Best Management Practices

for

Residual Herbicides and Water Quality

Project Team:

D.J.Rattray, D.M.Freebairn and N.C.Gurner

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Grains Research & Development Corporation

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Residual Herbicides and Water Quality

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Good better best

Never let it rest

Until your good is better

And better best

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Qualifier

This best management practices document has been designed based on research carried out in southern Queensland and northern New South Wales. It does not propose to be exhaustive in the risk factors that it covers.
The authors welcome any constructive comments, and a more than pleased for people to use parts of this assessment as they see fit.

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About this manual

Agricultural chemicals are an important part of today's agriculture, providing us with tools to control weeds, insects and diseases that normally would reduce yields and threaten enterprise viability.

Increasingly, we are being asked as agricultural practitioners to account for our action, in particular any off-site impacts of agriculture.

This manual describes a range of approaches to reduce the risk of agricultural chemicals leaving farms. In some cases these practices will improve the efficacy of chemical application by reducing losses.

Management options discussed include those practices that influence landscape processing of water, sediment and chemicals, farming operations, and chemical availability and handling issues.

Environmental benefits, agronomic considerations, and production costs and benefits are discussed for each practice.

This document can be used in conjunction with the Pesticide in Catchments risk assessment approach (PIC), a reference document on herbicide behaviour in soils and the Howleaky? model. Howleaky? can be used to explore a range of herbicide, tillage and agronomic practices for any specified paddock or location.

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1 Managing landscape risk

1.1 Of set areas or buffer zones

Description: An area set aside in a paddock that provides a buffer to streams and waterways.
Purpose: 1. To provide the necessary distance from waterways that is required by label conditions when using some chemicals. 2. To provide a buffer in which spray drift can settle. 3. To provide an area to act as a filter at the paddock edge removing some sediments and pesticide.
Environmental benefits: Buffers provide an area in which spray drift can settle, protecting streams from directly from drift contamination by pesticides. The amount of protection provided to streams by buffers will vary depending on the amount of drift anticipated. The additional benefits of runoff passing through these buffer areas will be provided in three ways before water enters streams. These are deposition of suspended sediments, increased infiltration of runoff and filtering of pesticides through direct adsorption to plants and organic matter
Agronomic considerations: Minimal, but need to keep the area weed free as well as vegetated.
Things to consider: Offsets do not necessarily require that a grass buffer be grown. The offset area can include the normal crop but where spraying is not conducted. Maintenance of buffer zone areas will need to be factored into farm management.
Cost and Benefits
Initial set-up costs: If a grass strip is used as a buffer the initial costs of planting and establishment will vary depending on the choice of species and season.
Ongoing costs: Maintenance costs to keep the buffer in good order will be incurred; these costs may be offset somewhat by the opportunity to harvest of graze. The other on-going cost to consider is the lost area of production.
Yield effects: While it is not envisaged that including a buffer will reduce yield, the buffer area may harbour pests or beneficial insects that may impact crop performance.

1.2 Contour banks

Description: Installing contour banks on hill slopes to reduce erosion..

Purpose:

1. To provide protection from the risk of erosion due to cropping on high slopes.
2. To provide a controlled channel for runoff to be transported safely from paddocks.
3. To reduce runoff velocities by decreasing the slope the runoff travels along.

Environmental benefits: Reduced erosion protects and retains valuable topsoil. It protects downstream water bodies by promoting the deposition of soil in the contour. The transport of pesticides that are attached to sediments will be reduced through this process of deposition.

Agronomy: Farming on contoured land can be problematic where large banks are used which cannot easily be traversed with equipment. Banks that have lower slope batters are generally not constructed as high and therefore do not provide the same degree of protection from overtopping by runoff.

Things to consider: Banks need to be designed to suit the situation. The type of climate, the land slope and your preferred farming method would all dictate the final design of the contour banks.

Cost and Benefits

Initial set-up costs: Costs of installation will vary, although they may be considered to be relatively high.

Ongoing costs: Ongoing maintenance costs will be incurred to keep the banks in good operating condition. Over time contour banks will fill with sediment that will need to be re-distributed across the paddock.

