Australian Government

NSW GOVERNMENT

Managing berries in extreme wet weather

NSW PRIMARY INDUSTRIES MANAGEMENT GUIDE

Melinda Simpson

berries AUSTRALIA

www.dpi.nsw.gov.au

Job no. 17068, PUB24/547

Disclaimer

The information contained in this publication is based on knowledge and understanding at the time of writing (February 2025) and may not be accurate, current or complete. The State of New South Wales (including Department of Primary Industries and Regional Development), the author and the publisher take no responsibility, and will accept no liability for the accuracy, currency, reliability or correctness of any information included in the document, including material provided by third parties. Readers should make their own inquiries and rely on their own advice when making decisions related to material contained in this publication.

Although funding for this product has been provided by Australian and NSW government agencies, the material contained herein does not necessarily represent the views of either government.

The product trade names in this publication are supplied on the understanding that no preference between equivalent products is intended and the inclusion of a product name does not imply endorsement by the department over any equivalent product from another manufacturer.

Always read the label

Users of agricultural chemical products must always read the label and any permit before using the product, and strictly comply with the directions on the label and the conditions of any permit. Users are not absolved from any compliance with the directions on the label or the conditions of the permit by reason of any statement made or omitted to be made in this publication.

Image acknowledgements

Unless otherwise stated, the images in this guide have been sourced from NSW DPIRD.

Cover photo

A drone flying over blueberry plants as a storm builds in the distance. Photo: Melinda Simpson, NSW DPIRD.

How to cite

Simpson M (2025) *Managing berries in extreme wet weather*. NSW Department of Primary Industries and Regional Development, Orange.

Department of Primary Industries and Regional Development

Managing berries in extreme wet weather

Lead author: Melinda Simpson
Development Officer – Blueberries
Department of Primary Industries and Regional Development
T 02 6626 1350
M 0447 081 765
E melinda.simpson@dpi.nsw.gov.au

Contributing authors:
Kevin Quinlan
Gaius Leong
Saleh Adnan
Craig Maddox
Jay Anderson (Southern Cross University)

Contents

Introduction

This publication offers specialised guidance for berry farming operations in extreme wet weather. The guide includes a range of subjects regarding extreme wet weather, such as a plant's response to being water-stressed, how to prepare short and long-term for flooding and extreme wet weather, and what growers can do immediately and after substantial rainfall.

Understanding how wet weather will affect your farm

Landscape position

The type and extent of damage from extreme wet weather will be strongly influenced by the farm's position within the landscape. Generally, berry production will be on 3 main landscape types: plateaus, hillsides or floodplains (Figure 1).

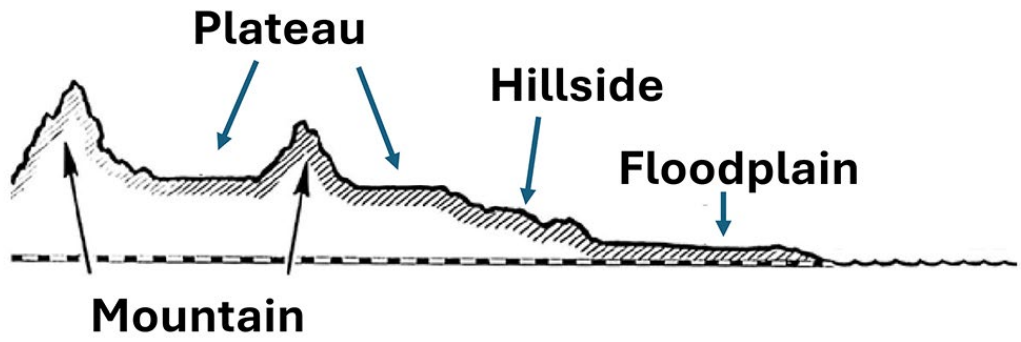


Figure 1. The 3 main landscape types for berry production (plateaus, hillsides or floodplains).

