep copies of any APVMA permits that are relevant to your spraying.

Growers in Victoria do not require APVMA off-label permits for certain off-label uses.

Always follow label and permit instructions.

Seek professional advice if you have concerns.

Keep Material Safety Data Sheets (MSDSs) for all pesticides used close to areas where chemicals are handled and consider placing copies in tractors used with spray equipment. These provide information about health hazards and safe handling, including transport, storage and spill clean-up.

In case of poisoning or exposure to pesticides, contact the Poisons Information Centre on 131 126. This is a 24-hour service.

Mixing

Make sure to site the mixing and washdown area away from water sources, drains and streams. The area should be constructed to contain spills for collection and disposal.

Never leave a spray unit unattended while filling.

As some drums are difficult to pour, use a specifically-designed drum pourer to minimise spillage.

Triple-rinse empty chemical containers and mixing equipment back into the vat.

Minimising spray drift

There are many strategies to minimise or prevent the chances of spray drift, starting with how you establish new horticultural sites.

Managing spray drift should be included in property management plans and specific spray plans can be developed which include identification of sensitive areas and options for minimising spray drift into those areas.

You should also consider the following strategies:

- Check the weather forecast before starting off. Do not spray if the wind direction and speed would cause the spray to drift on to sensitive areas or neighbours (see Weather Conditions section below). Under light wind conditions, wind direction is often variable and may result in unpredictable off-target movement.
- Avoid spraying on hot days (>30°C) or dry days (<40% relative humidity) as these conditions can increase the rate of evaporation of water-based sprays and may subsequently increase spray drift.
- Spray when winds are most consistent, generally early morning, early evening or at night.
- Select the right combination of spray unit, nozzle type and size, and pressure.
- Use the largest appropriate spray droplet size (except if using CDA equipment).
- When using a boom spray, keep the boom as low as possible, consistent with an even spray pattern at the correct target height. Check spray angles and adjust the height accordingly. Reduce the operating pressure and forward speed but maintain the dose, volume and spray quality within recommendations on the label.
- Consider not treating the boom-width or part of the boom-width closest to the boundary. This can also provide a useful tool to check spray efficiency and to help maintain beneficial insects.
- Modify spray equipment to help minimise spray drift. These modifications include low drift nozzles, shielded and covered spray booms and air-assisted spray equipment.
- For air-blast sprayers pay particular attention to weather conditions, good set-up and maintenance of equipment and barriers/buffer distances from neighbours.
- For aerial spraying, ensure that the spray contractor is aware of sensitive areas/neighbours and of their responsibility for any off-target application or spray drift.
- Ensure operators have appropriate training/competencies and relevant licences.
- Erect or plant barriers to catch possible spray drift, and establish buffer zones between production areas and neighbours or sensitive natural areas, such as wetlands and waterways (see *Buffer zones* later in this section).

Legal requirements are subject to change. Regularly check with Federal, State and Local authorities for updated requirements.

Weather conditions
Wind speed in the spray release zone is an important factor in determining spray drift. Meteorological measurement of wind speed is taken 10 m above ground, so care is needed in interpreting weather advice and actual wind speed at nozzle height.

Prior to spraying an assessment should be made of the wind speed and direction by using a simple wind speed meter or by watching the movement of plants, trees and clouds. This monitoring should continue during application.

Wind speed guide:

Approx. wind speed at boom height	Description	Visible signs	Spraying
Less than 2 km/hr	Calm	Smoke rises vertically	Not recommended. Use only 'medium' or 'coarse' spray quality
2 – 5 km/h	Light air	Direction shown by smoke drift	Acceptable spraying conditions
6 – 11 km/h	Light breeze	Leaves rustle, wind felt on face	Ideal spraying conditions
12 - 19 km/h	Gentle breeze	Leaves and twigs in constant motion	Increased risk of spray drift take special care
20 - 28 km/h	Moderate breeze	Small branches moved, raises dust or loose paper	Spraying inadvisable

Source: Northern Territory ChemCert Manual (Somervaille 1989) and MAFF, 1998 The Green Code

Delta-T calculations can be used as indicators of acceptable spray conditions. It is indicative of evaporation rate and droplet lifetime. When applying pesticides, Delta-T should ideally be between 2 and 8. For more information see Weather for Pesticide Spraying, Bureau of Meterology.

Buffer zones
Buffer zones are a very good way to reduce the risk of spray drift. Buffer zones can be established by planting trees and shrubs downwind of a production area. Vegetation that is tall, rough and thin is better at catching droplets than vegetation that is short, smooth and thick.

A droplet-catching barrier should be less than 50% porous, with a height about 1.5 times the height of spray release. Use multiple vegetation layers as a screen rather than a single layer. Vegetable growers should also consider establishing intercrop buffers such as rye corn or sweet corn as barriers.

• Protecting water supplies

Ensure pesticide cannot be back-syphoned into the water supply when filling spray tanks by installing an anti backflow device or pumping from a separate tank filled from the main water source.

Fill spray tanks with water and then move them away from waterways or water storages before adding chemicals.

Minimise movement of pesticides into stormwater or wastewater run-off by avoiding application of pesticides immediately before rain or irrigation, unless stated otherwise on the APVMA product label or permit.

• Consider community relations

Disputes involving environmental nuisance (for example issues related to application of agricultural chemicals, noise or dust) can can lead to a breakdown of good neighbourly relations.

Legal requirements are subject to change. Regularly check with Federal, State and Local authorities for updated requirements.

The best way to avoid problems is to attempt to get on well with your neighbours. Having a "good neighbour" policy and discussing aspects of farming with neighbours is one way to achieve this. Neighbours, particularly non-farming people, need to recognise that primary producers make their living through agricultural activities and that these activities are an important part of the economy and food chain.

Primary producers need to recognise that some activities can negatively impact on their neighbours and that at times it may be appropriate to adjust activites as far as reasonable to minimise the impact.

Disposal of pesticide containers

Under various State regulations, businesses are required to dispose of empty chemical containers safely. When purchasing, ask if used pesticide containers can be reused, returned, refilled or recycled.

Un-rinsed containers can hold as much as 3% of product concentrate. This means they can present a hazard to people who handle them and have potential to contaminate the environment.

Used containers that cannot be returned or recycled should be triple rinsed or pressure rinsed immediately after emptying the container as residues are more difficult to remove when they are dry. This is done by filling the container with clean water to approximately a quarter of capacity, replacing the cap, shaking and then adding the wastewater to the spray tank. This is repeated three times. Other disposal methods (e.g. pumping to sump or limed disposal pit) are not acceptable. Pressure rinsing is also an option and special equipment is available.

Puncture steel containers after rinsing so that they cannot be re-used. Pass a steel rod or crowbar through the neck/pouring opening and out the base of the container. Do not puncture plastic 20-litre containers included in reconditioning/reuse programs.

Empty pesticide containers must be stored in a designated, secure area (preferably locked), and disposed of either through a controlled approved disposal scheme, or according to a documented procedure that meets state or territory regulations. Access to this area must be restricted for both people and animals.

Ideally, property managers should be involved in any disposal scheme to remove rinsed chemical containers, and/or use the services of a licensed waste collector to remove unwanted pesticides.

The drumMUSTER scheme operates in all states. From January 2004, only containers carrying the eligible container logo will be collected under the drumMUSTER program. The drumMUSTER website (www.drummuster.com.au) contains details of collection days and locations. It also includes contact details for regional field officers. Pending disposal via drumMUSTER or other approved disposal methods, containers must be rinsed and stored in a separate secure area.

Disposal of surplus spray and washings

Avoid leftover pesticide by carefully calculating how much is needed for the area to be sprayed.

Do not allow leftover spray, rinsings from a spray tank or from empty pesticide or chemical containers to enter streams or drainage from the property. Make sure that any disposal method you use is safe for your chemical waste, location and circumstances as incorrect disposal can result in prosecution. Check your local laws regarding use and management of farm chemicals.

Legal requirements are subject to change. Regularly check with Federal, State and Local authorities for updated requirements.

Disposal methods may include:

- storing rinsate or surplus spray in an appropriately labelled container and use to make up the next compatible spray mix;
- diluting rinsate/surplus spray and spray on to target crop in a manner that will not exceed label rates or wash off chemical previously applied;
- spraying leftover pesticide and washings from rinsing after spraying on to an area of ground away from where people will be and from drains, low drainage areas, waterways and water

storages (follow label guidelines);
- emptying into a lime-filled pit (obtain advice as to quantities of lime and appropriate sites before using this method); or
- consider using enzyme products (new technology enzyme products are capable of almost complete breakdown of organophosphate insecticides, either in the spray tank or in a holding tank, and provide a useful option for rapid chemical clean-up).

Post-harvest dips may also be treated with lime to deactivate the agricultural chemical. Again specific advice should be sought regarding the most appropriate disposal practices. Information may be available on the chemical label and this should be checked first.

Spray equipment should be filled and washed in an area chosen and established for that purpose. Spillages and rinsings should not be able to escape from the area. Ensure the area is well away from watercourses and dams.

Remember, damage to the environment such as fish kills and the like are prosecutable offences and should be avoided.

Disposal of old, de-registered or unwanted pesticide concentrates

Unwanted chemicals, such as those that are no longer registered for use, should not be stored on farm for longer than is necessary to arrange for their disposal.

Make sure these chemicals are appropriately stored to prevent misuse. Storage in the chemical shed is recommended as long as the chemicals are clearly identified as not for use and, preferably, are segregated.

Ensure the containers do not leak.

One option for disposal of unwanted agricultural chemicals is ChemClear®. The ChemClear® program has a web-based booking system where growers can register chemicals for collection. There are two categories of chemicals – Group 1 and Group 2. Group 1 chemicals are collected free of charge, while disposal of Group 2 chemicals attracts a fee. For more details visit www.chemclear.com.au or call 1800 008 182.

Alternatively, a certified or approved chemical waste contractor or supply company can be used. If transporting these pesticides to a collection centre, place them on the back of a utility or truck, never in the boot or cabin of a vehicle, or back of a station wagon, where fumes may affect the driver or passengers. Ensure containers cannot leak during transport.

Contact your local council or waste management authority for advice on methods of waste disposal available in your local area. See Section 6 – Waste management for information on controlled/prescribed wastes.

Use and disposal of other chemical products

If rat and mouse baits are used, ensure they are enclosed in bait stations to prevent native birds and animals eating them. Dispose of used rodenticides or other pesticide baits, as well as carcases, in accordance with the product label. If carcases are being buried and the label does not give any special instructions, take care to bury them so that there is no risk of polluting surface or groundwater, and where dogs or native animals will not dig them up. Some baits have been developed that do not cause secondary poisoning.

Legal requirements are subject to change. Regularly check with Federal, State and Local authorities for updated requirements.

Dispose of contaminated wastes, such as protective clothing and materials used to deal with spillages in accordance with local regulations. Some waste disposal sites can deal with this sort of waste, while others cannot. Contact your local council or waste management authority for advice on methods of waste disposal available in your area. See Section 6 – Waste management for information on controlled/prescribed wastes.

Storing and handling fuels and oils

Take reasonable steps to secure vulnerable tanks against interference; this may be as simple as locking pumps or taps. Bund above-ground fuel tanks and provide some form of leakage protection for underground tanks. Materials for soaking up any spillages should be available at the storage area.

Check for leaks frequently and repair them promptly, especially with underground tanks (even slow leaks can have a major impact if allowed to continue).

If fuel tanks are bunded, all valves should be inside the bund and should still be closed and locked when not in use. Store flexible hoses for refuelling vehicles with the hose outlet in the bund.

Take water or fuel/oil out of the bund and dispose of it safely, e.g. by using a blanket that is specially made to absorb fuel/oil.

Consider installing an anti-siphon device if the inlet is lower than the highest fuel level of the tank.

Fuel storage facilities should be away from watercourses and with sufficient surrounding space to permit easy access, thus reducing the chance of accidental damage.

The risk of fire should be minimised.

Mobile fuel tanks should:

- be designed to protect them from accidental damage;
- have a contents gauge and be stable enough to travel around the property;
- have all connections and valves, where fuel could empty by gravity, kept locked when not in use;
- used with care, especially when near watercourses; and
- if possible, not be left near or uphill from a watercourse.

If fuel tanks are bunded, this should be done in accordance with the relevant State legislative requirements. For example, 125% of the largest container plus 25% of total volume.

Monitoring and recording

Records that can (and in some cases must) be kept include:

- staff training records;
- pesticide application records (spray diary), including details of date and time of application, operator, location/area treated, pest/disease target, pesticide used, rate, application equipment and weather conditions (particularly to support miminisation of risk of spray drift);
- chemicals register or inventory;
- waste disposal records (see Section 6 – Waste management) such as:
  - ChemClear® documentation, issued to prove chemicals have been booked in for collection and also when chemicals are collected, and
  - receipts and invoices from recycling or commercial disposal businesses;
- disposal of surplus agricultural chemicals (can be recorded on spray records, particularly if sprayed back over the crop);
- machinery maintenance;
- a farm map showing any buffer zones around paddocks, including sensitive areas and neighbours; and

Ensure that your pesticide spraying records comply with your State or Territory regulatory requirements.

References and further resources

Australian Pesticides and Veterinary Medicines Association – www.apvma.gov.au

Broadley, RH et al (2000) *Pesticide Application Manual* 3rd Edition QI00010. DPI&F Brisbane – http//dpishop.dpi.qld.gov.au/bookweb/details.cgi?ITEMNO=9780724234523
or contact the DPI&F Call Centre (phone 13 25 23).

Bureau of Meterology (BOM) *Weather for Pesticide Spraying* – www.bom.gov.au/info/leaflets/Pesticide-Spraying.pdf – Delta T calculations on BOM website – www.bom.gov.au/announcements/ag_bulletins.shtml

Chemclear Handling & storage tips, in *About ChemClear*, on the Chemclear® website – www.chemclear.com.au/

CSIRO, 2002 *Spray Drift Management Principles, Strategies and Supporting Information* – www.publish.csiro.au/nid/22/pid/3452.htm

Department of Agriculture, WA (2005), *Code of Practice for the use of Agricultural and Veterinary Chemicals in WA. 3rd Edition* – www.agric.wa.gov.au/pls/portal30/docs/FOLDER/IKMP/PW/CHEM/COP_BULLETIN.PDF

Department of Agriculture, *WA Legislation Controlling the Use of Agricultural Chemicals in WA*. Farmnote 39/2002 – www.agric.wa.gov.au/pls/portal30/docs/FOLDER/IKMP/PW/CHEM/FN039_2002.PDF

Department of Environment and Conservation, NSW – www.environment.nsw.gov.au/pesticides/index.htm – and www.environment.nsw.gov.au/chemicals/index.htm

Department of Primary Industries, Fisheries and Mines, Northern Territory – www.horticulture.nt.gov.au

Department of Primary Industries, Water and Environment, Tasmania, *Guidelines for managing leftover spray mixes, rinsings and washings (Tasmania)* – www.dpiwe.tas.gov.au/inter.nsf/Attachments/CPAS-5U326X?open

Department of Primary Industries, Water and Environment Tasmania, *On-farm Pesticide Storage*. DPIWE Tasmania – www.dpiwe.tas.gov.au/inter.nsf/WebPages/TTAR-62Q5Y2?open

Hughes, P (2005) *Spray right – reduce drift: Guidelines for drift reduction*. DPI&F Queensland – www2.dpi.qld.gov.au/fieldcrops/17047.html

Material Safety Data Sheets are available from manufacturer's websites or – www.pestgenie.com.au

Ministry of Agriculture, Fisheries and Food (MAFF) UK, 1998. *The Air Code* – www.defra.gov.uk/environ/cogap/aircode.pdf

Murray Darling Basin Commission (2004) Current recommended practice. *A directory for broadacre dryland agriculture*. See particularly the Integrated Pest Management section – www2.mdbc.gov.au/landmark/d_loads/CRPreport.pdf

Nursery and Garden Industry, *Australia Best practice manual for pesticide application in nursery and garden industry* CD – www.ngia.com.au

Wardlaw, F (2004) *Vegetable Integrated Pest Management in Tasmania*, (2004) – www.dpiwe.tas.gov.au/inter.nsf/WebPages/TTAR-68Q6CX?open

Weatherzone – www.weatherzone.com.au

Workplace Standards Tasmania Guidance note. *How to HAZCHEM placard premises storing dangerous goods* – www.workcover.tas.gov.au/attach/gb023pdf.pdf

4 Nutrient management

Objective – the productive capacity of the soil is maintained without detriment to the environment.

Most Australian soils are naturally low in nutrients. By managing nutrient application and soil fertility, production targets can be achieved without environmental harm.

It is important to apply fertilisers correctly because, if wrongly used, they may contribute to off-site degradation of groundwater and waterways, increase soil acidity, salinity and sodicity problems and contaminate soil.

Fertilisers may be lost from the production area through:

- inaccurate application;
- leaching past the root zone and into groundwater;
- moving as dissolved nutrients in surface water leaving farm paddocks;
- attaching to soil sediments and within organic particles in surface water leaving farm paddocks;
- attaching to wind-eroded soil particles; and
- volatilisation into the atmosphere.

Not only are these nutrients lost for crop production, such losses will potentially have downstream or off-farm impacts on the environment. The nutrients most at risk of causing off-farm impacts are:

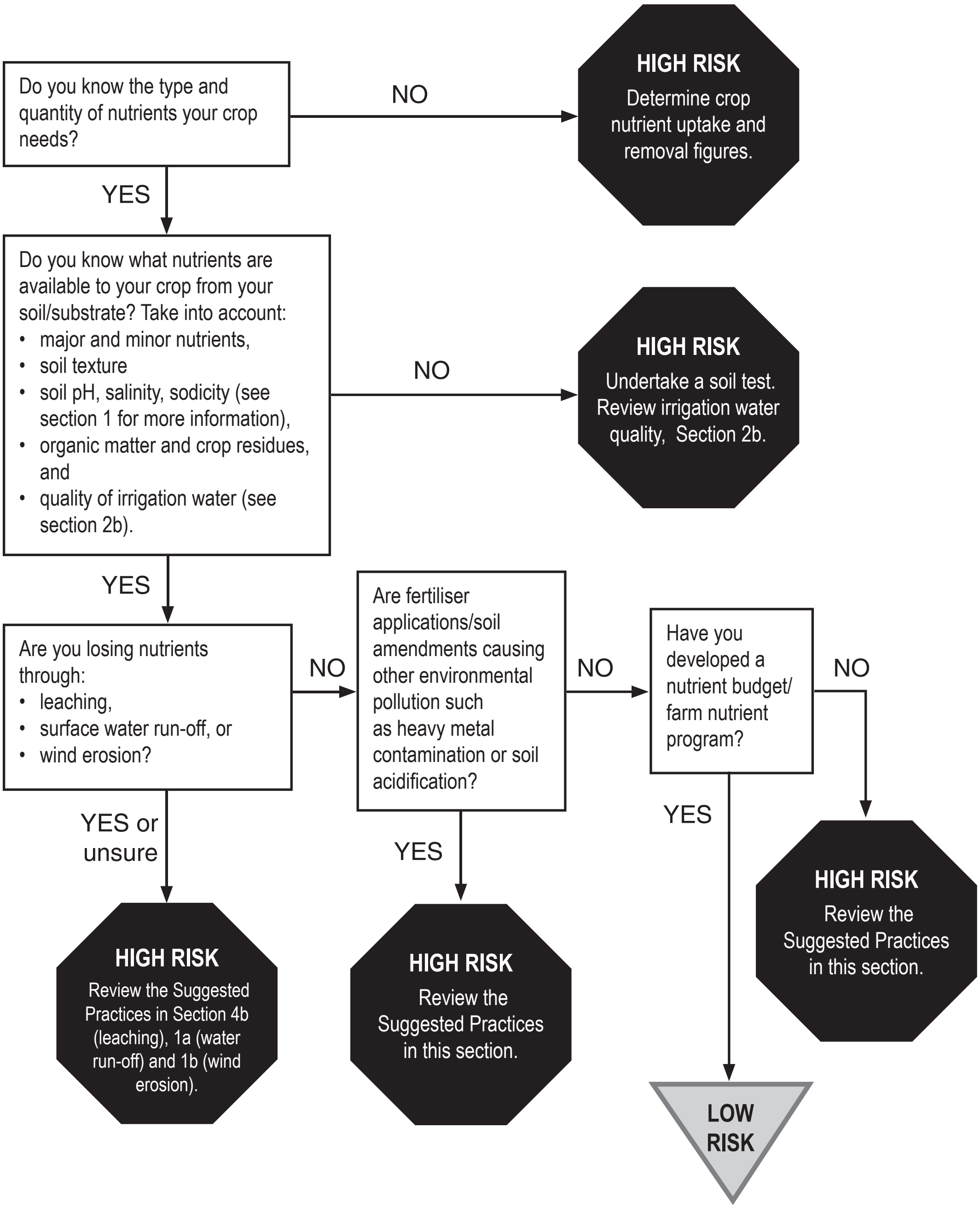
- nitrogen, a highly soluble element that is easily leached from the soil profile, dissolved in run-off water or volatilised into the atmosphere, and
- phosphorus, which binds strongly to soil particles and so can be lost by soil erosion through water and wind. Environmentally significant quantities of phosphorous can also be dissolved in run-off water when soil phosphorus levels are high.