Yield effects: Minor yield penalties will apply where contour banks are not farmed, therefore reducing the total area available for planting.

1.3 Grass waterways

Description: A natural or constructed channel that is usually broad and shallow, and permanently planted with vegetation..

Purpose:

1. To provide a stable and controlled pathway for runoff water.
2. To reduce the potential for gully erosion associated with runoff.
3. To absorb initial runoff. The first runoff event after spraying typically has the highest concentrations of the season. An area in which this water can infiltrate is very beneficial and will lead to reductions in off site losses of pesticides.

Environmental benefits: Positioned to receive concentrated flows of runoff water, a waterway reduces the water's erosive force and assists in the deposition of sediment. Excessive sedimentation should be avoided as this will quickly fill in a waterway, leading to increased instability. A stable outlet is required to prevent gully formation. The vegetative cover and shape of the waterway should be designed to prevent detachment of soil particles within the waterway area. Waterways are not designed to significantly reduce transport of sediments, rather to provide a safe or controlled pathway for runoff water.

Passing runoff water through a grassed waterway can result in pesticides that are soluble being adsorbed to plant and other organic material reducing the concentration downstream.

Agronomic considerations: Waterways need to be managed so as not to become a seed bank for weeds.

Things to consider Usefulness of waterways as a filter may be limited on steep slopes where velocity of runoff water exceed permissible levels or on very flat slopes where potential for sedimentation is excessive.

Grassed waterways may be used for limited grazing or harvesting for hay production.

Cost and Benefits

Initial set-up costs: Initial investment may include the cost of permanent fencing.

Ongoing costs: Maintenance costs can be minimised by controlling soil erosion from the contributing area, maintaining vegetative cover, and repairing any weak spots should they appear. Waterways will also take some cropping land out of production, which may be offset by harvesting for hay production and limited grazing

Yield effects: Overall crop production may be reduced to the extent that cropland is taken out of production, this can be partially offset by potential for harvesting and grazing

1.4 Vegetative barriers

Description: A strip of grass or other vegetation designed to increase the deposition of sediment and adsorb pesticides from runoff water.

Purpose:

1. To provide a barrier through which runoff passes that can reduce the load of sediments and pesticides in runoff water.
2. The three main actions are: infiltration of runoff water to assist in reducing soluble pesticides, deposition of sediment due to reduce runoff velocities reducing sediment bound pesticides and adsorption of pesticides to the vegetation and organic material directly.

Environmental benefits: Vegetative filter strips require a shallow, uniform sheet flow across the entire strip to be effective. A vigorous vegetative stand, usually grass such as vetiver, must be established in the filter strip area. Trees, or other deep-rooted plants, planted in filter strips can intercept subsurface flow. The primary mechanism for pollutant removal in vegetative filter strips is deposition. If the velocity of water in the filter strip area is sufficiently slowed, soil particles and associated pollutants will be deposited. Other mechanisms for pollutant removal include infiltration of the runoff water and associated pollutants into the filter strip area, adsorption of pollutants onto soil or organic matter, and absorption into vegetative material. Filter strips will be more effective in removing sediment and associated pollutants attached to soil particles than pollutants dissolved in runoff water.

Things to consider: Maintenance requirements for a vegetative filter strip include removal of any rills or small channels, controlled grazing or fencing to limit livestock accessibility, removal of sediment deposits, and management to maintain vigorous vegetative growth. Maintenance requirements will be reduced if erosion from above-slope areas is minimised

Cost and Benefits

Initial set-up costs: Initial costs will depend on the need for special construction to obtain shallow, uniform sheet flow. The cost of planting and establishment of vegetation will vary according to the choice of species and the seasonal conditions during establishment. Additional costs may be involved with carting water if establishment is attempted during particularly dry periods.

Ongoing costs: These will be variable depending on maintenance needs and management. Maintenance costs will be lowered if soil erosion is controlled in the contributing area through reduced need to remove deposited sediment.