Plateaus

Plateaus are usually flat or gently sloping, with inundation temporary, unless the area is a localised depression. During heavy rainfall, soil loss occurs where there is little to no ground cover and water accumulates (Figure 2). Periods of prolonged wet weather will temporarily saturate the soil, causing plant stress and increased pest and disease risks from those favoured by prolonged wet conditions. Plant death can occur from extended wet weather; however, it is generally slow due to a gradual decline in tree health.

Figure 2. Water pooling under blueberries.

Hillsides

On hillsides, plants are less likely to become inundated but are more likely to be exposed to soil loss, washouts (Figure 3) and landslides. During prolonged wet weather, it is likely that damage will occur from diseases and insects that favour wet conditions. Issues with accessing blocks can also occur due to tracks being too slippery or eroded to drive on.

Figure 3. Washouts on a blueberry farm caused by intense rainfall.

Floodplains

Floodplains are generally flat or gently sloping, which allows water to spread during floods. The lack of elevation prevents rapid flow, reducing the potential for erosion and damage, but increasing the risk of intense flooding. The unpredictability and intensity of floods can cause significant damage to plants (Figure 4) and infrastructure (Figure 5). Careful planning and strategies are required to minimise losses. In these areas, plants might be submerged in water for long periods and significant plant loss can occur.

Figure 4. Submerged blueberries. Photo: North Carolina State University.

Figure 5. Damage from high intensity rainfall to raspberries.

Plant damage caused by extreme wet weather

During periods of extreme wet weather, plants can suffer from waterlogging and submergence. **Waterlogging** is where the soil is saturated and there is a lack of air within the soil, creating an anaerobic environment. **Submergence** is where the soil is saturated (waterlogged) and water is also covering the land; part or all of the plant can be covered by water.

The following factors will influence the extent of damage suffered by plants:

1. **Waterlogging or submergence**: the type of damage will depend on whether the plant suffers from waterlogging or submergence. Generally, waterlogging will affect the roots, while submergence can affect the whole plant.
2. **Water depth**: generally plants with a greater volume of canopy under water will suffer more damage.
3. **Length of inundation**: the longer the plant parts are inundated with water, the worse the damage will be.
4. **Water quality**:
    - Warm water is more damaging than cold water as it has less capacity to hold dissolved oxygen.
    - Stagnant water is more damaging than flowing water as it holds less oxygen.
    - Sediment-laden water decreases light penetration, affecting both plant and soil organisms. Sediment can cover plant leaves, affecting the plant's ability to photosynthesise and create more carbohydrates during and after flooding.
5. **Tree health**: the poorer a tree's health, the longer it will take to recover. This reduced health can be due to insufficient carbohydrate reserves, a lack of leaves and/or roots, and pest and disease incidence.
6. **Phenological stage**: trees are more vulnerable just after a flush of growth or after fruit set when carbohydrate levels are low.
7. **Cultivar differences**: some cultivars might be more resilient to waterlogging than others.
8. **Frequency of floods or droughts** and time since the last flood or drought.

What happens to soil and plants when the roots get waterlogged?

When soil and plant roots are waterlogged, oxygen deprivation occurs. This results in several key biochemical and physiological processes being affected (Figure 6).