4a Nutrient requirements

Objective – to effectively manage nutrient inputs to meet crop requirements and soil characteristics.

To effectively manage nutrient inputs it is important to determine the amount and type of nutrients to apply for each cropping situation rather than using recipe-type application rates. This can be done through soil testing and nutrient budgeting.

Risk assessment



LOW RISK – You probably don't have a significant problem in this area. You may like to read the Suggested Practices section to check your understanding of the issue.
HIGH RISK – You need to take some action. Read the Suggested Practices for that topic.

Suggested practices

Selecting nutrient types and amounts

Objective methods such as soil testing, plant tissue testing and sap testing, combined with yield data and visual assessments of crop or tree health, provide the basis for good fertiliser management. Fertilisers should be applied efficiently, taking seasonal conditions into account. This means applying just enough nutrients for good crop growth without providing excess nutrients which may be lost off farm into groundwater and surface waterways.

An understanding of the role of different nutrients in plant growth, the levels needed for good growth by particular crops and the cycles of key nutrients such as nitrogen is important. It is a good idea to either do formal training to learn to estimate the quantity and type of fertiliser to use, or to use the services of a soil consultant or agronomist to decide on the nutritional needs of crops. Both over- and under-application of fertiliser can create problems.

The Australian fertiliser industry has established the Fertcare® program to assist in the sustainable use of fertilisers. Fertcare® provides training and accreditation for agronomy, sales and logistics staff. Training options also exist for growers, depending on their particular needs.

Nutrient deficiencies can lead to low yields, poor quality crops and financial loss. They can also lead to indirect environmental damage because other nutrients are used inefficiently and will be vulnerable to loss off-site. Poor crop growth also leads to reduced organic matter returns to the soil which can reduce soil health and cause erosion and still poorer crop growth.

The relatively low cost of fertiliser compared to other inputs means growers have tended to over-compensate with fertiliser application rather than face the risk of production losses.

Over-supply of fertiliser or incorrect use of blended fertilisers (e.g. NPK mixes) also brings problems. It is not only an unnecessary cost, but can cause reduced yields through toxic levels of nutrients or by inducing deficiencies through nutrient imbalances. Over-supply can also lead to long-term, off-farm impacts like degradation of sensitive environmental areas, algal blooms in waterways and groundwater contamination, and on-farm impacts such as increased soil acidity, soil sodicity and soil salinity.

Inorganic fertilisers are only one method for supplying nutrients. Cover crops, fallow crop residues, composts and animal manures not only add organic matter to the soil but also release significant amounts of nutrients as they break down. The gradual release of nutrients from organic sources can help to reduce the loss of nutrients off site. For example researchers have found that banana plant crop residues can contribute 60 kg N/ha to the following ratoon crop in Far North Queensland conditions. Crop residues from a cauliflower crop can contain about 170 kg of nitrogen (N), 27 kg of phosphorus (P) and 180 kg of potassium (K) per hectare. Animal manures can add significant amounts of phosphorus to the soil. Manures should be tested for nutrient content, chlorine levels and presence of contaminants such as heavy metals before application.

Fertilisers should be selected that have low levels of contaminants such as heavy metals (cadmium, lead or mercury). High levels in fertilisers may lead to accumulation in the soil or uptake by crops in excess of maximum levels for human safety (for information regarding maximum levels, see the Food Standards Code [www.foodstandards.gov.au]).

Soil and sap testing

Soil testing is a useful way to objectively measure the nutrient status of your soil. It is a particularly valuable nutrient management tool before planting a crop or orchard. Ongoing soil testing (say every one to three years) also provides valuable insights into longer-term trends in soil properties that may alert managers to developing sustainability problems. Soil organic carbon decline or the build-up of high available phosphorus levels are examples of this.

Legal requirements are subject to change. Regularly check with Federal, State and Local authorities for updated requirements.

Soil testing, plant tissue testing, sap testing and visual crop inspection can all be used post-planting to monitor nutrient availability and determine an appropriate post-planting fertiliser program.

Soil tests measure soil properties that influence nutrient availability to the plant. These include pH, electrical conductivity (a measure of salt content), organic carbon, individual macro- and micronutrients and other elements. It is a good idea to use a laboratory that is accredited to carry out the required tests. Look for NATA (National Association of Testing Authorities) accreditation, a laboratory that uses NATA methods or one that participates in Australian Soil and Plant Analysis Council (ASPAC) proficiency trials.

For soil test results to be meaningful, the sample must be carefully collected. When collecting a sample make sure it represents the area being tested, by taking into account the total area of the block, any changes in soil type within the block and the depth of sampling. The samples should be representative of the root zone. Taking a 10-15 cm sample from soil that has been worked to rooting depth will achieve this. In orchards, where soil is not worked, a shallow sample may not represent actual nutrient availability. Subsoil samples may be of value to determine nutrient availability for deep-rooting crops and identify possible causes for nutrient imbalances.

Sufficient samples should be collected to be representative of the site and should not include soil from any unusual areas. These samples should be bulked, mixed well and then a sub-sample of this bulk soil sample sent in for testing. The testing laboratory or its agent should provide instructions on taking the sample. Soil consultants or agronomists can also collect samples for you and there are accreditation programs for these services.

Nitrogen levels undergo dynamic changes during the season, being influenced by factors such as soil organic matter content, soil temperature and moisture. It is therefore important that soil samples for nitrogen budgets be taken separately from conventional soil samples and sampling should occur as close to the proposed nitrogen application date as possible to give an accurate picture of current nitrogen availability.

Soil test results and optimum soil nutrient levels should be discussed with an appropriately qualified person, such as an agronomist or soil consultant. Based on this interpretation and consideration of soil type, cropping history, specific crop needs and agronomy, a written fertiliser recommendation should be provided. This may include recommendations for adding lime, dolomite or gypsum.

Soil testing and analysis needs to be completed early enough to allow nutrients and soil ameliorants to be applied in a timely manner.

Sap testing can also be used to develop nutrient uptake graphs, so fertiliser applications can be timed to the appropriate growth stage of the crop. Samples for sap testing need to be collected carefully and tissues analysed by a suitably proficient laboratory.

Nutrient budgeting

Nutrient budgeting can help growers better understand the whole nutrient cycling and transformation system. This can lead to the design of more sustainable, integrated nutrition strategies.

A nutrient budget is like an accounting system for nutrients. It involves:

- estimating the amount of nutrients available from the soil (soil test results);
- obtaining uptake and removal figures for the target crop and the previous crop (to account for nutrients in crop residues, for example, consideration should also be given to the contribution of legumes to nitrogen availability). Figures should be in kg/tonne of crop grown (for uptake) and harvested (for removal);
- determining the target yield to calculate actual uptake and removal figures;
- calculating the amount of nutrients, especially nitrogen, that will be applied with irrigation water (50 ppm nitrate in irrigation water will add about 1 kg N/ha with every 10 mm of irrigation water applied);
- calculating the amount of nutrients already applied to a paddock;
- estimating the amount of nutrients that will be removed through harvested product;
- determining possible nutrient losses through leaching (see Section 2b – Water Quality), volatilisation or soil erosion (see Section 1a – Soil erosion caused by water, and Section 1b – Soil erosion caused by wind). Deep soil nitrate testing can be an important tool in assessing leaching; and

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- replacing nutrients lost to the system through appropriate fertiliser applications.

Nitrogen, phosphorus and other major nutrients are the main elements considered in nutrient budgeting. Along with soil, leaf and sap testing and visual assessments, nutrient budgeting is another tool for fine-tuning the nutrient management program.

A nutrient budget should be prepared for a 3–5 year rotation. Break or cover crops should be considered as 'catch crops'. Nutrients that have not been used by the previous crop will be taken up by the break crop, thus avoiding leaching past the root zone.

Reviewing local research and advice from agronomists can also assist in determining fertiliser requirements, particularly in situations where key information such as crop nutrient removal rates are not known.

It is also important to determine if any nutrients are required in "luxury" amounts (that is over and above the nutrient removal figures). For example, potassium may be applied at higher rates because of its role in preventing bruising.

Monitoring and recording

Soil test results, sap test results and corresponding fertiliser recommendations support responsible use of fertilisers. It is also a good idea to have documentation to support the credentials of the person providing the fertiliser recommendation.

Testing run-off and drainage water for nutrient content gives a good indication of any losses being experienced. Water can be monitored for nitrates using systems such as the CSIRO FullSTOP™

References and further resources

Fertilizer Industry Federation of Australia (2001). *Cracking the nutrient code* – www.fifa.asn.au

Department of Primary Industries, Fisheries and Mines, Northern Territory, Horticulture home page – www.horticulture.nt.gov.au/

Fertcare® – www.fertcare.com.au

FullSTOP™ wetting front detector – www.fullstop.com.au/

Incitec Fertilizers (2000-05) FertFact sheets – www.incitecfertilizers.com.au – soil and tissue sample collection methods are available on this website.

NSW Department of Primary Industries – www.dpi.nsw.gov.au – and search for fertiliser or nutrient management.

Crop Nutrient Calculator – www.agric.nsw.gov.au/reader/tropicalfrt/crop-nutrient-calculator.htm

4b Nutrient application

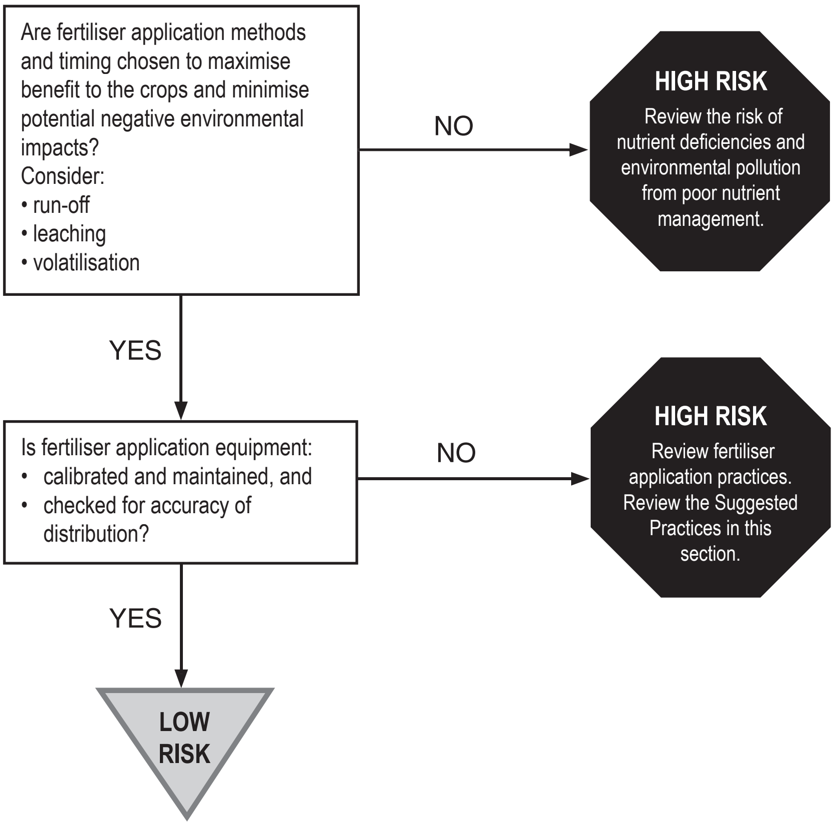
Objective – to ensure nutrient application methods and timing maximise benefits to the crop and minimise potential negative environmental impacts.

Applying fertilisers correctly is as important as using the correct amount and type of fertiliser. Effective fertiliser application involves:

- the right rate and frequency,
- the right time, and
- the right placement.

To achieve this, application equipment must be set up correctly.

Risk assessment



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HIGH RISK – You need to take some action. Read the Suggested Practices for that topic.

Suggested practices

When applying fertilisers, some general rules should be followed:

- Avoid applying fertilisers to saturated soil or when heavy rain is forecast.
- Avoid applying fertiliser during extended drought.
- Avoid fertiliser application to steeply sloping ground.
- Use contour drains to minimise run-off.
- Monitor soil moisture to avoid leaching of nutrients past the plant root zone.
- Maintain vegetation cover during typically rainy periods to minimise run-off and leaching.

● Type, timing and rates of application

Fertilisers need to be applied when they will do the most good for the crop. As a general rule, applying small amounts regularly is less likely to cause off-site losses from leaching and run-off. Schedule fertiliser applications according to seasonal conditions, cropping cycle and periods of greatest use by the crop. For instance, young vegetable crops require small amounys of nutrients until they begin to grow rapidly.

Nitrogen, in particular, should not be applied in large amounts while crops are young and nitrogen demand is low. Large applications of pre-plant fertilisers are vulnerable to loss in the slow growth period. Select the most suitable fertiliser type depending on the speed of availability of nutrients in relation to crop demand, acidity, alkalinity or salinity of fertiliser.

Pre-plant fertilisers should be incorporated. If there is a likelihood of heavy rain, minimise the amount of pre-plant fertiliser applied to reduce risks of fertiliser losses through leaching and soil wash from paddocks into nearby waterways. It may then be necessary to increase topdressed fertiliser applications later in the season. However, light rain or irrigation is beneficial to incorporation and to reduce volatilisation of some fertilisers such as urea.

An autosteering system for application equipment will allow precise applications without overlaps and may reduce fertiliser costs.

● Fertiliser placement

Accurate placement of fertilisers helps plants to access the nutrients required. Choose the right equipment and adjust it correctly to make sure fertiliser is applied to the area where it will do the most good but have the least impact on the environment.

Apply small amounts of fertiliser near the root zone of plants. Application methods suited to achieving this include:

- fertigation using micro/trickle irrigation systems,
- banding to the side or below seeds or transplants,
- banding or drilling fertiliser in beside plant rows,
- broadcasting fertiliser along the drip line of tree crops, and
- broadcasting fertiliser before the crop canopy closes.

Foliar application through spray equipment is a useful method for applying targeted amounts of micronutrients.

Be careful not to apply fertiliser to non-crop areas or adjacent to waterways. Take steps to prevent contamination of water sources from pump backflow during fertigation.

Legal requirements are subject to change. Regularly check with Federal, State and Local authorities for updated requirements.

● Care and calibration of equipment

Brand new spreaders can have poor spread patterns, and with use and 'wear and tear' even a well-set-up spreader can become inaccurate. Therefore fertiliser application equipment needs to be carefully calibrated and maintained to make sure it is capable of spreading fertiliser evenly at the correct rate.

Refer to the manufacturer's specifications when carrying out calibration.
Accu-Spread® is a testing and accreditation program that ensures your spreader can apply fertiliser evenly across the paddock, maximising productive response and minimising environmental risk.

Storage of fertilisers

All fertilisers including animal manures should be stored in such a way that prevents nutrients leaching into surface waterways and groundwater. Inorganic fertilisers should be stored in a covered area away from waterways. Manure heaps should also be covered to reduce leaching through rain.

Storage areas should be:
- protected from direct sunlight and rain;
- well ventilated with fresh air to keep fertilisers dry;
- designed to minimise the chance of pest infestation, mould growth and damage; and
- designed to confine any spillage and allow easy clean up.

Store fertiliser in a way that lowers the risk of seepage into groundwater. With the exception of fertilisers applied with agricultural chemicals, fertilisers should be stored separately from agricultural chemicals.

All liquid fertiliser storage should be bunded to eliminate the chance of run-off into waterways. In the absence of any national or state legislation, the bund should be 125% of the largest container, plus 25% of total volume stored.

In addition to regulations regarding storage of dangerous goods, there are new security regulations in place regarding ammonium nitrate that cover how these products are supplied, handled and stored. Advice from the appropriate local authority should be sought.

Disposal of packaging

Used fertiliser packaging should be stored in a manner that prevents contamination and environmental harm and meets local government waste disposal regulations.

Monitoring and recording

Fertiliser application records

It is recommended that an accurate record be maintained of all fertiliser applications, including foliar applications and fertigations. This applies both to organic (e.g. sheep, cattle, chicken manure) and inorganic fertilisers (e.g. superphosphate). Fertiliser application records are essential for nutrient budgeting.

Suggested headings in fertiliser records are:
- the location of the treated areas (block or paddock identification);
- application dates;
- the type of fertiliser used including the trade name, type of fertiliser or concentration of nutrients;
- amount of fertiliser applied per hectare (weight or volume);
- method of application and machinery used eg fertigation, spreader; and
- name of the operator applying the fertiliser.

Soil test results for the paddock and sap and leaf tests for the crop support these fertiliser records.

Machinery calibration and maintenance records

It is suggested that maintenance and calibration records for fertiliser application equipment be kept. This should include:

- equipment/machinery name;
- date on which calibration/maintenance was performed;
- work undertaken; and
- signature or initials of the person who performed the calibration/maintenance, or an appropriate invoice.

References and further resources

Accuspread – www.fertcare.com.au

Fertcare® – www.fertcare.com.au

Fertilizer Industry Federation of Australia (2001). *Cracking the nutrient code* – ww.fifa.asn.au

Incitec Fertilizers (2000) *Education Pack: Environmental facts* – www.incitecfertilizers.com.au

5 Biodiversity

Objective – native vegetation, wildlife and ecosystems are appropriately maintained and managed and, where possible and practical, contribute to regional biodiversity priorities.

Biodiversity is the variety of all life forms: the different plants, animals, fish, birds, insects and micro-organisms, their genes and the ecosystems of which they are a part. Biodiversity is increasingly being recognised for its contribution to farm sustainability and productivity.

Biodiversity does not just apply to native organisms, but the focus of this section is largely on managing native biodiversity. This does not imply that biodiversity is not important within the production area.

Native biodiversity refers to the biodiversity found in a particular locality. It is restricted to the local ecosystems and their components, be they native plants, animals or mico-organisms.

Native biodiversity provides many benefits that are essential to sustaining and fulfilling human life and maintaining productive agriculture. These benefits are called 'ecosystem services' and include:

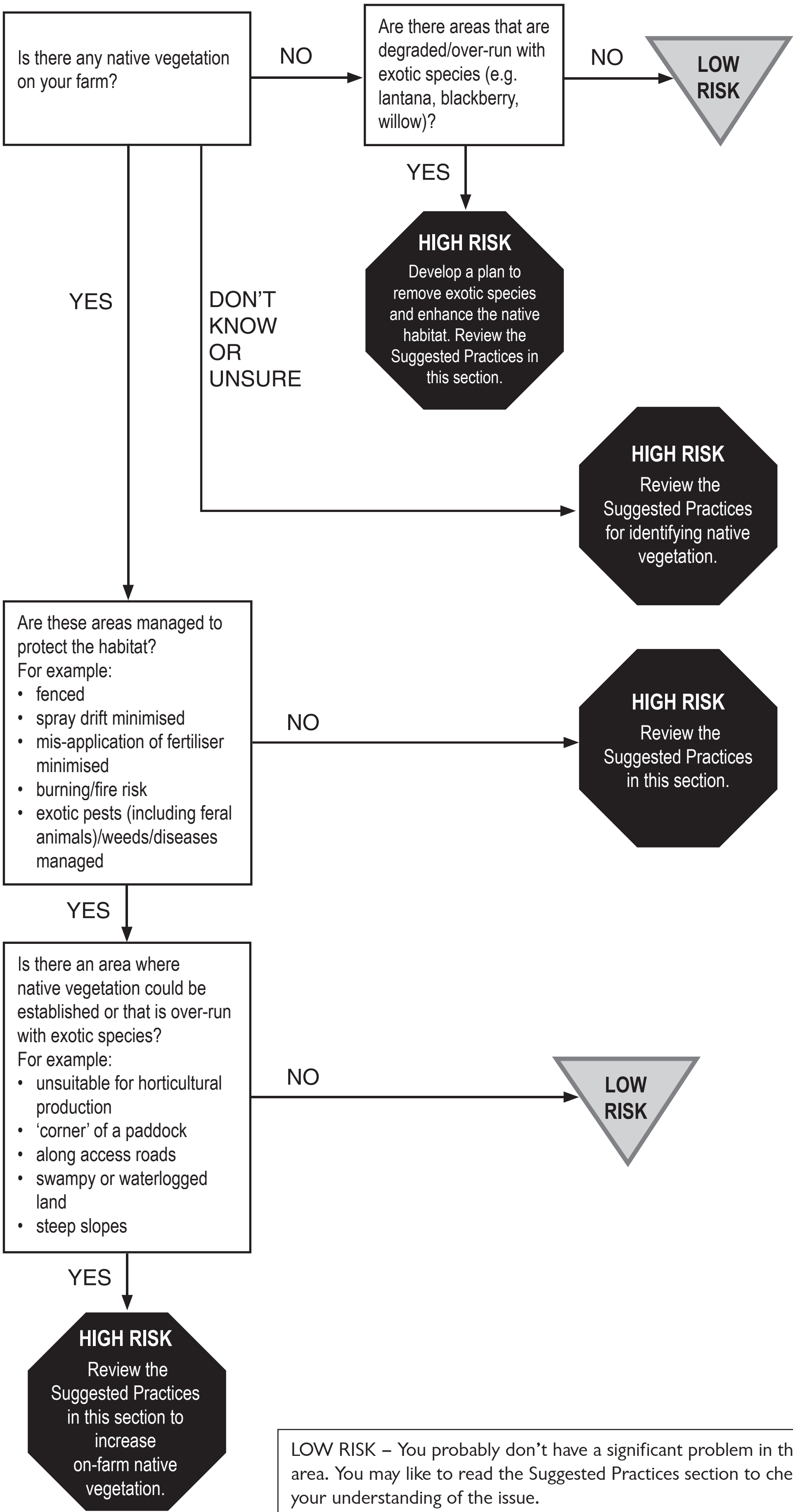
- fungi, worms and bacteria transforming sunlight, carbon and nitrogen into fertile soil;
- pollination from insects;
- regulation of climate;
- provision of shade and shelter from native vegetation; and
- waste absorption and breakdown.