Yield effects: Overall crop production may be reduced to the extent that cropland is taken out of production, this can be partially offset by potential for harvesting and grazing

1.5 Sediment detention basins

Description: An earth embankment constructed across the slope of minor watercourses to form a detention basin to capture suspended sediment and the first flush of sediment and pesticides.

Purpose:

1. To trap and collect soil particles from runoff by slowing runoff velocity and allowing sediments to drop out of suspension.
2. To capture small runoff events which can have high levels of pesticides early in the runoff season
3. To provide a point of stabilisation for active gullies.

Environmental benefits: Sediments and pesticides adsorbed to sediments are deposited in the detention basin area. Gully erosion is reduced by providing an area to slow runoff flow rates and provide deposited material to fill in active gullies. Generally the first runoff event after application of chemicals will have the highest concentration of pesticides, capturing these events can provide an additional buffer to the downstream environment. In some cases where follow-up events flush this captured runoff through the basin, no net benefit may be achieved.

Things to consider: Waterways may need to be redesigned to accommodate the additional depth of flow generated due to backwater flow effects of detaining water in the waterway. These storages may provide additional water supplies. In some cases small farm dams may already be serving a detention basin function.

Be aware that using farm dams for capturing runoff from cropping paddocks may mean that the water is not suitable for consumption or recreation by humans due to contamination by pesticide residues.

Evidence suggests that the half life of some pesticides can be increased in water. As pesticides are often broken down by light and biological activity, broader shallower storages will be more effective than deeper storages in breaking down pesticides.

Cost and Benefits

Initial set-up costs: High initial investment required for construction of basins.

Ongoing costs: Annual maintenance costs will be incurred to clean out deposited material from the basin, the frequency and cost of this operation will vary depending on erosion control on contributing land.

Yield effects: In some situations, a significant detention basin could be used for supplementary irrigation.

1.6 Strip-cropping

Description: Farming with alternating strips of growing crops and fallows. These strips are oriented to be at right angles to flood. Contour strip cropping can be implemented on hill slopes while strip cropping is typically restricted to floodplains.

Purpose:

1. To reduce flood water velocity and erosion on low slopes.
2. To increase stored soil moisture due to slowing water velocity and increasing potential for infiltration.

Environmental benefits: Strip cropping controls erosion by reducing water velocity, and provides an opportunity for sediment deposition to occur. To control water erosion, crop strips should follow the contour of the land whenever possible. Reducing velocity reduces soil particle detachment and transport within the erosion-resistant crop area and promotes deposition of sediments and pesticides from the erosion-susceptible crop areas upstream.

Agronomic considerations: Strip cropping requires much greater attention to crop rotations to maintain standing cover on at least 30% of the land at any one time

Things to consider Special attention needs to be paid to make sure the widths of the strips correspond to erosion control requirements, planter capabilities, and combine specifications

Cost and Benefits

Initial set-up costs: A topographic survey is typically required before a strip cropping layout is designed.

Ongoing costs: Slightly increased costs due to reduced rotation flexibility.

Yield effects: Increased moisture conservation and reduced soil erosion may increase yields. Weeds and pest benefits may be achieved due to crop rotation.

2 Managing farm operations risk

2.1 Spray operator training

Description: Ensuring that operators have accredited training in chemical application.
Purpose(s): 1. To improve compliance with chemical label directions 2. To ensure that correct nozzle selections are made for each pesticide application. 3. To ensure that the correct rates of pesticides are applied through knowing how to correctly set up and calibrate the spray rig. 4. To ensure that operators are aware of the effects that weather has on the potential for spray drift.
Environmental benefits: When applying pesticides correctly applying the recommended rates will assist in controlling weeds while at the same time minimising application rates. By not "over applying" pesticides, risk of loss in runoff is reduced. Choosing the correct nozzles and conditions for spraying will reduce the risk of spray drift. Spray drift can travel significant distances before settling, potentially resulting in neighbouring paddocks suffering crop damage or pollution of water bodies.
Agronomic considerations: Higher operator skill will typically result in more effective control of weeds and pests.
Things to consider: Training should be considered a key element in any farm enterprise.
Further information: There area documents and training available to assist with understanding and conduction calibration. Eg ChemCert training in all states, "Ask GB" series of workshops. Contact details are: Agricultural Spraying Kare Pty Ltd, askgb@bigpond.com, Phone 07 4613 4220
Cost and Benefits
Initial set-up costs: Some equipment such as flow rate meters may need to be purchased; a minor cost component of a spray operation.
Ongoing costs: The purchasing of replacement components before they break down will pay for itself in the long term. Proper maintenance of mechanical equipment requiring small component replacement is usually offset by the cost saving of major component failure. If over applications due to poor calibration has been occurring there will be savings in getting correct rates applied.
Yield effects: Yield benefits will be achieved through more effective control of weeds.