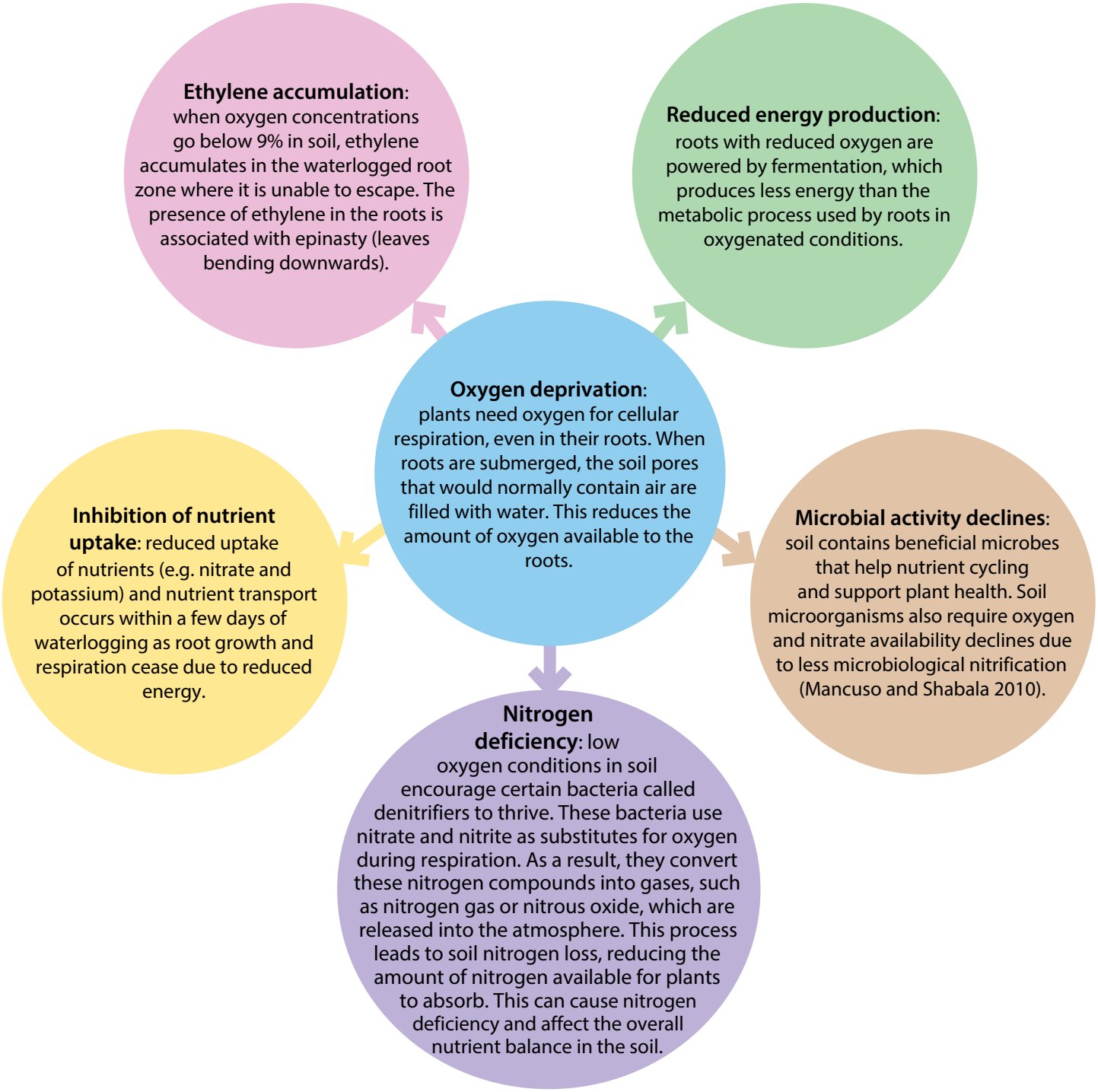


Figure 6. The biochemical and physiological processes affected by oxygen deprivation when soil and plant roots are waterlogged. Adapted from: Manghwar et al. (2024).

Preparation phase

Building a resilient farm

Site selection

Topography

Elevated and sloped land: a site at higher elevation with gentle slopes will facilitate natural drainage. Low-lying areas or depressions where water accumulates will be more prone to flooding.

Slope direction and waterlogging: north-facing slopes tend to dry out faster and are warmer due to longer sunlight exposure.

Soil characteristics

Soil drainage: select soil that is free draining such as sandy loam or loam. Avoid heavy clay that retains water and is prone to compaction.

Soil depth: ensure there is adequate topsoil to allow roots to grow without hitting a high water table. Shallow soil overlying rock or where a hardpan is close to the surface can be prone to waterlogging.

Access and infrastructure

Road access: setting up a site that ensures access roads to the site remain passable during extreme wet weather will help with continuing management and production while these adverse conditions persist.