(For more details see CSIRO: www.ecosystemservicesproject.org).

If native biodiversity and ecosystems deteriorate, then the quality of the soil, water, air and ultimately agricultural productivity declines.

To manage biodiversity on your property you need to know what native vegetation exists and if it is of special importance, consider the impacts of farming operations on the environment, and develop practical ways to manage any native vegetation as well as problem plants and animals. There may also be areas where revegetation can occur and can be co-ordinated to contribute to regional initiatives.

Risk assessment



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Suggested practices

By adopting farming practices that are compatible with biodiversity protection, land managers can work towards sustainable agriculture and integrating agricultural production with biodiversity protection.

In some instances, rather than identify and assess all the native biodiversity on your property (i.e. all native animals, plants and insects etc) it is more practical to use native vegetation as an indicator to identify if native biodiversity is present.

● Identify native vegetation on your property

An initial assessment should try to identify any local native vegetation (including naturally occurring trees, shrubs, herbs and grasses) still left on the farm (exclude plantations and vegetation established for commercial purposes). Dead trees should be included as important components as they provide habitat for native animals and insects. Create an inventory/file of this information.

Contact your State conservation, natural resources or sustainability department and ask them for any maps and/or lists of the native vegetation that is likely to be present and to provide advice regarding management of native plants and animals that may be on your property. Other people to help with identification include:

- field naturalists,
- Greening Australia,
- local catchment management authorities,
- Bushcare,
- Landcare groups,
- regional Natural Resource Management (NRM) groups, and
- local/State herbarium.

Universities and other research bodies are sometimes looking for farms on which to conduct studies of native plants and animals. This can be a good opportunity to learn more about the wildlife on your farm.

Attending field days in your catchment is also a good way to learn about local plant and animal species.

You may like to undertake a more complete and detailed assessment of all the species (native plants and animals) located, or likely to be present, on your property. You can ask a State biodiversity or environmental officer for advice. Biologists or ecologists are qualified to carry out this more detailed survey.

A full native biodiversity assessment could include:

- a map of the vegetation likely to be present prior to development;
- maps of the location and type of native plants and animals species currently known to be on the farm;
- a list of local plants and animals in danger of dying out (i.e. threatened species);
- a list of current farm activities that is helping/harming native plants and animals;
- future actions to improve biodiversity as well as maintaining farm productivity; and
- the expected improvement if these actions are followed.

The *Environmental Management in Agriculture: Native Biodiversity Resource Kit* provides guidance on these steps. See References and further resources later in this section.

● Consider surrounding properties

No farm works in isolation of its neighbours. Just because you haven't found any native vegetation on your property doesn't necessarily mean there is no native biodiversity, or that you can ignore the impacts your farm operations may have on surrounding properties. Look for native birds and listen for frogs – chances are both are present, indicating that suitable habitat is located in surrounding areas.

Legal requirements are subject to change. Regularly check with Federal, State and Local authorities for updated requirements.

Any basic knowledge of the surrounding area, aerial photos, satellite images or maps of vegetation will give you an idea of what native vegetation is located near your property.

Assess special importance

The Government has developed lists of plants that are considered important because of their rarity, they are particularly subject to threats, or may support other significant features (e.g. as a drought refuge for native animals).

Contact your local government, State conservation department or the regional catchment management authority/Natural Resource Management committee for information about any important or significant vegetation that may be in your region. Financial assistance may be available to assist with management of important vegetation. Check out conservation incentives on www.deh.gov.au or contact your local catchment authority.

The following categories may have been used to describe threatened plant species:

- Extinct – no reasonable doubt that the last member of the species has died.
- Critically endangered – extremely high risk of extinction in the immediate future.
- Endangered – very high risk of extinction in the near future.
- Vulnerable – high risk of extinction in the medium term.

Each of these categories may carry specific legislative responsibilities you are required to undertake. Current lists of threatened species can also be found at Environment Australia www.deh.gov.au.

Check biodiversity laws and regulations

Various biodiversity laws will apply to your property. These laws could be local, state or Commonwealth.

For instance, there may be legislative barriers to clearing of native vegetation (in addition to trees this may also include shrubs and grasses). The *Biodiversity Resource Guide* (www.daff.gov.au/emsbiodiversity) contains:

- the main national and state biodiversity legislative requirements including a very brief description and follow up contacts; and
- the main national and State biodiversity policy objectives that are relevant to landholders.

As laws and regulations can vary considerably between states and regions, you should contact your State conservation department and find out what laws apply to your property.

Refer to the following websites to access electronic copies of the Principal Acts and Statutory Rules in operation (most have advanced searching and browsing facilities that enables easy accessibility to specific clauses etc.):

- All Commonwealth and State Acts are at – http://scaleplus.law.gov.au/
- Australasian Legal Information Institute – www.austlii.edu.au
- Environmental Defenders Office, a network of independent community environmental law centres – www.edo.org.au

Assess off-farm impacts and threats

Site development or redevelopment works need to be assessed for their potential impacts on the existing environment.

Legal requirements are subject to change. Regularly check with Federal, State and Local authorities for updated requirements.

Management actions for biodiversity need to address the cause of decline or what threatens the continued existence of the native biodiversity. In many cases these threats have their origin in inappropriate land and natural resource management activities.

To assist you to assess your impacts on native biodiversity, potential management actions addressing threats should be organised according to farm activities. It is expected that each farm will be unique, therefore these actions should be considered as prompts which a land manager should use to broaden the search for solutions.

In the *Environmental impacts* section of these guidelines, you will note that most activities represent some form of impact both on and off-farm. However, the five key horticultural activities you may need to draw up specific actions for are:

- spray drift,
- fertiliser/water use and leakage,
- topsoil loss and erosion,
- control of pests (including native animal species), and
- disposal of waste.

An integrated property management plan such as a Whole Farm Plan (WFP), Property Management Plan (PMP) or similar, can help you to work through the range of potentially conflicting needs and allocate resources according to priority.

● Risk management

The suggested practices for managing biodiversity on growers' properties help growers to balance production requirements with the existence of native animals on their land.

There are many benefits to having native animals on or near agricultural land. For example, many native birds eat insect pests, pollinate plants and disperse native seed. However, occasionally problems may arise when native birds and animals eat or damage crops. Where growers are faced with 'problem' native animals, specialised advice must always be sought from your State conservation department to avoid exposing yourself to the risk of prosecution if any illegal response is adopted.

Avoid looking at symptoms of the problem, such as 'there are too many animals' – the question is why? Options for responding to problem animal management will include how to mitigate the problem and live with native animals. As standard practice, always consider non-lethal management options. These may include:

- netting,
- fencing,
- sound or light based systems (sirens, gas cannons),
- encouraging predators (e.g. hawks, although this may end up being lethal!), and/or
- providing alternative habitat.

If you have sought advice and trialled applicable non-lethal management options without success, as a last resort consider lethal management options (such as shooting). It is important to check whether wildlife is protected and be aware of any licensing requirements before undertaking lethal management options. These must only be implemented in a humane manner.

Exotic plants may also require specific management. Problem plants can be escapees or volunteers from commercial operations, such as escaped olive trees. In the right place these plants are not a problem, but once they start encroaching on native vegetation specific action is required. The landowner must take all reasonable measures to prevent the land being infested with a declared weed and take all reasonable measures to prevent a declared weed or potential weed spreading to other land.

Get rid of weeds to reduce potential for pest harbour and give native vegetation a better chance of survival (e.g. Bridal Creeper *Asparagus asparagoides* – a Weed of National Significance not only causes losses by shading citrus and avocado trees and interfering with fruit picking, it is also considered the most important weed threat to biodiversity).

Legal requirements are subject to change. Regularly check with Federal, State and Local authorities for updated requirements.

If you are planning to use herbicides for weed control rather than physical removal, take special care not to damage the area you are trying to improve or to contaminate waterways. Removing dense areas of weeds should coincide with revegetation or regeneration activities, otherwise further weed infestation may result. For more specific information on threats and control methods for individual weeds refer to www.weeds.crc.org.au

Environmental weeds and nursery propagation

Many of the plants introduced into Australia over the past 200 years for ornamental use have been beneficial and ecologically benign. A small percentage has run rampant, radically altering the ecosystems they have invaded. Examples are water hyacinth (*Eichhornia crassipes*), rubber vine (*Cryptostegia grandiflora*) and lantana (*Lantana spp.*).

Under recent legislation all new plants imported into Australia must be assessed by the Australian Quarantine and Inspection Service (AQIS) for their potential to become weeds. There is still concern that many 'new' weeds will emerge from plants already present in Australian gardens and nurseries.

Predicting potential invasive weed species in the range of ornamental plants in Australia is complex, and made more so by regional differences that may influence 'weediness' of a species. Local authorities and State governments are at various stages of addressing the issue of environmental weeds.

A national industry initiative between the nursery and garden industry, local and State governments and the community is working to highlight the most invasive garden plants still found in the nursery trade, promote alternatives and raise the awareness of the gardening community about environmental weeds.

To date, the project has highlighted 52 species of garden plants to be discouraged from use in Australian gardens, along with 17 species recognised as weeds of national significance that should never be made available for use in gardens. These plant species are listed in the Nursery Paper Issue No 2000:12 *Invasive plants not wanted in public or private gardens identified*. This list is a good starting point to identify problem species, but check with your State and local authority or State nursery association for current regional information.

● Practical management of native vegetation

Once you have found out which native plants are on your property (including their significance) you will have some idea about how to prioritise your actions to protect them. These actions may include:

- fencing off areas to exclude vehicles, people and stock. Select fence types that enable native animals to have access to natural drinking water sources and to move between habitats;
- leaving dead trees standing and logs, branches, twigs and rocks on the ground as homes for birds, insects and other animals; and
- not cleaning up places with native vegetation. By not tidying up understorey grasses, shrubs and fallen trees, birds and beneficial native animals will have places to hide from introduced predators or competitors or as a food source.

You can also ask a State biodiversity or environmental officer for advice or assistance on priorities for management.

Depending on the jurisdiction, it may be possible to enter into a voluntary conservation agreement or similar agreement with the relevant State agency to formalise protection of wildlife and significant habitat on part of your property. 'Land for Wildlife' is one such scheme and conservation incentives also exist (see www.deh.gov.au). Sometimes these agreements may contribute to providing compliance against international environmental standards.

Many pest animals not only prey on native animals but they also compete for the same space, food and shelter. Control animals such as rabbits, foxes and feral animals. Check local regulations and laws about the control of pest animals before you begin any control program.

Legal requirements are subject to change. Regularly check with Federal, State and Local authorities for updated requirements.

Integrated Pest Management (IPM) is an excellent management practice to maximise biodiversity on-farm. IPM strategies are designed to reduce reliance on pesticides while still managing pests. Reduced reliance on pesticides can provide an environment where a greater diversity of flora and fauna exists. This in turn can assist in building the numbers of pest predators to improve the control of pests.

Whole farm planning is a structured approach to making informed decisions for the use and management of all aspects of your property. Your State biodiversity or environmental officer, catchment management authority or natural resource management group can provide advice.

Fire management
Management of vegetation areas needs to also consider fire control and the role of fire in maintaining the diversity of plants that make up the bush. Much of Australia's flora has evolved in an environment where fires regularly occurred, and many plants require fire to assist regeneration.

Considerable care is required to manage fires and local authorities should be consulted and alerted before burning. Neighbours may also be affected by smoke and should also be consulted (see Section 7 – Air management).

The following points should be reviewed:
- Choose a fire regime to suit the desired outcome. If you are burning to reduce fuel loads then fires will need to be more frequent than if you were burning to promote tree regeneration.
- If you have threatened species, choose a fire regime that suits their needs.
- Time burning to suit the plants' lifecycles. These will vary depending on where you are in Australia, but generally autumn burns are best.
- Fireproof buildings and ensure sufficient fire breaks around production areas, boundaries and other areas that must not be burnt.
  (Taken from *Fire Management – guiding principles for managing your native vegetation*, see references and further resources later in this section.)

Consider options for increasing on-farm native vegetation

Think about planting windbreaks and shelterbelts using local native species. Shelterbelts and windbreaks may be best placed on the property boundaries and developed with consideration of establishing interconnecting wildlife corridors.

The resulting wind protection can contribute to overall farm productivity, plantings may provide habitat for beneficial native insects (i.e. contribute to Integrated Pest Management) as well as providing habitat for native species. Ideally, plantings should be at least 20 m wide to provide greater benefits, however, if space is limited, narrower shelterbelts can still provide some protection to crops and provide some habitat. Individual trees can also provide suitable habitats.

Choose some areas where it would be possible to begin a restoration project. It is a good idea to choose areas not currently used for farming, such as steep slopes, stream/dam sides, saline areas and wetlands. These areas are usually poorly utilised and don't make a major contribution to horticultural production.

Select a mix of native plants, including trees, shrubs and grasses, preferably native to your local area (known as provenance species). Plantings should copy nature and not be as regular as a crop.

Dams and waterways also significantly contribute to increasing biodiversity and providing habitat for native animals, birds, frogs, insects, fish, invertebrates and plants. Wetlands, bogs and marshy areas can be turned from unprofitable areas to rehabilitated areas of great ecological significance with fencing and revegetation.

Some local authorities and organisations will provide advice and support to landholders for revegetation activities. Flora, fauna and bush regeneration consultants are also available to assist in design of restoration projects.

Soil biodiversity

Soils contain many living organisms ranging from microscopic bacteria and fungi to burrowing animals. All play a part in maintaining natural soil processes, which are vital for maintaining the chemical and physical fertility of soil. Soil organisms rely on organic matter for food. By 'feeding' on organic matter, micro-organisms release organic nutrients in a mineral form available to plants for uptake. Increasing the organic matter content of your soil (such as by incorporating compost) can help boost the population size, diversity and activity of soil organisms. The organisms in the soil food web play a part in breaking larger pieces of litter into smaller fragments, mixing these throughout the soil profile, binding soil particles, providing channels for water access and maintaining the health of the plant. Bacteria and fungi

Legal requirements are subject to change. Regularly check with Federal, State and Local authorities for updated requirements.

are responsible for the rate of nutrient release to the soil and rhizosphere (the area around plant roots where the biology and chemistry of the soil are influenced by the root).

Biodiversity can be improved in production areas by strategies such as inter-cropping or alley cropping (growing two or more crops in the same area), rotations with a range of crops and cover crops, or by simply being more tolerant of weeds.

Work with others

Neighbouring land managers may have practical experience in addressing certain biodiversity issues that they can share. You can demonstrate your involvement in environmental issues and gain practical advice from fellow growers by joining local groups such as Landcare.

Contact these organisations to see if your on-farm activities can contribute to any local environmental projects and encourage your neighbours to work with you. It is a good idea to contact your regional NRM group to see how your property and activities may contribute to regional targets or strategies and to see if there is any financial assistance available to help you achieve your goals. The Commonwealth has developed a *Biodiversity Resource Guide* as part of the National Environmental Management Systems (EMS) training kit and provides state-by-state contact details. To find out more, visit www.daff.gov.au/emsbiodiversity

As animals travel between farms, it is a good idea to cooperate with your neighbours and connect your native vegetation with theirs.

Monitoring and recording

Records demonstrating that you have achieved progress with your management of native vegetation, fauna and ecosystems serve not only to prove to yourself that your property is a healthy environment, but can also demonstrate your environmental stewardship 'credentials' to your neighbours, authorities, wholesalers, retail customers and consumers, which may go a long way when next you wish to expand your operations, change your focus, access new markets or even sell your property.

A vegetation assessment is a good way to understand current on-farm biodiversity and establish a benchmark for your property. When repeated over time a reassessment can monitor and measure changes. Some guidance may be available from government environment departments and regional NRM groups. In the absence of better information, applying the general principle of trying to maintain the current condition of natural areas and taking some steps to improve them will benefit the environment and demonstrate your environmental stewardship.

A farm map and photos can be used to demonstrate revegetation of locally native species and future plans. You may find it helpful to record sightings of rare or unusual animals along with your vegetation assessment maps and documentation.

Records of training, implementation and the management of Integrated Pest Management on farm can be used to demonstrate some of the production biodiversity enhancements in your business.

A simple measure of soil biodiversity is to count the number of earthworms in a spade full of soil. More sophisticated measures of soil biodiversity can be provided by some research laboratories set up to measure parameters such as microbial and fungal biomass, microbial activity and nematode community analysis.

Strategies for control of problem native animals can be documented and kept along with any licences required.

References and further resources

Australian Museum on line, Australia's Biodiversity – www.amonline.net.au/biodiversity/

Bennett, A., Kimber, S. & Ryan, P. (2000) *Revegetation and Wildlife: A guide to enhancing revegetated habitats for wildlife conservation in rural environments*, Environment Australia, Canberra – www.deh.gov.au/land/publications/revegwild/index.html

Bushcare Tasmania, *Fire Management – Guiding principles for managing your native vegetation* – www.bushcare.tas.gov.au/care/man_fire.htm

Database of IPM Resources Australasia – www.ippc.orst.edu/cicp/australia.htm

Department of Agriculture, Fisheries and Forestry, Landcare page – www.daff.gov.au/landcare

Department of Environment and Heritage homepage – Australian Biodiversity – www.deh.gov.au/biodiversity/

Threatened Species and Threatened Ecological Communities – www.deh.gov.au/biodiversity/threatened/species/

Flora of Australia Online – www.deh.gov.au/biodiversity/abrs/online-resources/flora/main/

Environmental Tax Concessions - ATO – www.deh.gov.au/tax/index.html

Department of Primary Industries, Victoria *Land for Wildlife – Information Notes* – www.dpi.vic.gov.au/dpi/nreninf.nsf/childdocs/-9599F8E44B161F63CA256BC800079622?open

Department of Primary Industries, Water and Environment, Tasmania, *Vegetable Integrated Pest Management (IPM) in Tasmania: Manual* – www.dpiwe.tas.gov.au/inter.nsf/WebPages/TTAR-68Q6CX?open

Department of Sustainability and Environment, Victoria, *Environmental Management in Agriculture: Native Biodiversity Resource Kit* – www.dse.vic.gov.au > Conservation & Environment > Environmental Management in Agriculture

Department of Sustainabiltiy and Environment, Victoria, *How to Plan Wildlife Landscapes: a guide for community organisations* – www.dse.vic.gov.au > Conservation & Environment > Living Systems.

Department of Sustainabiltiy and Environment, Victoria, *Living Systems Resource Kit* – www.dse.vic.gov.au > Conservation & Environment > Living Systems > Living Systems Resource Kit

Environmental Protection Agency, *Landholders' role in nature conservation* – www.epa.qld.gov.au/nature_conservation/community_role/landholders/

Greening Australia – www.greeningaustralia.org.au

Lindenmeyer, D., et al. (2003) *Wildlife on Farms: How to conserve native animals*, CSIRO Publishing, Canberra.