2.2 Spray rig calibration and maintenance

Description: Calibration of spray equipment to ensure appropriate application rates and drop size.

Purpose(s):

1. To ensure the correct rates of pesticides are applied.
2. To reduce the risk of malfunctions during spraying operations. Breakdowns often mean that the spray rig operator comes into contact with concentrated forms chemical to undertake on-the-run repairs.
3. To reduce the risk of spray drift through proper nozzle selection, boom height and spray pressure.
4. Ensure that when suitable spray conditions are suitable that equipment is ready to go immediately.

Environmental benefits: Applying recommended rates will assist in controlling weeds while at the same time minimising application rates. By not over applying, the risk of chemicals being lost in runoff is reduced.

Under application due to incorrect calibration or loss due to spray drift or evaporation of the chemical should be avoided. Ultimately poor spray operations with unsuccessful weed kills may increase the risks of weed resistance to pesticides.

Agronomic considerations: Appropriate chemical application is contingent on good equipment being well maintained.

Things to consider: Nozzle and system monitors are available to assist in spray operation. These technologies do not eliminate the need to calibrate, check nozzle wear, and make decisions for nozzle type and pressure. Spray equipment have many components that need regular maintenance to ensure proper operation, including; the tank, agitation equipment, pumps, valves, line strainer, pressure gauges, hoses, booms, and nozzles. Calibration tests for boom sprays should include tests for nozzle uniformity, nozzle flow, and boom height. When undertaking calibrations, the operator will need to know the vehicle ground speed, nozzle spacing, nozzle flow rate, amount of pesticide to use, and amount of water to add.

Cost and Benefits

Initial set-up costs: Equipment such as flow rate meters may be required.

Ongoing costs: No extra cost beyond what is regarded as current best practice

Yield effects: Yield benefits will be achieved through more effective control of weeds.

2.3 Storage and handling

Description: Provision of adequate storage facilities for pesticides.

Purpose(s):

1. To minimise the risk of accidental spills or leakage of pesticides into the environment.
2. To reduce the risk of people accidentally coming into contact with chemicals.

Environmental benefits: Most agriculture chemicals are highly toxic to humans and the environment in their concentrated forms. Environmental or physical harm to people may occur in the event of a spill or leakage of chemicals during storage and handling. Ensuring that chemicals are correctly stored and handled reduces the risk of this happening.

Agronomic considerations: Minimal

Things to consider: When designing a storage facility, additional to the actual structure, a plan should be put in place to deal with an accidental spill. This includes having emergency numbers prominently displayed, having sawdust or sand to soak up the chemical and having suitable safety equipment on hand.

Further information: Workcover in both Queensland and New South Wales have excellent documents on storage and handling of chemicals for agricultural enterprises.

Web address http://www.workcover.nsw.gov.au/default.htm

Cost and Benefits

Initial set-up costs: If new storage facilities are required the cost of this may be relatively high. Modifications to existing facilities may provide a suitable alternative to meet the necessary standards.

Ongoing costs: Demonstrated lack of due diligence leaves and enterprise open to litigation.

Yield effects: Nil.