Infrastructure: consider the availability of infrastructure to manage excess water such as drainage systems or retention ponds. Infrastructure such as sheds should be sited out of flood-prone areas where possible. On floodplains, identify the 1 in 100-year flood height and mound earth to be at least this height, preferably higher, and place any infrastructure on the mound created.

Identifying poorly drained soil

Poorly drained soil can be identified by:

- **Detailed elevation mapping**, such as those from light detection and ranging (i.e. lidar; Figure 7), can provide enormous potential in modelling drainage designs for setting up new blocks and reworking established blocks. Using lidar before planting can show the areas of main water flow to avoid or divert water away from.
- **Vegetation**, such as rushes or sedges, that grow in areas frequently inundated by water.
- **Soil surveys**: digging soil pits to identify soil conditions and potential limitations, especially in areas suspected of being problematic.

Implementing effective drainage

Whether establishing a block for the first time or re-establishing areas of a farm, implementing effective drainage is essential. Poor drainage causes soil erosion and waterlogging, which limit plant productivity. Soil erosion removes resources from blocks, and waterlogging causes several physiological disorders and plant stress responses. Poorly drained soil increases the risk of diseases such as phytophthora root rot. At critical times, such as harvest or carrying out crop protection activities, poorly drained soil can limit access. It is best to avoid planting on poorly drained soil.