MAFF (1998) *The Soil Code* – www.defra.gov.uk/environ/cogap/soilcode.pdf

Natural Resource Management – www.nrm.gov.au

Natural Resource Management South-East Queensland, *Land for Wildlife technotes* – www.nrmseq.com/projects/programs/landforwildlife.html

- *22 principles to integrate wildlife with farm management*. Land for Wildlife Note No. 15. – www.nrmseq.com/downloads/2004/12_LFW_Technote15.pdf)
- *Fire as a wildlife habitat management tool*. Land for Wildlife Note No. 14 – www.nrmseq.com/projects/programs/landforwildlife.html

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New South Wales Department of Primary Industries, Soil health and fertility page – www.agric.nsw.gov.au/reader/soil-health-fertility

Northern Territory Department of Natural Resources, Environment and the Arts www.nreta.nt.gov.au

Nursery and Garden Industry Nursery Paper Issue No 2000:12 *Invasive plants not wanted in public or private gardens identified* – www.ngia.com.au >Publications and resources

Parks and Wildlife Service, Tasmania *Living with wildlife* – www.parks.tas.gov.au/wildlife/lww/lwwindex.html

Radcliffe, E.B and Hutchinson, W.D (eds.) (c 2000) *Radcliffe's IPM World Textbook* – www.ipmworld.umn.edu

Tracey, J, Bomford, M, Hart, Q, Saunders, G, Sinclair, R (in press) *Managing Bird Damage to Fruit and Other Horticultural Crops,* Bureau of Rural Sciences, Canberra

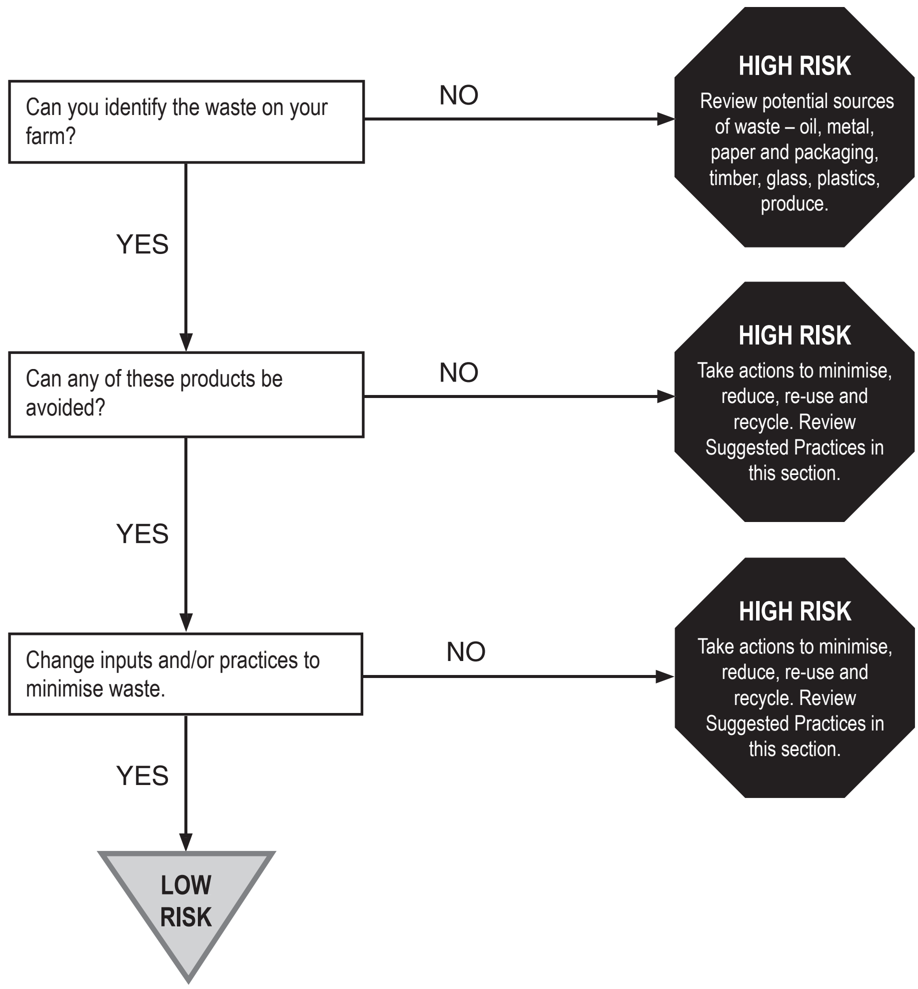
6 Waste management

Objective – waste products are avoided, minimised, reduced, reused or recycled wherever feasible or are disposed in a manner in line with community expectations and legislation.

Production processes create waste. This section covers waste that is created as part of horticultural operations. This waste is usually put into landfills/tips, which is not good use of valuable space and can result in other environmental impacts such as creation of greenhouse gases and pollution of groundwater (e.g. chemicals and nutrients).

This section does not address water or chemical waste. For more information on these topics see 2b – Water quality, 3 – Chemical management, and 4b – Nutrient application.

Risk assessment



LOW RISK – You probably don't have a significant problem in this area. You may like to read the Suggested Practices section to check your understanding of the issue.
HIGH RISK – You need to take some action. Read the Suggested Practices for that topic.

Suggested practices

Identify and prioritise waste products

The first step to managing waste is to determine the types of waste produced by your operations.

Examples of waste products include:

- Inert materials –
  - metal (car bodies etc),
  - rubble, and
  - glass (building materials, bottles).
- Persistent materials:
  - timber (wooden bins, pallets, crates),
  - packaging (waxed or unwaxed cartons, polystyrene boxes, plastic film, net wrap),
  - plastic (seedling trays, fertiliser and seed bags, mulch, irrigation drip tape, irrigation pipes), and
  - tyres.
- Biodegradable materials:
  - paper and cardboard (office paper waste, packaging),
  - substrate (any growing medium used in place of soil, for example potting mix, peat),
  - spent hydroponic solutions,
  - reject plants and vegetative waste, and
  - reject (unmarketable) produce.
- Toxic materials:
  - waste oil,
  - batteries,
  - waste pesticide/chemical liquids (dip solution, rinsates, etc), and
  - treated timber.

Are the wastes a danger to humans or the environment? Are the wastes subject to government regulation?

Once you have identified wastes, it is then useful to prioritise them. This can be done by considering the amount of that waste generated by the operation and the potential impact of the waste on the environment.

Waste avoidance or minimisation

After identifying and prioritising wastes from your operation, some sort of waste disposal plan will help you determine how you are going to deal with these wastes. Can they be eliminated, reduced, substituted for another less wasteful product, recycled or is the only option to send to conventional landfill? Sometimes you might not currently have too many options for dealing with wastes, particularly in remote areas where, for example, recycling options may be limited.

One option to reduce packaging is to opt for bulk supplies of inputs where appropriate. The exception is pesticides and fertilisers, where it is good practice to keep stored supplies to a minimum.

Minimising waste can have a positive financial impact, and is a matter of looking closely at what gets thrown out and how things are done to find opportunities to minimise the creation of waste in the first place. Take waste disposal into account when choosing products. Wherever possible choose methods and equipment that offer extended life and produce relatively low amounts of waste for disposal. Consider using materials that biodegrade after they have been used.

Legal requirements are subject to change. Regularly check with Federal, State and Local authorities for updated requirements.

Reuse or recycle

Materials can be reused within the operation or sent for recycling. For instance, wooden bins can be repaired rather than sent to waste. Storage areas can be established for materials such as timber and steel. Materials being sent for recycling (e.g. paper, oil, glass, timber, steel) need to be collected and separated into dedicated recycling containers or areas for pickup. The local council may have recycling facilities in conjunction with the rubbish tip, or a local charity may collect materials for recycling. When donating waste materials to outside groups or organisations, ensure they are safe before releasing them. Consider distributing out-of-specification produce that is safe to be consumed to charity organisations. Some of these organisations will collect from the farm.

Consider recycling substrates, particularly peat-based products, as not all sources of peat are environmentally sustainable.

Consider composting waste vegetation and produce. The composted product can be returned to production areas as a soil ameliorant. Waste produce can also be returned uncomposted to fallow areas. If recycling waste produce as feed for livestock, ensure it does not contain unacceptable chemical residues.

Ensure waste produce composting or dumping areas are well away from packing and handling facilities to avoid re-contamination of harvested produce with disease, and to avoid attracting vermin to the packing facility.

Also consider environmental impacts of compost sites, such as nutrient rich run-off and the potential for contamination of waterways (surface and groundwater).

Take advantage of returnable packaging systems, for example returnable bulk fertiliser bags.

Some States have websites that assist in finding recycling options, see References and Further Resources.

Consider reusing plastic materials. If an item can be used several times before it becomes unserviceable, the quantity of material that needs to be disposed of will be greatly reduced. To maximise recycling, take care when handling and using plastics.

If plastic items such as plant trays are reused, choosing more durable products can increase their life.

Waste oil from farming activities may be contaminated with substances such as metal particles from engine wear, fuel from incomplete combustion, rust, dirt, carbon, heavy metals and water. If not dealt with effectively, waste oil can lead to pollution of the environment and potential risk to public health and safety. Wherever practicable, waste oil should be recovered for reuse and recycling. It should be stored in a leak-proof container in a bunded area prior to collection by a reputable recycling business or delivery to a recognised disposal facility such as a local government collection depot or service station. Waste oil must never be applied to roadways as a dust mitigation strategy.

Contacting the manufacturer to see if a recycling system is in place is also a good option, for instance 'Netafim' is now able to take used drip tape back and recycle it.

Controlled/ prescribed wastes *are any wastes that are hazardous to human health or the environment either directly or indirectly. These can be, for example, flammable, corrosive, toxic or give arise to gases that have these properties. If in doubt as to whether a waste is controlled or not, contact your local environment agency.*

• Disposal

Disposal of materials should be the last resort and can include burning or burial in landfill (onsite or council disposal facility). There may be regulations related to burning of certain types of waste, particularly wastes that are defined as "controlled" or "prescribed" wastes. Controlled wastes include items such as agricultural chemicals and chemical containers, tyres and oil. These wastes need to be carefully managed and are closely regulated because of their potential adverse impacts on human health and the environment. Some controlled wastes, such as tyres, are not strictly hazardous but they may also need special management.

Consideration needs to be given to the other potential environmental impacts associated with disposal, such as creation of dark smoke and pollution of groundwater.

If disposing of waste materials on site, do not bury or dump them close to waterways or in a way that run-off or leachates from the waste material can contaminate waterways or groundwater.

Monitoring and recording

Records that can (and in some cases must) be kept include:

- waste management plans (can be as brief as a couple of sentences indicating major sources of waste and strategies taken to address them);
- official receipts, offered to participants in the drumMUSTER program when they bring drums in for disposal. This is a signed document distributed through authorised inspectors at official drumMUSTER collection sites, listing the number of drums brought in for disposal. The receipt provides proof of participation in drumMUSTER and therefore proof of responsible disposal;
- ChemClear® documentation, issued to prove chemicals have been booked in for collection and also when chemicals are collected; and
- receipts and invoices from recycling or commercial disposal businesses.

Disposal of surplus agricultural chemicals from the spray vat can be recorded on spray records.

The effectiveness of waste management can be assessed through water and soil tests.

References and further resources

Department of Environment and Conservation, NSW – www.environment.nsw.gov.au/waste/index.htm

Department of Heritage and Environment, *Used Oil Recycling* – www.oilrecycling.gov.au/index.html

Department of Heritage and Environment, *Waste and Recycling* – http://deh.gov.au/settlements/waste/

Department of Primary Industries, Victoria (2005) *Environmental Best Practice Viticulture* – www.dpi.vic.gov.au/dpi/nrenfa.nsf/FID/-9D5D0AFF7C8D9661CA256CBC00042B34?OpenDocument

Department of Primary Industries, Water and Environment, Tasmania, *Controlled Waste* – www.dpiwe.tas.gov.au/inter.nsf/WebPages/CDAT-64T89W?open

Department of Primary Industries, Water and Environment, Tasmania, *Waste and Recycling* page – www.dpiwe.tas.gov.au/inter.nsf/ThemeNodes/CDAT-53L6SJ?open

EcoRecycle Victoria – www.ecorecycle.sustainability.vic.gov.au/www/html/7-home-page.asp

Environmental Protection Agency, *Waste minimisation* page – www.epa.qld.gov.au/environmental_management/waste/waste_minimisation/

European Initiative for Sustainable Development in Agriculture – www.sustainable-agriculture.org/start.html

National Technical Committee for Organics Recycling (2004) *Best Practice Guidelines Series Composting, Edition 1*: February 2004, Waste Management Association of Australia – www.wmaa.asn.au/tech/OrganicsBPGuidelines.pdf

Northern Territory Department of Natural Resources, Environment and The Arts, *Key greenhouse Issues* page – www.nt.gov.au/nreta/environment/greenhouse/issues/waste.html

Northern Territory Department of Natural Resources, Environment and The Arts, *Waste Management and Licencing* page – www.nt.gov.au/nreta/environment/waste/acts/about.html

Murdoch University, General Recycling Links – wwwscience.murdoch.edu.au/teaching/m234/recycle.htm

New South Wales Department of Primary Industries (2003) *How to compost on farm* NSW DPI Agnote DPI -448 – www.agric.nsw.gov.au/reader/recycledorganics/ – and select this document.

Zero Waste SA, Recycling Information Directory – www.zerowaste.sa.gov.au/rid.php

7 Air management

Objective – air pollution from odours, dust, smoke, noise and greenhouse gases is minimised.

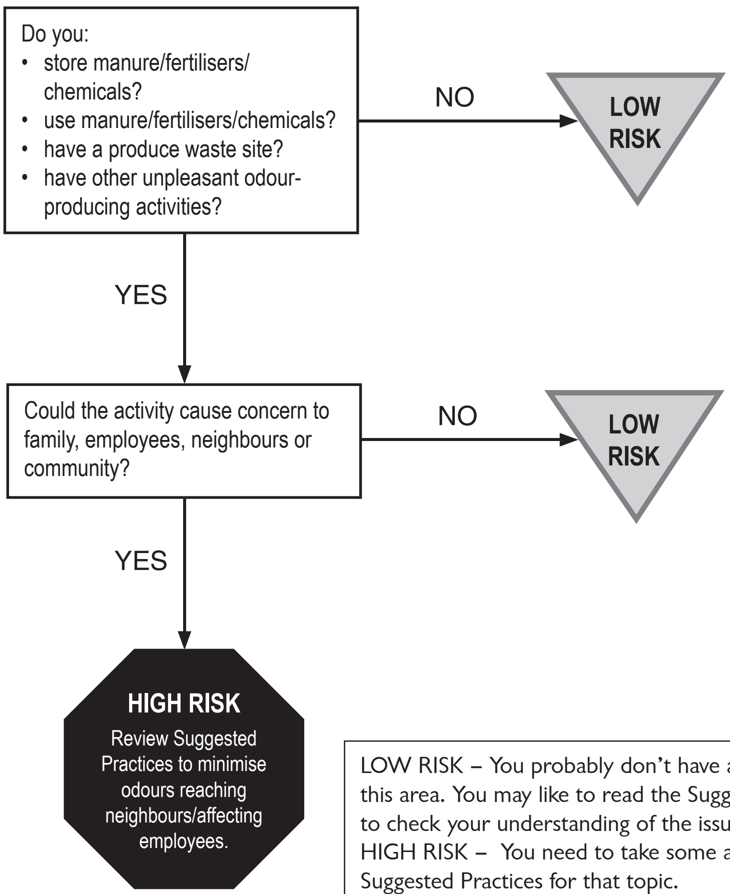
Air pollution issues, particularly odours, dust, smoke and noise, can often be of most significance to your immediate neighbours. Disputes involving environmental nuisance can arise as a result of the breakdown of good neighbourly relations. Considering impacts of farming activities on neigbours and, where appropriate, discussing aspects of farming with neighbours can help in their understanding of primary production. Similarly, primary producers need to recognise that some activities can negatively impact on their neighbours and that at times it may be appropriate to adjust activites as far as reasonable to minimise the impact.

7a Odour management

Objective – odours from horticultural enterprises are managed to minimise potential conflicts.

Odours can be caused by animal manures, fertilisers and chemicals, waste disposal sites for produce, composting sites and activities, mulches and waste management equipment.

Risk assessment



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HIGH RISK – You need to take some action. Read the Suggested Practices for that topic.

Suggested practices

Manure

For information on how to compost refer to *How to compost on farm* and other documents in the References and other resources section.

Animal manure is often stored and used in horticulture. However, most people do not like the smell of raw manure. Growers must make sure manure is stored and used in a way to minimise the nuisance to neighbours.

Replacing raw manure

Growers can reduce the nuisance to neighbours by replacing raw animal manure with other less odorous products such as composted or dry manure. Although more expensive, using already composted manure greatly reduces any offensive odour. If fresh manure is used, growers must store and use it in the correct way.

Manure, fertiliser and chemical storage

Manure storage areas should be as far from neighbours as possible. If possible, storage areas should be located to prevent prevailing wind causing an odour issue for neighbours.

Visually screening the storage area can reduce the perception of odour problems. Providing a natural or artificial barrier between the storage area and the public eye can be very beneficial. Good ways of making a visual screen include planting a thick row of trees or putting up high solid fences.
Protection of stored manure (and compost) from rain, and containment of run-off effluent can avoid contamination of adjacent soils, work areas and waterways.

Manure application

Unfortunately, you cannot always keep a large distance between the area where manure is spread and the neighbours. The first thing that you can do is to always contact neighbours before spreading manure. This gesture will probably go a long way in maintaining good relationships with the public.

Whenever possible, you should schedule times to spread manure when it will have the least impact on neighbours. In general, manure spreading should be done on weekdays during office hours. At these times, neighbours are more likely to be away from home. If possible avoid spreading manure on weekends, holidays or when social events are taking place.

Carefully consider the weather before spreading manure. Manure should not be spread when the wind direction is going to take the smell to a neighbour. Even under appropriate weather conditions, the more manure used, the more likelihood that the smell will be excessive. Extra manure will not provide additional benefits to the crop and will only make the smell worse. Odours are reduced and drying is quicker when less manure is used and the manure is well spread out.

Another good practice is to dig the manure into the soil as quickly as possible. This practice also has positive implications for food safety. Ideally, manure should be incorporated as soon as spread. The best method is to incorporate it as it is put on, or to inject it. Adequate soil moisture to allow rapid initial breakdown of the applied manure helps to reduce odour. This is not possible or desirable in some permanent crop situations. Managers need to assess the risk of odour problems against the risk of soil compaction and loss of groundcover exposing the soil to erosion from incorporating manure.

As with the storage area, natural and man-made barriers between production areas and neighbours can greatly reduce the likelihood of complaints.

Legal requirements are subject to change. Regularly check with Federal, State and Local authorities for updated requirements.

Produce waste disposal sites

Packing sheds often have produce waste disposal areas, which can produce odours. The same principles apply as for storage of animal manures:

- Disposal areas should be as far away as possible, and if possible, downwind of neighbours.
- Visual screening of the disposal area reduces the perception of odour problems.

Ideally, waste disposal sites should be regularly covered with soil to minimise odours and the risk of disease transmission, pest build-up and vermin.

Composting waste is also an option. Done correctly, aerated and balanced this is a low odour process. Adding gypsum to materials to be composted can cause strong sulphurous odours as the compost matures.

Monitoring and recording

A farm map can be used to document sites of any manure storage areas, produce waste sites or other odour-producing activities and proximity of these areas to neighbours. Evidence of adequate recording and/or planning is beneficial.

Odours can be monitored by visiting these areas and smelling for yourself!

A complaints register can record the nature of complaints and how they were resolved.

Records of application date and cultivation date can be useful to substantiate prompt incorporation of manure.