2.4 Mixing areas

Description: Provision of adequate mixing facilities for pesticides.
Purpose(s): 1. To minimise the risk of accidental spills or leakage of pesticides into the environment during mixing. 2. To reduce the risk of people accidentally coming into contact with pesticides.
Environmental benefits: Most agriculture chemicals are highly toxic to humans and the environment in their concentrated forms. Environmental or physical harm to people may occur in the event of a spill or leakage of chemicals during mixing. Ensuring that chemicals are mixed in an area that has bunding and that is not close to waterways, bore holes or housing.
Agronomic considerations: Nil
Things to consider: When designing a mixing facility things to consider would include the ability to contain a spill on site. To be able to effectively wash down and capturing the runoff. To have adequate clean water on hand for emergencies.
Further information: Workcover in both Queensland and New South Wales government have excellent documents on storage and handling of chemicals for agricultural enterprises. Web address http://www.workcover.nsw.gov.au/default.htm
Cost and Benefits
Initial set-up costs: Facilities need not be excessively expensive. A concrete pad with a sump for collecting the runoff from wash downs should suffice.
Ongoing costs: Demonstrated lack of due diligence leaves and enterprise open to litigation should a spill contaminate a waterway.
Yield effects: Nil.

3 Managing chemical availability and off paddock movement risk

3.1 Pesticide mode of action rotation

Description: Rotating pesticides with different modes of action for pest and weed control.
Purpose(s): To reduce the load of any particular chemical being exported from farms in runoff. Minimising the risk of weed or pest resistance to a particular mode of action chemical, last preserving the "market life" of important chemistry.
Environmental benefits: Over a number of seasons the risk of any one particular chemical being lost in runoff is reduced. Across a catchment this will equate to a reduced risk of high loads of any one chemical through a broader spectrum of chemistry. Reducing the risk of weed resistance will ensure all that low rates of chemical are required for effective weed in the longer term. In some cases, loss of use of a particular chemical group would require even more expensive chemistry, or the need for increased tillage and thus higher sediment loads.
Agronomic considerations: Herbicide diversity is an integral component of an integrated weed management program. Advice may be required to design a system whereby chemical and crop rotations can be developed.
Things to consider May require training in understanding chemicals not previously used.
Further information: A list of the range of modes of actions by the National Registration Authority (www.nra.gov.au). Contact you agronomist or chemical supplier for further advice.
Ongoing costs: This will vary depending on current chemical use patterns. Many farms will be using Atrazine and Glyphosate as primary weed control chemicals and the introduction of other chemicals with higher costs may be high. In the longer term this may be off set by better weed control and an ability to reduce application rates.
Yield effects: Efficacy varies between chemicals and chemical groups, but diversity is a key plank of herbicide resistance management.

3.2 Using less persistent or more strongly soil bound chemicals

Description: Choosing pesticides that have a short life in the environment and lower risk of being lost off farm in runoff.
Purpose(s): 1. To use chemicals which do not persist in the environment? 2. To use chemicals which have the ability to strongly bind to soil particles and other organic matter, to be used in conjunction with erosion reduction practices. 3. To reduce the risk of offsite contamination of receiving water bodies by using lower risk chemicals.
Environmental benefits: Environmental benefits are achieved when there is less chemical available in the soil, or if soil sorbed, should run off occur the chemical will be bound to the soil and thus not move off-site. Chemicals with short half lives only pose a risk for a short period and thus have a lower risk of transport.
Agronomic considerations: Farming system need to be able to operate with minimal use of residual herbicides, but the residual nature of some chemicals is what makes them valuable for weed control. When runoff is likely (wet soil, rainfall forecast), water soluble chemicals which are persistent are not recommended.
Things to consider: Choice of pesticides is currently based on paddock conditions, target weeds and cost. Choosing chemicals based on environmental reasons requires some compromises.
Cost and Benefits
Initial set-up costs: No set-up costs expected.
Ongoing costs: Residual herbicides such as Atrazine are relatively inexpensive compared to some contact herbicides. Therefore choosing other chemicals may have some costs, but this must be balanced with what is responsible industry behaviour.
Yield effects: Minimal.

3.3 Band spraying chemical

Description: Using a band of chemical over crop rows rather than whole paddock application.

Purpose(s):

1. To use residual herbicides “in row” and contact herbicides or tillage between rows
2. To reduce the risk of chemical export by reducing chemical inputs at the broad acre scale.