References and further resources

Ministry of Agriculture, Fisheries and Food (MAFF) UK, 1998. *The Air Code* –
www.defra.gov.uk/environ/cogap/aircode.pdf

National Technical Committee for Organics Recycling (2004), *Best Practice Guidelines Series Composting*, Edition 1: February 2004, Waste Management Association of Australia –
www.wmaa.asn.au/tech/OrganicsBPGuidelines.pdf

New South Wales Department of Primary Industries (2003) *How to compost on farm,* Agnote DPI - 448 – www.agric.nsw.gov.au/reader/recycledorganics/ – and select this document

Northern Territory Department of Natural Resources, Environment and The Arts –
www.nreta.nt.gov.au

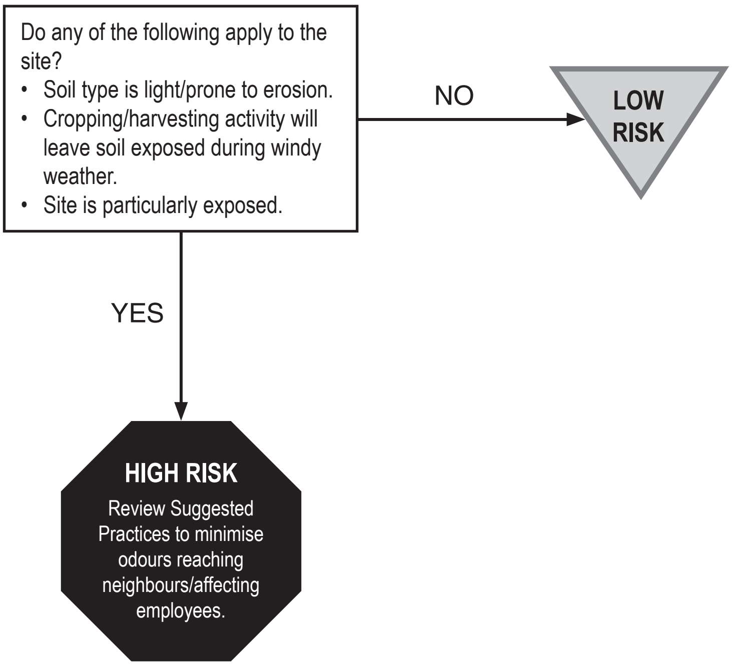
7b Dust management

Objective – to manage dust to minimise on and off site impacts.

Excessive dust can cause annoyance and in some cases health problems to neighbours and staff. Dust created around packing sheds can also settle on packed produce, affecting visual quality and potentially having food safety implications.

The combination of soil type, farming system and weather patterns contributes to the risk of soil erosion by wind.

Risk assessment



LOW RISK – You probably don't have a significant problem in this area. You may like to read the Suggested Practices section to check your understanding of the issue.
HIGH RISK – You need to take some action. Read the Suggested Practices for that topic.

Suggested practices

Legal requirements are subject to change. Regularly check with Federal, State and Local authorities for updated requirements.

Control measures may include planting shelterbelts and windbreaks where practical, modifying cultural practices or reconsidering the appropriateness of particular cropping activities on exposed sites.

Constructing or planting a shelterbelt/windbreak will slow the velocity of wind across a site (shelterbelts/windbreaks should be designed to allow 30-50% of the wind to pass through). The protective effects from a shelterbelt/windbreak reduce with distance away from it (protection extends no more than 20 times the height of the vegetation).

Vegetation shelterbelts/windbreaks also provide wildlife habitat, assist in minimising spray drift, reduce the visual and noise impacts of site activity and can improve the quality of crops.

Choose cultivation practices carefully:

- Working soil to fine tilth in dry windy weather should be avoided if possible. Pre-irrigation to wet dry soil before cultivation will help to reduce dust.
- Use slower cultivation speeds when there is a risk of dust.
- Uncultivated crop stubble provides protection against wind erosion.
- Minimise the amount of time soil is left without vegetation or a cover crop.
- Minimum tillage techniques should be used where practical.
- Inter-row spacings and headlands should have groundcover whenever possible.

Applying mulches to the surface of seedbeds after drilling on sandy soils is an effective control measure. Use of plastic mulch along plant rows will also contribute to dust control.

Wetting down, sealing and use of 'minimal dust materials' (for example blue metal or hardstand) for the surfaces of frequently used traffic ways (transport delivery and pickup areas, harvested produce delivery points and forklift routes at the packing shed) will dramatically reduce the dust problem. Do not apply oil to trafficways due to the potential for it to end up in waterways.

Monitoring and recording

See Section 1a – Land and soil management, for details of ways to assess soil erosion by wind.

If dust is a major issue to neighbouring areas, cultivation records may be kept (as part of paddock records) to detail soil conditions when soils are worked and the equipment used.

Farm maps should show roads, sensitive areas and soil types and can be used to demonstrate the placement of current and planned shelterbelts and the direction of prevailing winds.

The effectiveness of these practices can be assessed by observing dust levels on windy days.

References and further resources

Ministry of Agriculture, Fisheries and Food (MAFF) UK, 1998. *The Air Code* –
www.defra.gov.uk/environ/cogap/aircode.pdf

7c Smoke management

Objective – to manage smoke to minimise on and off-site impacts.

Risk assessment

LOW RISK – You probably don't have a significant problem in this area. You may like to read the Suggested Practices section to check your understanding of the issue.
HIGH RISK – You need to take some action. Read the Suggested Practices for that topic.

Suggested practices

If burning in the open is the only practical method of disposal of materials, and it is legal in your area, precautions should be taken to prevent producing dark smoke and causing a nuisance. Burning of waste is banned, or requires a permit, in many local government areas. Before burning check local bushfire restrictions/permits and local government restrictions and requirements.

Do not burn plastics, rubber, tyres or other materials known to produce dark smoke. Where possible recycle, reuse or dispose of these waste items at local authority waste depots. Do not burn plastics or chemicals under any circumstances as they release toxic fumes and residues.

Legal requirements are subject to change. Regularly check with Federal, State and Local authorities for updated requirements.

Avoid burning if it will cause a nuisance to nearby residential areas. Check wind direction before burning – only burn when wind direction is away from neighbours.

As a courtesy, inform immediate neighbours before burning.

Be aware of localised landscapes that can induce smoke problems, such as valleys.

Materials should be dry and have low moisture content. Do not burn green vegetation. Keep fires small and continually add combustible material, minimising the depth of the combustion area. Minimise the quantity of incombustible material added to the fire. Wherever possible keep incombustible materials separate from materials to be burnt. For better combustion, agitate the base of the fire to improve air supply.

If fire produces dark smoke, don't add any more material that burns slowly.

Monitoring and recording

The quantity of dark smoke produced during burning operations can only be assessed visually.

Records of other disposal options for materials that are likely to produce dark smoke can also be retained.

References and further resources

Air Resources Board, California, *Smoke Management Program* – www.arb.ca.gov/smp/smp.htm

Department of Heritage and Environment, Air Quality Factsheet – *Air Quality* – www.deh.gov.au/atmosphere/airquality/index.html

Department of Heritage and Environment, Air Quality Factsheet – *Smoke from Biomass Burning* – www.deh.gov.au/atmosphere/airquality/publications/biomass.html

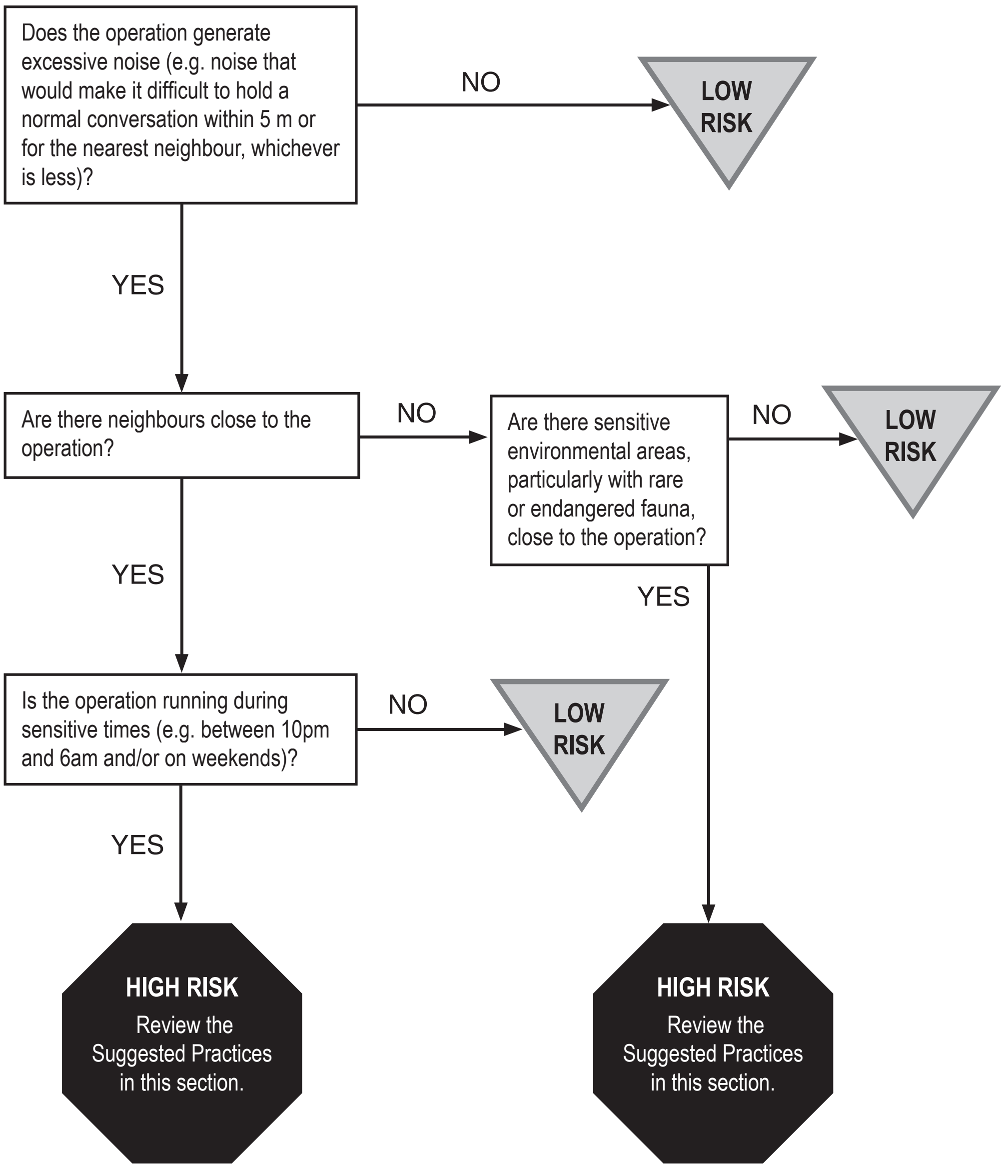
Ministry of Agriculture, Fisheries and Food (MAFF) UK, 1998. *The Air Code* – www.defra.gov.uk/environ/cogap/aircode.pdf

7d Noise management

Objective – to manage noise to minimise on and off-site impacts.

Noise many not seem like an environmental management issue for growers, however most State legislation for environmental protection includes noise as part of the definition of the environment. For this reason, noise management is included in the environmental assurance process for horticultural businesses.

Risk assessment



LOW RISK – You probably don’t have a significant problem in this area. You may like to read the Suggested Practices section to check your understanding of the issue.
HIGH RISK – You need to take some action. Read the Suggested Practices for that topic.

Suggested practices

Identify and consider local government regulations.

Buffer zones are useful to reduce noise and are also helpful to mitigate impacts of off-target spray application.

Where pumps are located close to residential areas, consider changing from diesel to electric pumps or creating a sound barrier around the pump. Electric pumps will most likely be run at night time, when electricity tariffs are lower.

Consider muffling equipment where daytime intermittent noise levels are excessive. Where normal methods are not sufficient to reduce noise to acceptable levels, equipment that is continuously operated may require soundproofing or artificial mounds to help absorb and deflect the noise.

Some forms of seasonal activity, or current and accepted industry practice like harvesting, may require the use of machinery at night. Where sensitive places are close to noise and night-time activities occur, consider starting work closer to the sensitive area and moving away as night falls. The converse applies for early morning activities.

Where noise may be an issue, keeping records of machinery use may be beneficial.

Use bird deterrents, such as gas guns, and frost protectors in a considerate manner and in accordance with local bylaws.

Transport operators picking up packed produce should be reminded not to use exhaust brakes where this noise would create a nuisance to neighbours.

Monitoring and recording

Records of machinery maintenance should be maintained. In situations where a more definitive measure of noise is required, organisations such as state OH&S agencies can assist with testing.

References and further resources

Department of Employment and Workplace Relations, *Australian Farm and Rural OHS Resources* – www.nohsc.gov.au/OHSInformation/Agriculture/default.asp

EPA South Australia, *Draft Environmental Noise Guidelines for Audible Bird Scarers* – www.epa.sa.gov.au/pdfs/bird_scarers.pdf

Legal requirements are subject to change. Regularly check with Federal, State and Local authorities for updated requirements.

7e Greenhouse gases

Objective – to ensure sources of greenhouse gases are identified and emissions are reduced wherever feasible.

Greenhouse gases of greatest concern in agriculture are methane (CH_4) and nitrous oxide (N_2O). Methane arises from livestock, mainly through digestion (enteric fermentation). Nitrous oxide is released from soils through application, oxidation and natural transport of fertilisers and soil disturbance.

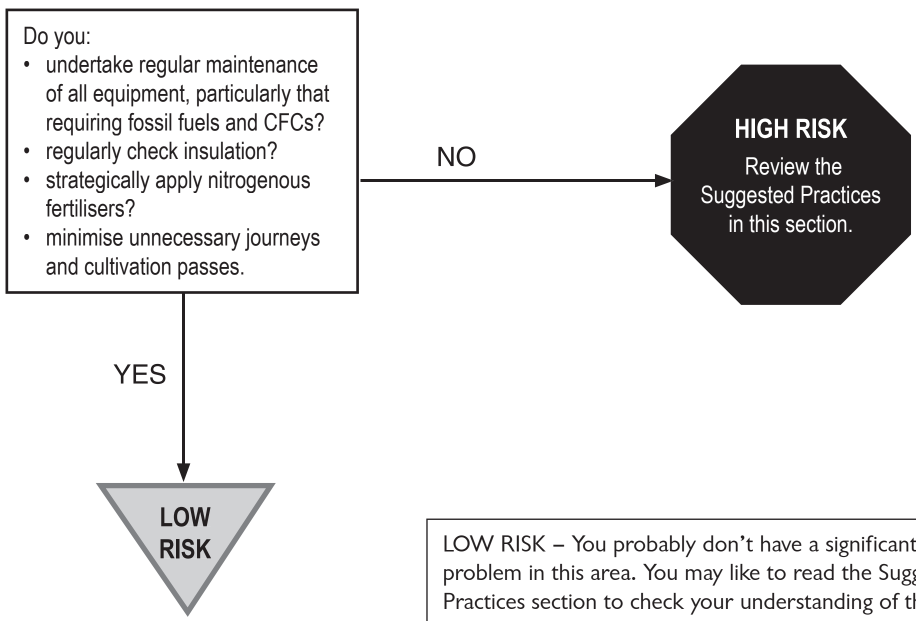
Agricultural activities such as planting, growing and harvesting produce little net carbon dioxide (CO_2), as it is absorbed by growing plants. However, carbon dioxide emissions from transport and energy sources remain a significant issue. Chlorofluorocarbons or CFCs (used for refrigeration and aerosol propellants) were also significant greenhouse gases but are now generally prohibited from use.

An important issue is the high global warming potential of methane and nitrous oxide, expressed as 'carbon dioxide equivalents' or CO_2-e. The CO_2-e of CH_4 is 21 while the CO_2-e of N_2O is 310. This means that methane has a global warming effect that is 21 times greater than carbon dioxide while that of nitrous oxide is 310 times greater! The implication is that we should be especially careful to avoid methane and, particularly, nitrous oxide emissions.

In the horticulture sector, while methane may be produced from composting processes and stagnant pools of contaminated water, it appears not to be a major concern. Careful use of fertilisers and minimising soil disturbance play an important role in reducing greenhouse emissions and in reducing the operating costs of horticulture operations.

All the major greenhouse gases have natural sources, but human activity increases the amount released. It is now generally agreed that this pollution has added to the natural greenhouse effect and will cause the temperature of the earth's surface to rise. Because some of the greenhouse gases last for a long time in the atmosphere, it is important that any action to reduce emissions of greenhouse gases is taken as early as possible.

Risk assessment



LOW RISK – You probably don't have a significant problem in this area. You may like to read the Suggested Practices section to check your understanding of the issue.
HIGH RISK – You need to take some action. Read the Suggested Practices for that topic.

Suggested practices

● Carbon dioxide

The most effective way of reducing carbon dioxide emissions is to use energy more efficiently and to exploit non-fossil fuels as alternative sources of energy.

Maintain engines by following the manufacturers' recommendations. A reduction of 5-15% in fuel consumption can be obtained by servicing air cleaners and fuel injectors regularly.

Choose tractors and machinery that are suitable for the tasks they will be performing. Use the lowest-powered tractor capable of doing the required job or adjust machinery (i.e. increase the width of implements) to match the tractor power.

Minimise unnecessary journeys and cultivation passes. Install GPS on tractors to prevent overlap or missed coverage.

Maintain equipment in good condition and operate efficiently.

Reduce loss of heating/cooling through effective insulation and preventing unintentional ventilation.

Heated glasshouses, mushroom houses and polythene-covered structures are major users of energy. Economise on fuel by precise control of the correct temperature regimes, using thermal screens and correct maintenance and insulation of boilers and burners.

Compact fluorescent lighting is far more energy efficient that incandescent bulbs for use in greenhouses and work areas.

Consider the use of energy sources other than fossil fuels. Many energy companies now offer what is called 'green power', which is produced from renewable energy sources such as wind, hydro and solar. This electricity may cost a little more than conventional power from coal-fired power stations. However, costs can be maintained to the same total cost by improving energy-use efficiency. Some growers and processors have large amounts of organic waste (or by-product), such as cores, skins, peels, outer leaves, tops, seeds, stems, shells, husks and other plant parts, and are looking at ways that the waste can be composted to produce methane that can be used as a fuel. For information on green power see www.greenpower.gov.au/pages/

Large amounts of fossil fuel are needed to manufacture nitrogen fertilisers. Only use fertilisers at the rates suitable for the cropping situation. Ensure fertiliser spreaders are properly maintained and use suitable settings for different types of fertiliser.

Carbon dioxide is also created from the breakdown of liming materials in the soil.

● Nitrous oxide

Nitrous oxide from agriculture is released from nitrogen compounds in manures, fertilisers, crops, soils and watercourses. It is likely to be produced in oxygen-free conditions. The most effective way to reduce the release of this gas is to use nitrogen fertilisers and manures efficiently so that crop requirement is met while losses of nitrogen are minimised.

Maintaining good soil structure (see Section 1c – Soil structure) will help to keep the soil well aerated and reduce the potential for an oxygen free environment.

Legal requirements are subject to change. Regularly check with Federal, State and Local authorities for updated requirements.

● Chloroflurocarbons (CFCs)

Apart from their effect as greenhouse gases, CFCs also damage the ozone layer. CFCs were used in refrigeration equipment but are now generally prohibited. If your equipment uses CFCs, it is important to keep refrigeration equipment properly maintained to minimise the risks of leaks of refrigerant. Whenever such equipment is serviced, make sure that no refrigerant is lost. Do not allow unused equipment to deteriorate on site. Specialist contractors can safely remove refrigerant so that it can be recycled or destroyed. CFC's have not been used in refrigeration equipment since 1995.

Monitoring and recording

Records of a responsible approach to minimising greenhouse gases include:

- maintenance records for equipment,
- checks of insulation, and
- fertiliser records detailing use of nitrogenous fertilisers.

An assessment of the business expenditure on fossil fuels as compared to yields may also be useful to give a broad view of the efficiency of operations.

References and further resources

Australian Conservation Foundation (2001) *Clearing the Common Wealth, Land Clearing in Commonwealth Countries* – www.acfonline.org.au/uploads/res_clearing_commonwealth.pdf

Department of the Environment and Heritage, *Atmosphere* page – www.deh.gov.au/atmosphere/index.html

Foran, B (1998), *Looking for opportunity and avoiding obvious potholes: Some future influences on agriculture to 2050*.

Greenhouse in Agriculture, Grains Research Project, Greenhouse Gases Dryland Grain production (has horticultural principles) – www.greenhouse.unimelb.edu.au/Grains2.pdf

GreenPower – www.greenpower.gov.au/pages/

Ministry of Agriculture, Fisheries and Food (MAFF) UK, 1998. *The Air Code* – www.defra.gov.uk/environ/cogap/aircode.pdf

NOVA, Impact of global warming on biodiversity and general environmental news – www.science.org.au/nova/envir.htm

CSIRO – www.cse.csiro.au/publications/1998/lookingforops-98-13.pdf

8 Energy management

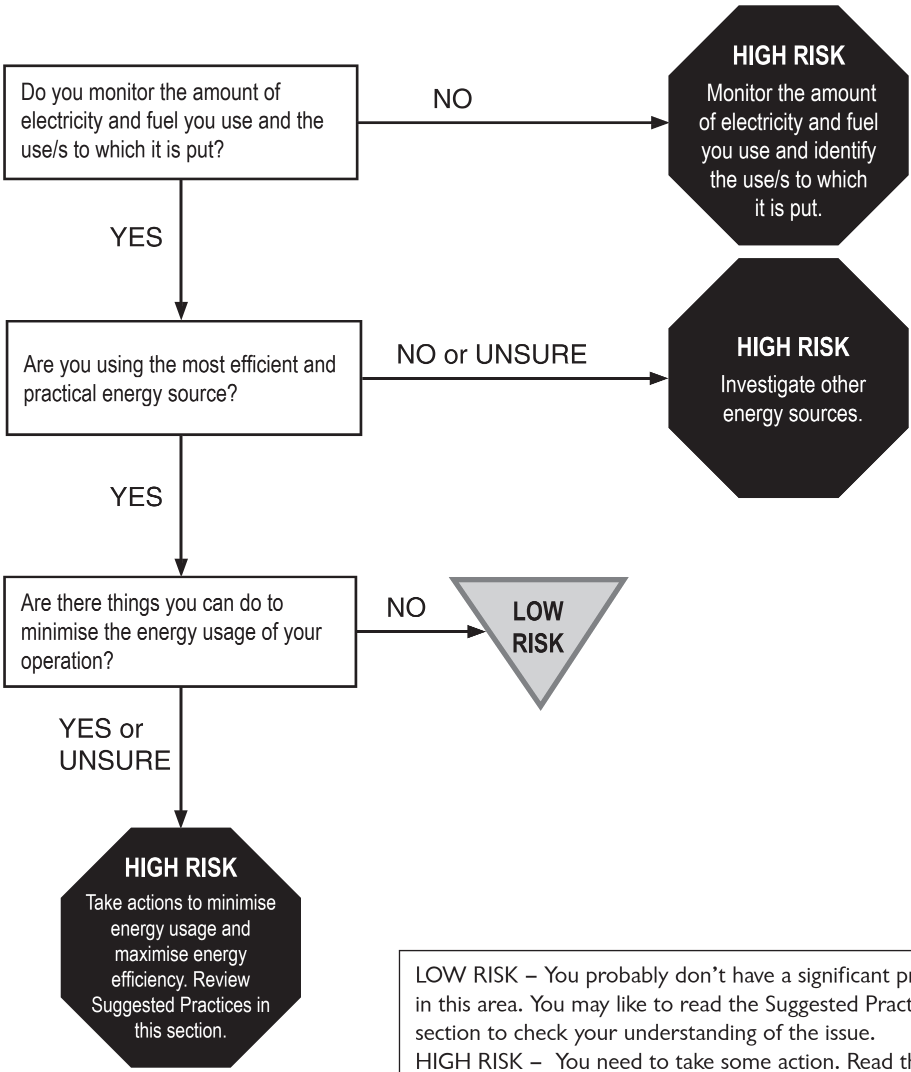
Objective – energy inputs are known and reduced wherever feasible in the production system.

Although energy from sunlight is essential for growth, the energy balance of agricultural systems depends on additional energy, from non-renewable sources, to power machinery. Sustainable practices can improve the balance of energy and contribute to efficient energy use.

Most of our energy (including more than 90% of our electricity) comes from fossil fuels such as oil, coal and gas. Burning of fossil fuels releases carbon dioxide (CO_2), nitrous oxide (N_20) and methane (NH_4) into the atmosphere. This has resulted in the greenhouse effect known as 'global warming'.

In assessing the total energy used in agricultural production 'from field to fork', synthetic fertiliser and pesticide manufacture are important indirect energy inputs; while irrigation, cultivation, harvesting and transport are major direct energy inputs. By managing the amount of fertiliser and pesticide applied as well as the more tangible direct agricultural activities, greenhouse gas emissions can be reduced.

Risk assessment



LOW RISK – You probably don't have a significant problem in this area. You may like to read the Suggested Practices section to check your understanding of the issue.
HIGH RISK – You need to take some action. Read the Suggested Practices for that topic.

Suggested practices

Reduce energy use through improved efficiency. Consider energy efficiency when new buildings, equipment and vehicles are purchased.

Consider an energy audit. Energy companies can give expert advice on how to save electricity and most can conduct an energy audit to identify areas for improvement.

Irrigation

Pumping water for irrigation is one of the main ways energy is used in horticultural production. Growers can use less energy and save costs by carefully choosing the type of irrigation equipment they use. Keeping irrigation equipment in good condition can also save energy. Irrigation pump engines should be serviced and well tuned. Make sure motors, switches and control panels are clean. Check connections to make sure they are tight, and lubricate moving parts. Variable speed electric motors are generally more efficient than fuel-driven pumps. Pumps will wear more quickly if water contains a lot of dirt or organic matter, leading to leaks and reduced energy efficiency. Regularly check and maintain inlet sieves.

The amount of energy used by your irrigation system depends on:

- system flow rate (larger-diameter pipes reduce flow rate losses due to friction, thus reducing pumping costs);
- operating pressure (aim for low pressure systems, the less friction in the system the less pressure you need to start with);
- hours of operation (utilise as much off peak power as possible – in many cases off peak power is cheaper because it is generated whether it is used or not [e.g. coal and wind generation]); and
- the combined efficiency of all the components.

Choose pumps that match the pressure flow you need. Pumps need to be used in their best operating range for best efficiency. Pumps should run at or above 65% efficiency. Some agricultural companies may be able to test your pump for efficiency. Pumps wear out over time – they may still pump water, but it is costing significantly more because of impeller wear. This test can help you know if a pumping plant is wasting energy.

Vehicles and equipment

Maintain and service vehicles and equipment regularly to ensure efficient operation. Well-maintained equipment operates better and costs less to run. This is good both for your business and the environment. Keeping engines tuned can cut greenhouse gas emissions by up to 15%. It is a good idea to have a regular maintenance program for all the equipment, machinery and vehicles used on your farm. Maintenance intervals will vary to suit levels and conditions of use for each vehicle and piece of equipment.

Consider whether a smaller, lighter vehicle can do the same job, thereby using less fuel.

Install or turn on the power-save function on office equipment such as computers and photocopiers. Turn them off when you finish work.

Fuel

Legal requirements are subject to change. Regularly check with Federal, State and Local authorities for updated requirements.

Try to save fuel. Every litre of petrol or diesel saved greatly lowers greenhouse emissions and reduces production costs. Keep track of fuel use and set targets for saving fuel. Another good idea is to switch from diesel/petrol to LPG or compressed natural gas in cars, trucks and motor bikes. This can cut greenhouse gas emissions by 10 to 15%. Use a percentage of bio fuels, which come from renewable resources.

Use electric fork lifts instead of internal combustion engine forklifts.

Lighting

By using energy-efficient lighting you can save money and help the environment at the same time. For example, energy efficient compact fluorescent bulbs have about one-quarter lower wattage and about eight times the life of standard incandescent bulbs. This saves energy and lowers maintenance costs. Replacing mercury vapour yard lights with energy-efficient, high-pressure sodium lights can sometimes greatly cut electricity usage and costs.

Place movement sensors and timers on lighting systems so they are only on when required.

Coolrooms

Coolrooms should be properly designed and built to make sure that energy is not wasted. This includes fitting the right temperature control devices and keeping them properly calibrated. Incorrect calibration by only 1°C can greatly increase running costs and may affect the quality of stored produce. Don't overlook the huge thermal losses that occur through an uninsulated floor. A little more spent at the outset is quickly recovered. Polystyrene is the floor insulant of choice.

Once coolrooms have been built they need to be maintained and serviced. Regularly check things such as door seals, hinges and catches. This will minimise leaking of warm air into the coolrooms. The building should be checked for damage to insulation panels, roof and walls. If possible, build coolrooms with a shade roof covering or within a shed to reduce thermal loads. Windbreaks also reduce airflow onto the exterior surfaces and associated heat transfer.

Always try to remove field heat from produce (pre-cool) before storing it in the coolroom as this can greatly reduce the amount of energy used. You should also minimise the time coolroom doors are open. Don't open doors often or hold them open for a long time. If doors need to be kept open during some daily operations, use plastic door strips, automatic coolroom doors or rapid-rise curtains. These devices can help to keep warm air out of the coolroom. When forklifts are in coolrooms for extended periods, consider using electric forklifts (as opposed to gas) for heat and OH&S gains. Gas forklifts can also release gases that affect produce quality (maturity and taste).

Renewable resources

The efficient use of renewable energy resources such as hydro-electricity, solar or wind power should be targeted since the use of non-renewable sources, such as fossil fuel, is not sustainable in the long term. Switch to more environmentally-friendly renewable energy sources, or what is known as 'green power', where this option is available (see www.greenpower.gov.au/pages/ for more information).

Minimise use of fossil fuel for power generation, for example:

- optimise field operations, including transportation from field to packhouse,
- carefully select equipment, and
- ensure proper and timely maintenance of equipment.

Minimise the input of synthetic fertilisers and consider alternative organic and renewable fertiliser technologies taking into account crop needs, fertiliser cost and comparative costs (including fuel use) of delivery and spreading.

Review practicality of best current waste re-use, recycling and disposal technologies available.

Reducing greenhouse gases

See Section 7e – Greenhouse gases.

Legal requirements are subject to change. Regularly check with Federal, State and Local authorities for updated requirements.

Monitoring and recording

Energy usage can be monitored by checking electricity and fuel bills. Energy efficiency over time can be assessed against production yields or throughput.

Remember the strong relationship between energy saved and your chequebook!

Other records that can be useful include:

- coolroom and machinery maintenance records,
- thermometer or temperature monitoring device calibration records,
- irrigation records, and
- internal energy audits.

References and further resources

Department of Primary Industries, Victoria Ecologically Sustainable Agriculture Initiative – www.dpi.vic.gov.au/ and use search for 'ecologically sustainable agriculture'.

EcoBiz program, includes sections on energy efficiency, waste and water use efficiency – www.epa.qld.gov.au/environmental_management/sustainability/industry/ecobiz/

European Initiative for Sustainable Development in Agriculture, home page – www.sustainable-agriculture.org/start.html

Greenpower, *Who Sells Greenpower* – www.greenpower.gov.au/pages/Home-Who-Sells.php

New South Wales, Department of Primary Industries, *Soil health: the foundation of sustainable agriculture* – www.agric.nsw.gov.au/reader/soil-management-guides/soil-health-proceedings-sp.htm

Nova, *Feeding the future – sustainable agriculture* – www.science.org.au/nova/071/071key.htm

The Australian Society of Agronomy, *The Development of Ecological Performance Indicators for Sustainable Systems* – www.regional.org.au/au/asa/2001/4/c/kemp.htm

Unilever, environment and society page – www.uniq.unilever.com/ourvalues/environmentandsociety

University of New England, *Sustainable Agriculture Resources* page – www.une.edu.au/agronomy/agsystems/organic/links/

Review checklist **(A Microsoft Word version of this Checklist is on the CD.)**

This review checklist identifies the range of environmental issues that should be addressed on-farm in horticulture. The checklist covers 20 topics divided into eight sections which match the colored tabs of this folder.

The checklist can be used to supplement existing audit checklists used by certification bodies or for internal audits carried out by individual businesses.

As with any generic checklist, you may not consider some items to be relevant and they can be excluded.

By working through the checklist you will get an idea of your priority areas and you can then read the relevant topic in more detail. (We have provided a second 'working' copy of the checklist under the Work sheets heading. Use these to complete your first review.)

The Checklist is divided into tables covering a range of topics. Select a topic and turn to the matching topic in the main working section of the guidelines and look for the Risk Assessment diagram. By working though the Risk Assessment you can quickly determine if that particular topic of the guidelines is significant for your business.

If the topic is significant for your business, complete the relevant checklist table and record the answers.

Read the Suggested Practices for the topic to explore your management options.

Date:

	Yes	No
Are you aware of any targets, priorities or objectives of your Natural Resources Management group/Catchment Management Authority?		
Have you considered this information to assist you in identifying issues that might be important for your property?		

1 Land and soil management	Yes	No	Not relevant	Needs attention	Actions taken	Actions required
					In the past 12 months	In the next 12 months
1a Soil erosion caused by water						
1 An assessment of the risk of soil erosion by water has been undertaken						
2 Based on the result of the risk assessment, are further actions required?						
3 If so, what actions are needed or have been undertaken?						
• Soil cover maximised						
• Water control measures in place						
• Soil structure improved						
• Sediment traps in place						
4 The effectiveness of the actions is being monitored and recorded						

1 Land and soil management	Yes	No	Not relevant	Needs attention	Actions taken	Actions required
					In the past 12 months	In the next 12 months
1b Soil erosion caused by wind						
5 An assessment of the risk of soil erosion by wind has been undertaken						
6 Based on the result of the risk assessment, are further actions required?						
7 If so, what actions are needed or have been undertaken?						
• Soil cover maximised						
• Windbreaks in place to moderate wind speed						
• Soil structure improved						
• Other management strategies in place						
8 The effectiveness of the actions is being monitored and recorded						

1 Land and soil management	Yes	No	Not relevant	Needs attention	Actions taken	Actions required
					In the past 12 months	In the next 12 months
1c Soil structure						
9 An assessment of the soil structure has been undertaken						
10 Based on the result of the risk assessment, are further actions required?						
11 If so, what actions are needed or have been undertaken?						
• Appropriate cultivation methods used						
• Cultivation undertaken at appropriate time						
• Traffic minimised and controlled						
Steps taken to promote soil structure such as:						
• Increasing organic matter						
• Approriate crop rotations						
12 The effectiveness of the actions is being monitored and recorded						

1 Land and soil management	Yes	No	Not relevant	Needs attention	Actions taken	Actions required
					In the past 12 months	In the next 12 months
1d Salinity						
13 An assessment of the risk of groundwater and soil salinity has been undertaken						
14 An assessment of the risk of irrigating with saline water has been undertaken						
15 Based on the result of the risk assessments, are further actions required?						
16 If so, what actions are needed or have been undertaken?						
• Determination of the source of salinity (irrigation water, groundwater or soil salinity)						
• Advice sought on irrigation strategies						
• Action taken to lower water table						
• Actions taken to minimise rise in water table (including review of irrigation requirements and improvement of subsurface drainage)						
• Alternate source of irrigation water or shandying/diluting saline water						
• Leaching fraction applied						
• Vegetation cover maintained						
• Specialist advice sought						
17 The effectiveness of the actions is being monitored and recorded						

1 Land and soil management	Yes	No	Not relevant	Needs attention	Actions taken	Actions required
					In the past 12 months	In the next 12 months
1e Soil acidity and alkalinity						
18 An assessment of the risk of soil acidity or alkalinity has been undertaken						
19 Based on the result of the risk assessment, are further actions required?						
20 If so, what actions are needed or have been undertaken?						
• Soil pH is monitored regularly						
• The relative acidifying impact of fertilisers is considered when deciding on fertiliser purchase/ application						
• The potential for leaching is considered prior to applying fertilisers or irrigation post-fertiliser application.						
• Lime or dolomite is applied as required						
21 The effectiveness of the actions is being monitored and recorded						

1 Land and soil management	Yes	No	Not relevant	Needs attention	Actions taken	Actions required
					In the past 12 months	In the next 12 months
1f Sodicity						
22 An assessment of the risk of sodicity has been undertaken						
23 Based on the result of the risk assessment, are further actions required?						
24 If so, what actions are needed or have been undertaken?						
• Gypsum or lime applied (dependent on soil pH)						
• Soils not deep ripped						
• Surface drainage improved or raised beds used						
• Irrigation water slightly saline						
• Specialist advice sought						
25 The effectiveness of the actions is being monitored and recorded						

2 Water management	Yes	No	Not relevant	Needs attention	Actions taken	Actions required
					In the past 12 months	In the next 12 months
2a Irrigation efficiency						
26 An assessment of the irrigation efficiency has been undertaken						
27 Based on the result of the risk assessment, are further actions required?						
28 If so, what actions are needed or have been undertaken?						
• Property goal defined						
• Soil survey undertaken						
• Irrigation system suitable for property goal and is efficient way of applying water to crop						
• Water budget developed						
• Crop water requirements and water availability understood						
• Irrigation schedule developed						
- Soil moisture measurement/ assessment carried out						
• Strategies implemented to manage nutrient input and salinity						
29 The effectiveness of the actions is being monitored and recorded						

2 Water management	Yes	No	Not relevant	Needs attention	Actions taken	Actions required
					In the past 12 months	In the next 12 months
2b Water quality						
30 An assessment of irrigation water quality has been undertaken						
31 An assessment of the risk to downstream water quality has been undertaken						
32 Based on the result of the risk assessments, are further actions required?						
33 If so, what actions are needed or have been undertaken?						
• Irrigation water quality tested						
• Quality of water leaving property tested						
• Water quality tests take place at appropriate times						
• Watercourses are protected						
• Soil erosion is controlled						
• Fertilisers are appropriately stored						
• Nutrient application is appropriately managed						
• Environmental impact of fertiliser storage and application is minimised						
• Agricultural chemicals are appropriately stored						
• Agricultural chemicals are appropriately applied (spray drift and contamination of waterways are considered)						
• Fuels and oils are appropriately stored and transported (mobile fuel tanks)						
• Septic tanks and manure storage areas well away from watercourses						
34 The effectiveness of the actions is being monitored and recorded						

2 Water management	Yes	No	Not relevant	Needs attention	Actions taken	Actions required
					In the past 12 months	In the next 12 months
2c Managing wastewater						
35 An assessment of the risk of mismanaging wastewater has been undertaken						
36 Based on the result of the risk assessment, are further actions required?						
37 If so, what actions are needed or have been undertaken?						
• Drains and water storage facilities in place						
• Wastewater is recycled or re-used						
• Wastewater is treated						
38 The effectiveness of the actions is being monitored and recorded						

3 Chemical management	Yes	No	Not relevant	Needs attention	Actions taken	Actions required
					In the past 12 months	In the next 12 months
39 An assessment of the risk of misapplication, incorrect handling, storage, application and disposal of chemicals, surplus spray and chemical containers has been undertaken						
40 An assessment of the risk of spray drift has been undertaken						
41 Based on the result of the risk assessments, are further actions required?						
42 If so, what actions are needed or have been undertaken?						
• IPM strategies employed						
• Chemicals safely stored						
• Materials available to deal with chemical spillage						
• Chemicals used responsibly and by trained personnel						
• Mixing and washdown areas appropriate						
• Spraying when weather conditions are least likely to cause spray drift						
• Using appropriate drift minimisation strategies (e.g. large droplets, not spraying next to sensitive areas, boom kept low, modifying spray equipment)						
• Water supplies protected from chemical contamination						
• Appropriate disposal of empty chemical containers						
• Appropriate disposal of surplus chemicals, dip tank contents and washings						
• Appropriate disposal of old, de-registered or unwanted chemicals						
• Appropriate disposal of other chemical products (e.g. rodent baits) or contaminated goods						
• Fuels are safely stored away from watercourses						
43 The effectiveness of the actions is being monitored and recorded						

4 Nutrient management	Yes	No	Not relevant	Needs attention	Actions taken	Actions required
					In the past 12 months	In the next 12 months
4a Nutrient requirements						
44 An assessment of nutrient requirements has been undertaken						
45 Based on the result of the risk assessment, are further actions required?						
46 If so, what actions are needed or have been undertaken?						
• Nutrient requirements of crop understood						
• Soil, sap or leaf test undertaken						
• Test results assessed by a suitably qualified/competent person and appropriate recommendations made						
• Nutrient budget developed						
• Nutrients applied do not exceed crop needs (as indicated by soil, leaf and/or sap tests)						
• Fertilisers low in contaminants are used						
47 The effectiveness of the actions is being monitored and recorded						

4 Nutrient management	Yes	No	Not relevant	Needs attention	Actions taken	Actions required
					In the past 12 months	In the next 12 months
4b Nutrient application						
48 An assessment of potential nutrient losses to the environment (leaching, run-off, wind) has been undertaken						
49 Based on the result of the risk assessment, are further actions required?						
50 If so, what actions are needed or have been undertaken?						
• Type, rate and timing of application of fertiliser are appropriate						
- Nutrients that are most readily lost (N and K) are applied in small amounts often to match plant growth						
- Fertiliser applications are timed to match crop growth/need						
• Fertiliser placement appropriate						
- Fertilisers applied where crop can most easily use them						
• Fertiliser application equipment regularly calibrated and maintained						
• Fertilisers are safely stored, protected from direct sunlight and away from watercourses						
51 The effectiveness of the actions is being monitored and recorded						