Environmental benefits: Banding of chemicals can reduce chemical export in line with the reduced broad acre application rate. i.e. a 50% band will reduce risk and chemical export by 50%.

Agronomic considerations: Band spraying may achieve significant reductions in chemical usage and reduce chemical costs, while maintaining the same concentration of chemical in the band. Alternative weed control strategies may be required for leave inter-row area such as cultivation or knock down herbicides is.

Things to consider Requires on-going monitoring of weeds in the non-sprayed area. Difficulties may be experienced with gaining access later in the season once crop is at its full height, this may require specialist spray rig such as a spray-coupe.

Further information: Local engineering companies will be able to supply costs of shields.

Agronomic advice should be sought.

Cost and Benefits

Initial set-up costs: Setting up for banding should be a low cost exercise, only requiring that nozzles over the inter-row area be shut off during spraying operations. If inter-row shield spraying is used in-crop for weed control, investment in shields will be required.

Ongoing costs\benefits: This can vary depending on the need for inter-row weed control. Chemical use reduction will be a saving, however further passes for cultivation or the need for other chemicals during the growing season may reduce these savings.

Yield effects: Negligible effects as long as inter-row weeds are controlled. If weeds are not controlled a yield penalty may result.

3.4 Chemical incorporation

Description: Application of residual herbicides such as Atrazine and Dual are incorporated to 5cm during a pre-plant or at planting application.

Purpose(s):

1. To incorporate herbicides into the soil profile to improve the efficacy.
2. To reduce the risk of runoff of residual herbicides through lower surface soil concentrations.

Environmental benefits: Herbicide concentrations in runoff are closely related to the amount of herbicide in the top couple of few centimetres of soil. Incorporation reduces this amount by mixing it deeper in the soil profile. Incorporation can reduce herbicide export from a paddock by 50%.

Agronomic considerations: Using this technique requires that the application of the herbicide must be done before or at planting.

Things to consider Incorporation is not suitable in zero-tillage systems, but may have a role for minimum tillage farming. Cultivation increases the risk of erosion and the export of sediments and nutrients to streams while chemical and incorporation reduces the risk of chemical movement. Clearly consideration of this practice needs to balance several risks.

Cost and Benefits

Initial set-up costs: No costs would be expected.

Ongoing costs: Ongoing cost of passing over the paddock at spraying with cultivation implements.

Yield effects: Minimal.

3.5 Timing of application of pesticides

Description: Chemical application is carried out with consideration for climatic and soil water conditions.
Purpose(s): 1. To reduce applications of pesticides that occurs when the risk of runoff is high. 2. To use less mobile pesticides when runoff risk is high.
Environmental benefits: By avoiding the use of chemicals during forecast wet periods or when the soil is wet or very wet, risk of chemical movement will be reduced. It may be difficult to anticipate the risk of runoff in the short term. However long term risk assessment shows that the period between October and February is the period when most of our runoff can be expected and poses the greatest risk. These the risk periods can be quickly assessed using tools such as Howleaky?
Agronomic considerations: Timing of applications may be difficult in some situations as other constraints of planting windows or weed pressure may dictate the spraying window. Application of residual chemicals before the summer storm period can often be accommodated, but attention to efficacy must be considered.
Things to consider: Alternative strategies for applications may need to develop before the season starts which account for the season expected. Seasonal climate forecasting may provide indications for the risk of the upcoming season.
Further information: Risk-assessment tools and seasonal forecast bulletins for your region.
Cost and Benefits
Initial set-up costs: No set up costs.
Ongoing costs: On-going costs may include the need to use more expensive methods of weed control later in the season, such as aerial applications.
Yield effects: There may be yield penalties for foregoing applications of pesticides or fertilisers at critical times.

3.6 Precision application techniques

Description: The use of application techniques that provide pest control and reduce pesticide usage rates. Various methods include using GPS guidance systems to reduce overlap, band spraying, spot spraying and weed mapping to target heavily infested areas.