5 Biodiversity	Yes	No	Not relevant	Needs attention	Actions taken	Actions required
					In the past 12 months	In the next 12 months
52 An assessment of risk to biodiversity has been undertaken.						
53 Based on the result of the risk assessment, are further actions required?						
54 If so, what actions are needed or have been undertaken?						
• Native vegetation on the property is identified						
• Native vegetation on surrounding properties is identified						
• Initial assessment of the importance of native flora and fauna on property and nearby undertaken						
• Biodiversity laws and regulations checked						
• Threats to native biodiversity identified						
• Strategies developed for managing ‘problem’ plants and native animals						
• Practical ways to manage native vegetation developed						
- habitats protected						
- habitats improved						
- habitats created						
• Soil biodiversity encouraged						
• Join forces with others						
55 The effectiveness of the actions is being monitored and recorded						

6 Waste management	Yes	No	Not relevant	Needs attention	Actions taken	Actions required
					In the past 12 months	in the next 12 months
56 An assessment of the opportunities to minimise waste has been undertaken.						
57 Based on the result of the risk assessment, are further actions required?						
58 If so, what actions are needed or have been undertaken?						
• Sources of waste identified and prioritised						
• Waste avoidance or minimisation strategies in place						
• Re-use, or recycling carried out wherever possible						
• Disposal methods appropriate for particular types of waste						
59 The effectiveness of the actions is being monitored and recorded						

7 Air management	Yes	No	Not relevant	Needs attention	Actions taken	Actions required
					In the past 12 months	In the next 12 months
7a Odour management						
60 An assessment of the risk of odour has been undertaken.						
61 Based on the result of the risk assessment, are further actions required?						
62 If so, what actions are needed or have been undertaken?						
• Composted manure used in preference to raw manure						
• Animal manure stored to minimise concern to neighbours/community/employees						
• Manure applied in a manner that minimises concern to neighbours/community/employees						
• Waste produce disposed of in a manner that minimises concern to neighbours/ community/employees						
63 The effectiveness of the actions is being monitored and recorded						

7 Air management	Yes	No	Not relevant	Needs attention	Actions taken	Actions required
					In the past 12 months	In the next 12 months
7b Dust management						
64 An assessment of the risk of dust has been undertaken.						
65 Based on the result of the risk assessment, are further actions required?						
66 If so, what actions are needed or have been undertaken?						
• Shelterbelts and windbreaks in place						
• Appropriate cultivation practices, minimising working soil to fine tilth in dry windy weather						
• Mulches applied to seedbeds						
• Traffic ways wetted down or sealed						
67 The effectiveness of the actions is being monitored and recorded						

7 Air management	Yes	No	Not relevant	Needs attention	Actions taken	Actions required
					In the past 12 months	In the next 12 months
7c Smoke management						
68 An assessment of the risk of smoke has been undertaken						
68 Based on the result of the risk assessment, are further actions required?						
70 If so, what actions are needed or have been undertaken?						
• Alternate disposal options explored for materials that create dark smoke						
• Materials burnt when smoke will cause minimal concern to neighbours/ community						
• Materials burnt in a manner that minimises smoke creation						
71 The effectiveness of the actions is being monitored and recorded						

7 Air management	Yes	No	Not relevant	Needs attention	Actions taken	Actions required
					In the past 12 months	In the next 12 months
7d Noise management						
72 An assessment of the risk of noise has been undertaken						
73 Based on the result of the risk assessment, are further actions required?						
74 If so, what actions are needed or have been undertaken?						
• Buffer zones established						
• Reducing noise from equipment (e.g. use electric motors, muffle equipment, sound proofing)						
• Minimising noise generation at times that causes concern to neighbours/ community						
75 The effectiveness of the actions is being monitored and recorded						

7 Air management	Yes	No	Not relevant	Needs attention	Actions taken	Actions required
					In the past 12 months	In the next 12 months
7e Greenhouse gases						
76 An assessment of the risk of greenhouse gas emissions has been undertaken						
77 Based on the result of the risk assessment, are further actions required?						
78 If so, what actions are needed or have been undertaken?						
• Reducing carbon dioxide emissions through more efficient energy use and, where possible, using non-fossil fuels						
• Where possible sourcing 'green power'						
• Reducing nitrous oxide emissions through efficient use of nitrogenous fertilisers						
• Reducing CFC emissions through maintenance of refrigeration equipment						
79 The effectiveness of the actions is being monitored and recorded						

8 Energy management	Yes	No	Not relevant	Needs attention	Actions taken	Actions required
					In the past 12 months	In the next 12 months
80 An assessment of the opportunities to minimise energy usage has been undertaken						
81 Based on the result of the risk assessment, are further actions required?						
82 If so, what actions are needed or have been undertaken?						
• Energy audit undertaken and action plan developed						
• Irrigation equipment appropriate for flow required and regularly maintained						
• Fuel usage monitored, LPG and natural gas used where possible						
• Energy-efficient lighting						
• Efficient coolroom design and equipment regularly maintained and calibrated						
• Where possible renewable resources used						
• Greenhouse gas emissions minimised						
83 The effectiveness of the actions is being monitored and recorded						

Process steps and inputs

Crop production – process flow

This diagram shows a flow of steps that may occur while growing crops in the ground, the inputs that could introduce an environmental impact and the areas in which processes may have an impact. In practice the steps do not follow a set order after planting and some steps are not required for all crops. For hydroponics, the nutrient solution and the root support medium are extra inputs. For nursery container production, pots and growing media are extra inputs.

Input	Process step	Activity can have impact on ...
Soil, fertilisers, soil additives, fumigants, herbicides, equipment	Site selection	Land and soil, water, nutrient, biodiversity
Growth substrate, hydroponic solution, equipment	Prepare a site	Land and soil, water, nutrient, biodiversity, air, waste, energy
Seeds, planting material, equipment	Planting	Land and soil, water, nutrient, biodiversity, air, waste, energy
Water, energy, growing additives	Irrigating	Land and soil, water, biodiversity, air, waste
Soil/foliar fertilisers, soil additives, water, equipment	Crop nutrition	Land and soil, water, nutrient, biodiversity, air
Insecticides, fungicides, water, equipment	Pest/disease management	Land and soil, water, biodiversity, air
Herbicides, equipment	Weed control	Land and soil, water, biodiversity, air
Equipment, materials	Pruning/training	Biodiversity
Chemicals, water, equipment	Crop/growth regulation	Land and soil, water, biodiversity, air
Chemicals, materials	Weather/vermin protection	Biodiversity, air
Picking containers, equipment, people	Harvest	Land and soil, water, biodiversity, air, waste, energy
Vehicle	Field packed (see separate flow chart) / Transport and shed packing (see separate flow chart)	Land and soil, water, air, waste, energy
Livestock, vehicle	Post-harvest site management	Land and soil, water

Field packing – process flow

This diagram shows a flow of steps that may occur during field packing of fresh produce and the inputs for each step that could introduce an environmental impact. Some steps are not required for all crops. For example, some crops are not washed before packing and others are not pre-cooled before dispatch.

Input	Process step	Activity can have impact on ...
Picking containers, equipment, people	Harvest (from previous flow chart)	Land and soil, water, biodiversity, air, waste, energy
Water, sanitiser, equipment	Washing	Land and soil, water, biodiversity, waste
People, equipment packaging, bulk bins	Grading and packing	Land and soil, water, biodiversity, air, waste, energy
Pallets	Palletising	Air, waste
Vehicle	Transport	Land and soil, water, air, waste, energy
Water and sanitiser (hydrocooling), equipment	Precooling/storage	Land and soil, water, biodiversity, air, waste, energy
Vehicle	Dispatch	Land and soil, water, biodiversity, air, waste, energy

Shed packing – process flow

This diagram shows a flow of steps that may occur during shed packing of fresh produce and the inputs for each step that could introduce a food safety hazard. The order and presence of steps varies with crops.

Input	Process step	Activity can have impact on ...
Water, people, equipment	Receive/unload	Land and soil, water, biodiversity
Bulk bins	Curing	Air, waste, energy
Water and sanitiser (hydrocooling), equipment	Precooling	Land and soil, water, air, waste, energy
People, water, surfactant, equipment	Destemming/dehanding/defuzzing/trimming	Land and soil, water, biodiversity, waste
Water, sanitiser, equipment	Washing	Land and soil, water, biodiversity, waste
Insecticide, fungicide, water, equipment	Chemical treatment	Land and soil, water, biodiversity, waste
Wax, equipment	Waxing	Land and soil, water, biodiversity
Equipment	Drying/polishing	Biodiversity, air, waste, energy
People, packaging, bulk bins, equipment	Grading and packing	Land and soil, water, biodiversity, air, waste, energy
Ice, equipment	Top-icing	Air, waste
Pallets	Palletising	Air, waste
Water and sanitiser (hydrocooling), equipment	Precooling/storage	Land and soil, water, biodiversity, air, waste, energy
Vehicle	Dispatch	Land and soil, water, biodiversity, air, waste, energy

Nursery container production – process flow

This diagram shows a flow of steps that may occur during production of containerised nursery plants and the inputs that could introduce an environmental hazard and the areas in which processes may have an impact. In practice, the steps do not follow a set order after planting and some steps are not required for all situations.

Input	Process step	Activity can have impact on ...
Growing media, soil, fertilisers, soil additives, equipment	Source growing media	Water, nutrient, biodiversity
Equipment, growth substrate, herbicides, fumigants	Prepare media	Water, biodiversity, air, waste, energy
Seeds, planting material, equipment	Planting	Water, biodiversity, air, waste, energy
Water	Irrigating	Water, biodiversity, air, waste
Soil/foliar fertiisers, soil additives, water, equipment	Crop nutrition	Water, nutrient, biodiversity, air
Insecticides, fungicides, water, equipment	Pest/disease management	Water, biodiversity, air
Herbicides, equipment	Weed control	Water, biodiversity, air
Herbicides, insecticides, fungicides, water, equipment	Crop/growth regulation	Water, biodiversity, air
Chemicals, fertiliser, water, equipment	Re-pot (if required)	Land and soil, water, biodiversity, air
Equipment, vehicle	Transport to dispatch area	Air, waste, energy
People, packaging equipment	Package	Waste, energy
Vehicle	Dispatch	Land and soil, water, biodiversity, air, waste, energy

Environmental impact identification table

Growing the crop

Step	Hazard (the thing that happened, the thing you do)	Environmental impact – on farm	Environmental impact – off farm
Select site	Soil erosion	Loss of topsoil and nutrients	Sedimentation of rivers/waterways Nutrients and agricultural chemicals entering rivers/waterways
	Removal or destruction of rare/endangered flora or fauna	Loss of biodiversity	Reduction of wildlife corridors
	Catchment management plan or other statutory requirements not considered/adhered to	Legislative penalties	Compromises catchment aims and objectives
	Horticultural production (monoculture)		Loss of biodiversity, reduction of wildlife corridors
	Unaware of existence of rare/endangered flora or fauna		Loss of biodiversity, reduction of wildlife corridors
	Detrimental impact on riparian zones, wetlands or other sensitive vegetation types	Soil erosion Reduction of water quality	Sedimentation of rivers/waterways Nutrients and agricultural chemicals entering rivers/waterways Loss of biodiversity, reduction of wildlife corridors
	Detrimental impact on water resource/environmental flows	Reduction of water availability and quality	Sedimentation of rivers/waterways Loss of aquatic habitat
	Inappropriate land use or clearing	Salinity Reduction of arable land Sodicity Reduction of arable land Soil erosion Waterlogging	Reduction of arable land Spread of saline land and water Effects on buildings Effects on native vegetation Reduction of arable land Sedimentation of rivers/waterways Nutrients and agricultural chemicals entering rivers/waterways Effects on native vegetation
Prepare site	Soil erosion	Loss of topsoil and nutrients	Sedimentation of rivers/waterways Nutrients and agricultural chemicals entering rivers/waterways
	Detrimental impact on soil structure, soil compaction	Degradation of soil quality Increased run-off	Sedimentation of rivers/waterways Increased run-off
	Oil or fuel spillage	Contamination of land Contamination of surface water and/or groundwater	Contamination of surface water and/or groundwater
	Inefficient or polluting equipment	Atmospheric pollution by greenhouse gases Contamination of land Contamination of surface water and/or groundwater Wasting resources	Atmospheric pollution by greenhouse gases Contamination of surface water and/or groundwater

Step	Hazard (the thing that happened, the thing you do)	Environmental impact – on farm	Environmental impact – off farm
Prepare site (cont.)	Nutrient leaching (inappropriate rate or type of fertiliser)	Contamination of surface water and/or groundwater Eutrophication of surface waters and algal blooms Soil contamination Soil acidification Adverse impact on flora and fauna	Contamination of surface water and/or groundwater Atmospheric pollution by greenhouse gases Eutrophication of surface waters and algal blooms Adverse impact on flora and fauna
	Pollution – inappropriate application of fertiliser to non-cropping areas (throwing into waterways, dams, remnant vegetation)	Contamination of surface water and/or groundwater Eutrophication of surface waters and algal blooms Soil contamination Soil acidification Adverse impact on flora and fauna	Contamination of surface water and/or groundwater Eutrophication of surface waters and algal blooms Adverse impact on flora and fauna
	Pollution – inappropriate storage of fertilisers	Contamination of surface water and/or groundwater Eutrophication of surface waters and algal blooms Soil contamination Adverse impact on flora and fauna	Contamination of surface water and/or groundwater Eutrophication of surface waters and algal blooms Adverse impact on flora and fauna Discomfort or inconvenience of local residents (odour)
	Pollution – inappropriate storage of agricultural chemicals	Contamination of surface water and/or groundwater Soil contamination Adverse impact on flora and fauna	Contamination of surface water and/or groundwater Adverse impact on flora and fauna
	Pollution – inappropriate disposal of agricultural chemicals, surplus agricultural chemicals and rinsates	Contamination of surface water and/or groundwater Soil contamination Adverse impact on flora and fauna	Contamination of surface water and/or groundwater Adverse impact on flora and fauna
	Pollution – inappropriate mixing site for agricultural chemicals	Contamination of surface water and/or groundwater Soil contamination Adverse impact on flora and fauna	Contamination of surface water and/or groundwater Adverse impact on flora and fauna
	Traffic – noise, dust, fumes	Adverse impact on flora and fauna Movement of contaminants (chemical, weed seed) by machinery	Inconvenience to local residents Adverse impact on flora and fauna
Prepare nursery potting media	Pollution – leaching of nutrients and other soluble pollutants Pollution– litter and other floating contaminants Pollution – dust, odour	Contamination of surface and/or groundwater Contamination of surface and/or groundwater Inconvenience to staff	Contamination of surface and/or groundwater Contamination of surface and/or groundwater Inconvenience to local residents
Planting	Soil erosion	Loss of topsoil and nutrients	Sedimentation of rivers/waterways Nutrients and agricultural chemicals entering rivers/waterways
	Detrimental impact on soil structure, soil compaction	Degradation of soil quality Increased run-off	Sedimentation of rivers/waterways Increased run-off
	Oil or fuel spillage	Contamination of land Contamination of surface water and/or groundwater	Contamination of surface water and/or groundwater

Step	Hazard (the thing that happened, the thing you do)	Environmental impact – on farm	Environmental impact – off farm
Planting (cont.)	Inefficient or polluting equipment	Atmospheric pollution by greenhouse gases Contamination of land Contamination of surface water and/or groundwater Wasting resources	Atmospheric pollution by greenhouse gases Contamination of surface water and/or groundwater
	Traffic – noise, dust, fumes	Adverse impact on flora and fauna Movement of contaminants (chemical, weed seed) by machinery	Inconvenience to local residents Adverse impact on flora and fauna
	Nutrient leaching (inappropriate rate or type of fertiliser)	Contamination of surface water and/or groundwater Eutrophication of surface waters and algal blooms Soil contamination Soil acidification Adverse impact on flora and fauna	Contamination of surface water and/or groundwater Atmospheric pollution by greenhouse gases Eutrophication of surface waters and algal blooms Adverse impact on flora and fauna
	Pollution - inappropriate application of fertiliser to non cropping areas (throwing into waterways, dams, remnant vegetation)	Contamination of surface water and/or groundwater Eutrophication of surface waters and algal blooms Soil contamination Soil acidification Adverse impact on flora and fauna	Contamination of surface water and/or groundwater Eutrophication of surface waters and algal blooms Adverse impact on flora and fauna
	Inefficient use of water resource	Rising water table Increasing soil salinity from rising water table Soil erosion (see above) Nutrient leaching (see above) Waterlogging Contamination of land and water from run-off of contaminated water (chemicals/nutrients) Adverse impact on flora and fauna (environmental flows, reduction of habitat in dams/lakes) Depletion of water table (water taken from bores) Reduction of water quality	Rising water table Increasing soil salinity from rising water table Soil erosion (see above) Nutrient leaching (see above) Contamination of land and water from run-off of contaminated water (chemicals/nutrients) Loss of aquatic habitat, adverse impact on flora and fauna (environmental flows, reduction of habitat in dams/lakes) Depletion of water table (water taken from bores) Reduction of water quality
	Energy inefficiency – irrigation equipment/timing of irrigation	Atmospheric pollution by greenhouse gases Wasting resources	Atmospheric pollution by greenhouse gases
	Pollution – leaching of nutrients	Contamination of surface water and/or groundwater Eutrophication of surface waters and algal blooms Soil contamination Adverse impact on flora and fauna	Contamination of surface water and/or groundwater Eutrophication of surface waters and algal blooms Adverse impact on flora and fauna

Step	Hazard (the thing that happened, the thing you do)	Environmental impact – on farm	Environmental impact – off farm
Planting (cont.)	Salinity/sodicity – inappropriate rate of irrigation or quality of irrigation water Selecting environmental weeds for nursery propagation and sale	Reduction of arable land Soil erosion Waterlogging	Reduction of arable land Spread of saline land and water Effects on buildings Effects on native flora and fauna Loss of biodiversity
Irrigating	Soil erosion	Loss of topsoil and nutrients	Sedimentation of rivers/waterways Nutrients and agricultural chemicals entering rivers/waterways
	Detrimental impact on soil structure, soil compaction	Degradation of soil quality Increased run-off	Sedimentation of rivers/waterways Increased run-off
	Oil or fuel spillage	Contamination of land Contamination of surface water and/or groundwater	Contamination of surface water and/or groundwater
	Inefficient or polluting equipment	Atmospheric pollution by greenhouse gases Contamination of land Contamination of surface water and/or groundwater Wasting resources	Atmospheric pollution by greenhouse gases Contamination of surface water and/or groundwater
	Traffic – noise, dust, fumes	Adverse impact on flora and fauna Movement of contaminants (chemical, weed seed) by machinery	Inconvenience to local residents Adverse impact on flora and fauna
	Inefficient use of water resource	Rising water table Increasing soil salinity from rising water table Soil erosion (see above) Nutrient leaching (see above) Waterlogging Contamination of land and water from run-off of contaminated water (chemicals/nutrients) Adverse impact on flora and fauna (environmental flows, reduction of habitat in dams/lakes) Depletion of water table (water taken from bores) or water from rivers and creeks Reduction of water quality	Rising water table Increasing soil salinity from rising water table Soil erosion (see above) Nutrient leaching (see above) Contamination of land and water from run-off of contaminated water (chemicals/nutrients) Loss of aquatic habitat, adverse impact on flora and fauna (environmental flows, reduction of habitat in dams/lakes) Depletion of water table (water taken from bores) or water from rivers and creeks (environmental flows) Reduction of water quality
	Energy inefficiency – irrigation equipment/timing of irrigation	Atmospheric pollution by greenhouse gases Wasting resources	Atmospheric pollution by greenhouse gases
	Pollution – leaching of nutrients	Contamination of surface water and/or groundwater Eutrophication of surface waters and algal blooms Soil contamination Adverse impact on flora and fauna	Contamination of surface water and/or groundwater Eutrophication of surface waters and algal blooms Adverse impact on flora and fauna