Purpose(s):

1. To apply pesticides and fertilisers to only those areas of the paddock that requires treatment, using precision agriculture principles.
2. To reduce overlapping applications of pesticide, thereby reducing costs and environmental risks.
3. To reduce overall paddock application rates so that the export of pesticides off site is reduced.

Environmental benefits: Reduction in chemical exports can be achieved using new technology. For example, 'spot spraying' can reduce chemical application rates by 90%. GPS guidance technology can minimise machinery overlap, thus reducing total pesticide loads.

Agronomic considerations: Precision agriculture techniques (GPS guidance, remote sensing, yield mapping and weed mapping) all provided potential for reducing chemical loads, targeting inputs to where they are needed, and improving overall agronomic management..

Things to consider Spot spraying technology is available and precision agriculture is developing quickly.

Further information:

A good website that covers much of the technology of precision agriculture can be found at the Queenslands Department of Primary Industries web-site:
http://www2.dpi.qld.gov.au/fieldcrops/3165.html

Cost and Benefits

Initial set-up costs: Set-up cost may be high for spot spraying or GPS technology.

Ongoing costs: On-going costs should be reduced due to reduced chemical rates. May choose to use more expensive but more targeted herbicides.

Yield effects: implementation of a higher level of agronomic observation and skill typically should result in higher yields and returns.

3.7 Split application of herbicides

Description: Herbicides are applied twice at lower rates.
Purpose: 1. To reduce the concentration of pesticides on the soil at any one time, reducing potential for pesticide loss.
Environmental benefits: Apply one-half to two-thirds of a residual chemical prior to planting and one-third to one-half immediately following planting reduces the amount of chemical available at any one time. In addition, the early application is made at a time when runoff is less likely. This practice has the potential to reduce residual chemical losses by 25% compared to a typical one applications strategy.
Agronomic considerations: Weed control costs may be more effective with two applications are instead of one.
Things to consider Achieving suitable spraying conditions may become a challenge as there is a need to spray twice. This means there will be two periods of time when the risk of spray drift may occur.
Cost and Benefits
Initial set-up costs: No costs to set up as current equipment is utilised.
Ongoing costs: Costs associated with two passes of spray equipment.
Yield effects: No yield penalty expected.

3.8 Matching cropping frequency to water supply

Description: Monitoring soil moisture to facilitate planting crops based on soil water rather than a fixed rotation.
Purpose: 1. By optimising cropping frequency, maintain soil water at a lower level thus reducing runoff risk. 2. To improve the water use efficiency of the system by adapting cropping frequency to ambient conditions.
Environmental benefits: By ensuring a soil water deficit is maintained, risk of runoff and erosion is decreased. Pesticides are transported from paddocks in runoff and attached to sediments. By reducing the total amounts of both reduces the total load of pesticides transported.
Agronomic considerations: Opportunity cropping requires the cropping rotation to be flexible. Keeping to a fixed crop rotation is generally not recommended.
Things to consider Opportunity cropping requires that a high-level of agronomic skills, and attention to monitoring of system status (soil moisture, soil nitrate, weed and disease loads)
Cost and Benefits
Initial set-up costs: Minimal
Ongoing costs: Higher levels of management may require better monitoring systems and more agronomic advice
Yield effects: Opportunity cropping can result in more crops with lower individual yields, but high-performance of the cropping system.