Step	Hazard (the thing that happened, the thing you do)	Environmental impact – on farm	Environmental impact – off farm
Irrigating (cont.)	Salinity / sodicity – inappropriate rate of irrigation or quality of irrigation water	Reduction of arable land Soil erosion Waterlogging	Reduction of arable land Spread of saline land and water Effects on buildings Effects on flora and fauna
Crop nutrition	Pollution – inappropriate storage of fertilisers	Contamination of surface water and/or groundwater Eutrophication of surface waters and algal blooms Soil contamination Adverse impact on flora and fauna	Contamination of surface water and/or groundwater Eutrophication of surface waters and algal blooms Adverse impact on flora and fauna
	Pollution - inappropriate application of fertiliser to non cropping areas (throwing into waterways, dams, remnant vegetation)	Contamination of surface water and/or groundwater Eutrophication of surface waters and algal blooms Soil contamination Soil acidification Adverse impact on flora and fauna	Contamination of surface water and/or groundwater Eutrophication of surface waters and algal blooms Adverse impact on flora and fauna
	Nutrient leaching (inappropriate rate or type of fertiliser)	Contamination of surface water and/or groundwater Eutrophication of surface waters and algal blooms Soil contamination Soil acidification Adverse impact on flora and fauna	Contamination of surface water and/or groundwater Atmospheric pollution by greenhouse gases Eutrophication of surface waters and algal blooms Adverse impact on flora and fauna
Pest/ disease/weed management	Pollution – inappropriate storage of agricultural chemicals	Contamination of surface water and/or groundwater Soil contamination Adverse impact on flora and fauna	Contamination of surface water and/or groundwater Adverse impact on flora and fauna
	Pollution – inappropriate disposal of used chemical containers	Contamination of surface water and/or groundwater Soil contamination Adverse impact on flora and fauna	Contamination of surface water and/or groundwater Adverse impact on flora and fauna Impacts on landfill capacity
	Pollution – inappropriate disposal of agricultural chemicals, surplus agricultural chemicals and rinsates	Contamination of surface water and/or groundwater Soil contamination Adverse impact on flora and fauna	Contamination of surface water and/or groundwater Adverse impact on flora and fauna
	Pollution – off target application of agricultural chemicals	Contamination of surface water and/or groundwater Soil contamination Adverse impact on flora and fauna Disruption of Integrated Pest Management strategies Adverse impact on other crops	Contamination of surface water and/or groundwater Adverse impact on flora and fauna

Step	Hazard (the thing that happened, the thing you do)	Environmental impact – on farm	Environmental impact – off farm
Pruning / training	Escapes/volunteer growth	Adverse impact on flora and fauna, invasion of native habitat Requirement for control measures to be implemented (chemical, mechanical etc)	Adverse impact on flora and fauna, invasion of native habitat Requirement for control measures to be implemented (chemical, mechanical etc)
Crop / growth regulation	Pollution – inappropriate storage of agricultural chemicals	Contamination of surface water and/or groundwater Soil contamination Adverse impact on flora and fauna	Contamination of surface water and/or groundwater Adverse impact on flora and fauna
	Pollution – inappropriate disposal of used chemical containers	Contamination of surface water and/or groundwater Soil contamination Adverse impact on flora and fauna	Contamination of surface water and/or groundwater Soil contamination Adverse impact on flora and fauna Impacts on landfill capacity
	Pollution – inappropriate disposal of agricultural chemicals, surplus agricultural chemicals and rinsates	Contamination of surface water and/or groundwater Soil contamination Adverse impact on flora and fauna	Contamination of surface water and/or groundwater Adverse impact on flora and fauna
	Pollution – off target application of agricultural chemicals	Contamination of surface water and/or groundwater Soil contamination Adverse impact on flora and fauna Adverse impact on other crops	Contamination of surface water and/or groundwater Adverse impact on flora and fauna
Weather/ vermin protection	Trapping fauna (in netting)	Adverse impact on flora and fauna	Adverse impact on flora and fauna
	Noise generation (scarers)	Disturbance to other fauna	Discomfort or inconvenience of local residents Disturbance to other fauna
	Change to visual landscape		Inconvenience to local residents
Harvest	Oil or fuel spillage	Contamination of land Contamination of surface water and/or groundwater	Contamination of surface water and/or groundwater
	Inefficient or polluting equipment	Atmospheric pollution by greenhouse gases Contamination of land Contamination of surface water and/or groundwater Wasting resources	Atmospheric pollution by greenhouse gases Contamination of surface water and/or groundwater
	Traffic – noise, dust, fumes	Adverse impact on flora and fauna Movement of contaminants (chemical, weed seed) by machinery	Inconvenience to local residents Adverse impact on flora and fauna
	Soil erosion	Loss of topsoil and nutrients	Sedimentation of rivers/waterways Nutrients and agricultural chemicals entering rivers/waterways
	Detrimental impact on soil structure, soil compaction	Degradation of soil quality Increased run-off	Sedimentation of rivers/waterways Increased run-off
	Escapes/volunteer growth	Adverse impact on flora and fauna, invasion of native habitat Requirement for control measures to be implemented (chemical, mechanical etc)	Adverse impact on flora and fauna, invasion of native habitat Requirement for control measures to be implemented (chemical, mechanical etc)

Step	Hazard (the thing that happened, the thing you do)	Environmental impact – on farm	Environmental impact – off farm
Transport to packing shed	Oil or fuel spillage	Contamination of land Contamination of surface water and/or groundwater	Contamination of surface water and/or groundwater
	Inefficient or polluting equipment	Atmospheric pollution by greenhouse gases Contamination of land Contamination of surface water and/or groundwater Wasting resources	Atmospheric pollution by greenhouse gases Contamination of surface water and/or groundwater
	Traffic – noise, dust, fumes	Adverse impact on flora and fauna Movement of contaminants (chemical, weed seed) by machinery	Inconvenience to local residents Adverse impact on flora and fauna
	Soil erosion	Loss of topsoil and nutrients	Sedimentation of rivers/waterways Nutrients and agricultural chemicals entering rivers/waterways
	Detrimental impact on soil structure, soil compaction	Degradation of soil quality Soil compaction Increased run-off	Sedimentation of rivers/waterways Increased run-off
Post-harvest site management	Use of livestock to remove crop residues (scavengers)	Soil compaction Degradation of soil quality Increased run-off Escapes/volunteer growth	Sedimentation of rivers/waterways Increased run-off Escapes/volunteer growth
	Weed transmission by scavengers	Requirement for control measures to be implemented (chemical, mechanical etc) Inefficient and polluting equipment	Requirement for control measures to be implemented (chemical, mechanical etc)

Based on 'Growing the crop' process flow – *Guidelines for on-farm food safety for farm produce process flow* (DAFF, 2004)

Field Packing

Step	Hazard	Environmental impact – on farm	Environmental impact – off farm
Washing	Soil erosion – inappropriate disposal of wash water	Loss of topsoil and nutrients	Sedimentation of rivers/waterways Nutrients and agricultural chemicals entering rivers/ waterways
	Pollution – inappropriate disposal of wash water, particularly if containing sanitisers/agricultural chemicals	Contamination of surface water and/or groundwater Soil contamination Adverse impact on flora and fauna	Contamination of surface water and/or groundwater Adverse impact on flora and fauna
Grading and packing	Pollution – inappropriate disposal of waste produce	Contamination of land, surface water and/or groundwater Adverse impact on flora and fauna	Contamination of surface water and/or groundwater Adverse impact on flora and fauna Discomfort or inconvenience of local residents
	Oil or fuel spillage	Contamination of land Contamination of surface water and/or groundwater	Contamination of surface water and/or groundwater
	Pollution – inappropriate disposal of unsatisfactory packaging		Rubbish in waterways Inconvenience to local residents Atmospheric pollution by greenhouse gases
	Noise	Adverse impact on/disturbance of fauna	Adverse impact on fauna Inconvenience to local residents
Palletising	Pollution – inappropriate disposal of unsatisfactory pallet wrap		Rubbish in waterways Inconvenience to local residents Atmospheric pollution by greenhouse gases
Transport	Oil or fuel spillage	Contamination of land Contamination of surface water and/or groundwater	Contamination of surface water and/or groundwater
	Inefficient or polluting equipment	Atmospheric pollution by greenhouse gases Contamination of land Contamination of surface water and/or groundwater Wasting resources	Atmospheric pollution by greenhouse gases Contamination of surface water and/or groundwater
	Traffic – noise, dust, fumes	Adverse impact on flora and fauna Movement of contaminants (chemical, weed seed) by machinery	Inconvenience to local residents Adverse impact on flora and fauna
	Soil erosion	Loss of topsoil and nutrients	Sedimentation of rivers/waterways Nutrients and agricultural chemicals entering rivers/ waterways
	Detrimental impact on soil structure, soil compaction	Degradation of soil quality Increased run-off	Sedimentation of rivers/waterways Increased run-off

Step	Hazard	Environmental impact – on farm	Environmental impact – off farm
Precooling / storage	Noise	Adverse impact on/disturbance of fauna	Inconvenience to local residents Adverse impact on fauna
	Pollution – use of electricity and coolants	Atmospheric pollution by greenhouse gases Wasting resources	Atmospheric pollution by greenhouse gases (CFC refrigerants)
	Pollution – coolant leakage	Contamination of land Contamination of surface water and/or groundwater	Contamination of surface water and/or groundwater
Dispatch	Oil or fuel spillage	Contamination of land Contamination of surface water and/or groundwater	Contamination of surface water and/or groundwater
	Inefficient or polluting equipment	Atmospheric pollution by greenhouse gases Contamination of land Contamination of surface water and/or groundwater Wasting resources	Atmospheric pollution by greenhouse gases Contamination of surface water and/or groundwater
	Traffic – noise, dust, fumes	Adverse impact on flora and fauna Movement of contaminants (chemical, weed seed) by machinery	Inconvenience to local residents Adverse impact on flora and fauna
	Soil erosion	Loss of topsoil and nutrients	Sedimentation of rivers/waterways Nutrients and agricultural chemicals entering rivers/ waterways
	Detrimental impact on soil structure, soil compaction	Degradation of soil quality Increased run-off	Sedimentation of rivers/waterways Increased run-off

Based on ‘Field Packing’ process flow – *Guidelines for on-farm food safety for farm produce* process flow (DAFF, 2004)

Shed packing

Step	Hazard	Environmental impact – on farm	Environmental impact – off farm
Receive/ unload	Soil erosion – inappropriate disposal of dump tank/wash water	Loss of topsoil and nutrients	Sedimentation of rivers/waterways Nutrients and agricultural chemicals entering rivers/waterways
	Pollution – inappropriate disposal of dump tank/wash water, particularly if containing sanitisers/ agricultural chemicals	Contamination of surface water and/or groundwater Soil contamination Adverse impact on flora and fauna	Contamination of surface water and/or groundwater Adverse impact on flora and fauna
	Pollution – inappropriate disposal of waste produce	Contamination of surface water and/or groundwater Adverse impact on flora and fauna	Contamination of surface water and/or groundwater Adverse impact on flora and fauna Discomfort or inconvenience of local residents
Curing	Inefficient or polluting equipment	Atmospheric pollution by greenhouse gases Wasting resources	Atmospheric pollution by greenhouse gases
	Noise	Adverse impact on/disturbance of fauna	Inconvenience to local residents Adverse impact on flora and fauna
Precooling	Noise	Adverse impact on/disturbance of fauna	Inconvenience to local residents Adverse impact on flora and fauna
	Pollution – use of electricity and coolants	Atmospheric pollution by greenhouse gases Wasting resources	Atmospheric pollution by greenhouse gases (CFC refrigerants)
	Pollution – coolant leakage	Contamination of land Contamination of surface water and/or groundwater	Contamination of surface water and/or groundwater
Destemming/ dehanding/ defuzzing /trimming	Pollution – inappropriate disposal of dump tank/wash water, particularly if containing surfactant/ sanitisers/agricultural chemicals	Contamination of surface water and/or groundwater Soil contamination Adverse impact on flora and fauna	Contamination of surface water and/or groundwater Adverse impact on flora and fauna
	Pollution – inappropriate disposal of waste produce	Contamination of surface water and/or groundwater Adverse impact on flora and fauna	Contamination of surface water and/or groundwater Adverse impact on flora and fauna Discomfort or inconvenience of local residents
Washing	Soil erosion – inappropriate disposal of wash water	Loss of topsoil and nutrients	Sedimentation of rivers/waterways Nutrients and agricultural chemicals entering rivers/waterways
	Pollution – inappropriate disposal of wash water, particularly if containing sanitisers/agricultural chemicals and/or organic matter	Contamination of surface water and/or groundwater Soil contamination Adverse impact on flora and fauna	Contamination of surface water and/or groundwater with chemicals and organic matter Adverse impact on flora and fauna
Chemical treatment	Pollution – inappropriate storage of post harvest chemicals	Contamination of surface water and/or groundwater Soil contamination Adverse impact on flora and fauna	Contamination of surface water and/or groundwater Adverse impact on flora and fauna

Step	Hazard	Environmental impact – on farm	Environmental impact – off farm
Chemical treatment (cont.)	Pollution – inappropriate disposal of used chemical containers	Contamination of surface water and/or groundwater Soil contamination Adverse impact on flora and fauna	Contamination of surface water and/or groundwater Adverse impact on flora and fauna Impacts on landfill capacity
	Pollution – inappropriate disposal of post harvest chemicals, surplus post harvest chemicals and rinsates	Contamination of surface water and/or groundwater Soil contamination Adverse impact on flora and fauna	Contamination of surface water and/or groundwater Adverse impact on flora and fauna
Waxing	Pollution – inappropriate disposal of waxes	Contamination of surface water and/or groundwater Soil contamination Adverse impact on flora and fauna	Contamination of surface water and/or groundwater Adverse impact on flora and fauna
Drying / polishing	Inefficient or polluting equipment	Atmospheric pollution by greenhouse gases Wasting resources	Atmospheric pollution by greenhouse gases
	Noise	Adverse impact on/disturbance of fauna	Inconvenience to local residents Adverse impact on ~~flora and~~ fauna
Grading and packing	Pollution – inappropriate disposal of waste produce	Contamination of surface water and/or groundwater Adverse impact on flora and fauna	Contamination of surface water and/or groundwater Adverse impact on flora and fauna Discomfort or inconvenience of local residents
	Pollution – inappropriate disposal of unsatisfactory packaging		Rubbish in waterways Inconvenience to local residents Atmospheric pollution by greenhouse gases
	Inefficient or polluting equipment	Atmospheric pollution by greenhouse gases Wasting resources	Atmospheric pollution by greenhouse gases
	Noise	Adverse impact on/disturbance of fauna	Inconvenience to local residents Adverse impact on ~~flora and~~ fauna
	Oil or fuel spillage	Contamination of land Contamination of surface water and/or groundwater	Contamination of surface water and/or groundwater
Top-icing	Inefficient or polluting equipment	Atmospheric pollution by greenhouse gases Wasting resources	Atmospheric pollution by greenhouse gases
Palletising	Pollution – inappropriate disposal of unsatisfactory pallet/product wrap		Rubbish in waterways Inconvenience to local residents Atmospheric pollution by greenhouse gases
Precooling/ storage	Noise	Adverse impact on/disturbance of fauna	Inconvenience to local residents Adverse impact on fauna
	Pollution – use of electricity and coolants	Atmospheric pollution by greenhouse gases Wasting resources	Atmospheric pollution by greenhouse gases (CFC refrigerants)
	Pollution - coolant leakage	Contamination of land Contamination of surface water and/or groundwater	Contamination of surface water and/or groundwater

Step	Hazard	Environmental impact – on farm	Environmental impact – off farm
Dispatch	Oil or fuel spillage	Contamination of land Contamination of surface water and/or groundwater	Contamination of surface water and/or groundwater
	Inefficient or polluting equipment	Atmospheric pollution by greenhouse gases Contamination of land Contamination of surface water and/or groundwater Wasting resources	Atmospheric pollution by greenhouse gases Contamination of surface water and/or groundwater
	Traffic – noise, dust, fumes	Adverse impact on flora and fauna Movement of contaminants (chemical, weed seed) by machinery	Inconvenience to local residents Adverse impact on flora and fauna
	Soil erosion	Loss of topsoil and nutrients	Sedimentation of rivers/waterways Nutrients and agricultural chemicals entering rivers/waterways
	Detrimental impact on soil structure, soil compaction	Degradation of soil quality Increased run-off	Sedimentation of rivers/waterways Increased run-off
General packing shed amenities	Pollution – inappropriate disposal of sewage	Contamination of land, surface water and groundwater Adverse impact on flora and fauna	Inconvenience to local residents Adverse impact on flora and faun
	Pollution – use of electricity	Atmospheric pollution by greenhouse gases Wasting resources	Atmospheric pollution by greenhouse gases Inconvenience to local residents (lighting at night)
	Noise	Adverse impact on/disturbance of fauna	Inconvenience to local residents Adverse impact on fauna

Based on 'Shed Packing' process flow – *Guidelines for on-farm food safety for farm produce process flow* (DAFF, 2004)

Glossary

Acid sulphate soil –the common name given to soils containing iron sulphides.

Acidity – the strength (concentration of hydrogen [H+] ions) of an acidic substance; measured as pH. Acid substances have a pH of 1 – 7. The opposite of alkalinity.

Alkalinity – the strength (concentration of hydrogen [H+] ions) of an alkaline substance; measured as pH. Alkaline substances have a pH of 7– 14. The opposite of acidity.

Biodiversity – the variety of life on our planet, measurable as the variety within species, between species, and the variety of ecosystems.

Bund – an embankment, wall or other structure designed to trap or contain liquids.

Climate change – this term is commonly used interchangeably with 'global warming' and 'the greenhouse effect' but is a more descriptive term. Climate change refers to the buildup of man-made gases in the atmosphere that trap the sun's heat, causing changes in weather patterns on a global scale. The effects include changes in rainfall patterns, sea level rise, potential droughts, habitat loss, and heat stress.

Constructed wetland – conversion of an area into a wetland by building dikes, small dams and/or shaping land to provide an appropriate water regime for hydrophytic vegetation.

Crop coefficient (Kc) – the proportion of water used by individual crops compared to the water that is used by a reference crop. The reference crop is a green, uniform, actively-growing crop such as grass or lucerne.

Environmental flow – water provisions needed to sustain the ecological values of our water resources.

Eutrophication – the enrichment of water by nitrogen or phosphorus, causing algae and higher forms of plant life to grow too fast which disturbs the balance of organisms present in water and the quality of the water concerned.

Evapotranspiration (ETo) – refers to the total loss of water from a green, uniform, actively growing reference crop such as grass or lucerne. ETo is calculated from wind speed, solar radiation, humidity and temperature.

Field capacity – refers to the soil water content after rainfall or irrigation at the point where drainage stops.

Fertigation – the application of nutrients through irrigation systems.

Greenhouse gases – gases that trap the heat of the sun in the Earth's atmosphere, producing the greenhouse effect. The two major greenhouse gases are water vapor and carbon dioxide. Other greenhouse gases include methane, ozone, chlorofluorocarbons, and nitrous oxide.

Groundwater – water that infiltrates the soil and is stored in slowly flowing reservoirs (aquifers); used loosely to refer to any water beneath the land surface.

Leaching fraction – leaching is applying irrigation water in excess of soil moisture depletion level to remove salts in the root zone. The excess water, expressed as a percentage of the applied irrigation water, is the leaching fraction.

Natural Resource Management (NRM) – describes the management of our natural resources – land, soil, native vegetation, biodiversity, and water (both fresh and marine).

Nutrient – element or compound essential for animal and plant growth. Common nutrients in fertilizer include nitrogen, phosphorus and potassium.

Nutrient leaching – the process by which soluble nutirents in the soil are washed into a lower layer of soil or are dissolved and carried away by water.

Readily available water (RAW) – the amount of water in the soil that is readily available to the crop. This is between field capacity and a no stress situation.

Regulated deficit irrigation (RDI) – an irrigation strategy to manipulate vegetative growth, yield and quality with water stress.

Rhizosphere – the zone of soil surrounding a plant root where the biology and chemistry of the soil are influenced by the root.

Riparian land – any land that adjoins or directly influences a body of water and includes;

- land immediately alongside small creeks and rivers, including the river bank itself;
- gullies and dips which sometimes run with water;
- areas surrounding lakes; and
- wetlands and river floodplains which interact with the river in times of flood.

Salinity – a measure of how much salt there is in water or soil.

Sedimentation – the accumulation of earthy matter (soil and mineral particles) washed into a river or other water body, normally by erosion, which settles on the bottom.

Sodicity – a sodic soil has an exchangeable sodium percentage (ESP) of more than 6. This means that sodium comprises more than 6% of the total exchangeable cations in the soil.

Soil erosion – the wearing away of land surface by wind or water. Erosion occurs naturally from weather or run-off, but can be intensified by land-clearing practices related to farming, residential or industrial development, road building or timber cutting.

Substrate – any growing medium used in place of soil, for example potting mix.

Turbidity – a measure of water clarity or 'murkiness'. Soil particles in water increase the turbidity.

Water quality – a term used to describe the chemical, physical, and biological characteristics of water, usually in respect to its suitability for a particular purpose.

Water table – the level below which soil or rock is saturated with water.

Water use efficiency (WUE) – WUE is calculated by the amount of yield produced per megalitre (ML) of irrigation water applied. It can also be calculated by the production value in dollars per ML of irrigation water applied.

Wildlife corridors – is a link of wildlife habitat, generally native vegetation, which joins two or more larger areas of similar wildlife habitat.

Further resources

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