3.9 No tillage and minimum tillage

Description: Farming systems in which tillage is reduced or eliminated, and crop residues are maintained on the soil surface throughout the year. Reduced-tillage systems aim to have a minimum of 30% residue cover, particularly in periods of high erosion risk.
Purpose: 1. To maximise conservation of soil water by protecting the soil from evaporation and promoting infiltration 2. To protect the soil from wind and water erosion 3. To improve water quality by reducing sediment loads through decreased erosion and slowing of runoff.
Environmental benefits: maintaining soil cover, either through crop residue or growing crops is critical for reducing runoff amount and velocity and soil erosion. Sediment loads and soil chemical concentrations can be reduced by 90%. Reduced-tillage systems allow some level of mechanical weed control; incorporation of pesticides and tillage for amelioration of soil compaction and surface roughness.
Agronomic considerations: In continuous cropping systems, reduced-tillage can increase incidence of certain diseases that live on crop residue. Attention to crop rotations is necessary to reduce risk of disease. Some weeds may be difficult to control in zero tillage situations.
Things to consider: Changing a tillage system typically requires a change in mindset as well as some of the logistics issues such as tillage, planting and spray equipment. A typical entry point is to try new practices in one or two paddocks initially.
Further information: Agronomic support is often required with any new system, particularly one is that are more dependent on herbicides for weed control
Cost and Benefits
Initial set-up costs: May require purchase or lease of high-residue tillage equipment. Existing equipment can often be used with low-cost modifications.
Ongoing costs: May require higher costs for weed control than in conventional tillage, but rising fuel and equipment costs are being balanced by slower rises in herbicide costs
Yield effects: Higher yields are possible due to increased moisture conservation. Where no crop rotation is practiced, diseases and weeds may decrease yields.

3.10 Control traffic farming

Description: Control traffic farming (CTF) is a system where the wheel widths of heavy machinery are matched, allowing the tyres to run on permanent tracks.

Purpose:

1. To reduce compaction in the root zone optimising conditions for water entry and root growth
2. To increase infiltration by increasing the size and number of soil pores, eliminating hard pans and improving water use efficiency.
3. To reduce input costs to elimination of implement overlaps.

Environmental benefits: Reducing compaction increases infiltration capacity of the soil and therefore reduces the risk of pesticide runoff. Removing plough layers from paddocks also reduces the risk of lateral flow movement. This lateral flow can contain high concentrations of soluble pesticides. If this lateral flow water reaches the surface at a break of slope this can pose a risk of leached chemicals re-emerging to become runoff.

In CTF systems wheeled areas should not be sprayed as these areas are most likely to generate runoff.

Agronomic considerations: Farming on permanent wheel tracks helps eliminate soil compaction. Paddocks can be considered to consist of two distinct areas, road beds and root beds. The road beds should not be cultivated or planted. With traditional traffic systems at least 50 percent of the surface will be run over by the tractor, implements and harvester wheels. With CTF the area trafficked can be reduced to 16 percent and root zone compaction caused by trafficking reduced. To achieve this, tractors, sprayers and harvesters need to run on the same permanent tracks.

Things to consider Many farmers adopting controlled traffic start by matching only the seeding and spray equipment. At harvest soil damage is small, providing conditions remain dry. Researchers indicate damage can be substantial when harvest conditions are wet. If high cover levels can be maintained, tillage direction is not a major consideration.

Further information: Several CTF conferences have been held over the last six years. Proceedings from loose conferences contain technical information and case studies.

Cost and Benefits

Initial set-up costs: Modifying or purchasing equipment so that wheel spacings are consistent can be a significant start-up cost.

Ongoing costs: Controlled traffic farming can reduce tractor power requirements significantly and inputs can be reduced through less overlap. Rapid adoption of CTF indicates positive financial outcomes.

Yield effects: Reduced compaction and better water relations all point to improved yields and economic performance.

4 Appendix 1. Feedback from growers on the potential applicability of practices outlined in this manual.

Marked practices (•) show the top 10.

Practice	Western Downs	Central Queensland
Off sets and buffer zones	•	•
Contour banks		
Grass waterways	•	•
Vegetative barriers	•	•
Sediment detention basins	•	
Strip-cropping	•	
Spay operator training		
Spray rig calibration and maintenance		
Storage, handling and disposal		•
Pesticide mode of action rotation		•
Using less persistent and/or sediment bound chemicals		
Band spraying chemical	•	•
Chemical incorporation	•	•
Timing of application of pesticides – Crop stage		•
Precision application techniques		
Split application of herbicides	•	
Opportunity cropping (dry profile)		•
No and minimum tillage	•	•
Control traffic farming		
Rotating crops and chemicals	•	•
Row spacing / population		•
Rate selection / additives		•
Record keeping		•

(Information from grower surveys conducted in Condamine and Emerald, 2004)