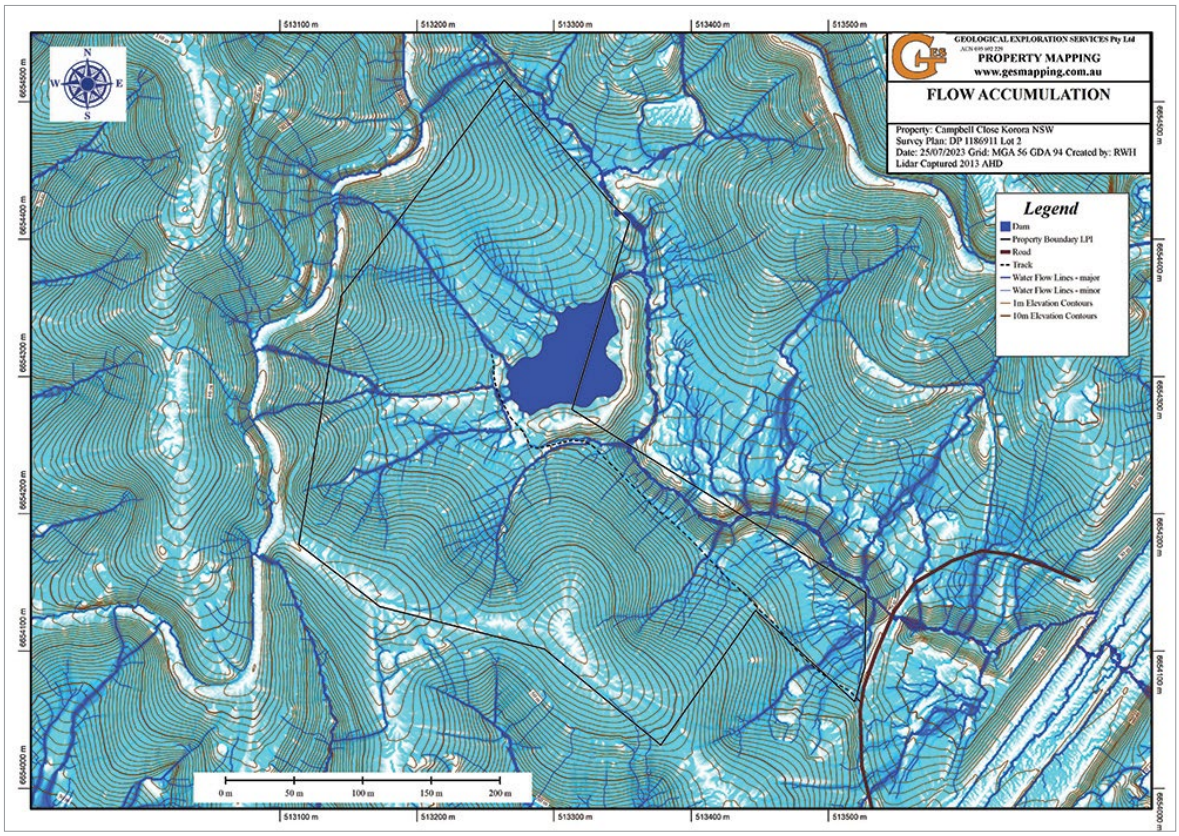


Figure 7. Lidar mapping showing drainage lines in a blueberry block. Photo: Bob Howard, GES Mapping.

Mounding

Mounding blueberries grown in the ground, particularly on flat land, ensures adequate drainage, which is essential for growth (Figure 8). This elevation helps prevent waterlogging, which can lead to root rot and other issues. Creating small mounds for pots to sit on when growing in substrate is also beneficial as it helps improve drainage and prevent waterlogging (Figure 9).

Figure 8. Mounded blueberries to prevent waterlogging.

Figure 9. Raspberries growing in substrate require a small mound to improve drainage.

Sub-surface drains

Sub-surface drains are trenches (Figure 10) with gravel and ag pipe at the base. They run sub-surface water away to create a more aerated soil environment. They are best installed before planting permanent crops. Sub-surface drains are used as part of a system to improve growing conditions. They will not completely resolve the site's limitations.

Before constructing sub-surface drains, it is important to test the soil for sodicity, as sodic soil tends to disperse when wet, potentially clogging drainage systems. This dispersion can reduce the effectiveness of the drainage and increase maintenance needs.

Sub-surface drains need to:

- be deep enough (usually >0.5 m deep) to create an adequate oxygenated root zone above them and not be disturbed by orchard operations.
- have risers at least every 100 m or less of drain run to help with clean-out.
- run water to a stable discharge point.

Figure 10. Installing a sub-surface drain.

Before embarking on any drainage work, always check if approvals are required for this work on your farm. For more information, refer to *Saving soil: a landholders guide to preventing and repairing soil erosion* (https://www.dpi.nsw.gov.au/__data/assets/pdf_file/0008/270881/saving-soil-complete.pdf).

Establish ground cover

Establish ground cover as soon as possible after creating mounds, especially on steeper slopes and next to the mound. Immediately after earthworks are completed, a quick-to-establish grass such as millet or ryegrass (depending on the time of year) should be sown. As this germinates, it will help prevent erosion, such as scouring down the edge of mounds (Figure 11). On most blueberry orchards with slopes greater than 10 degrees, growers will need to maintain permanent ground cover in the inter-row and on grassed waterways.

Figure 11. Scouring down the side of blueberry mounds after rainfall where ground cover was not established.

The best way to have permanent ground cover is to select plants that are well adapted to the climate, soil, and enterprise so they persist without much attention. Ground cover spread by runners is easy to establish and provides a secure hold, which resists erosion.

Grasses make better ground cover than most other plants as they have a fibrous root system and are cheap to establish and maintain. Perennial grasses are preferable as they provide year-round protection from soil erosion and last from season to season. Species such as kikuyu, couch and carpet grass make excellent ground cover as they establish well, spread easily and provide good ground contact.

Planting

Plants should be sourced from nurseries that follow strict hygiene procedures to ensure planting material is of a high standard and free from diseases such as phytophthora.

Before planting, inspect each plant for healthy leaves and filled-out roots. Be aware of plants with roots that have been in a pot or bag that was too small. Do not plant weak or diseased plants.

Variety selection

Choosing varieties suited to the landscape and climate is another way to reduce the effect of severe wet weather. For example, in high rainfall areas, choose blueberry varieties that are less susceptible to rust.

Make an emergency flood plan for your farm

Creating a farm that is resilient to floods and extreme weather helps growers return to a more productive, healthy orchard quickly. Preparing your farm should help to reduce some of the damage. Have a plan that has set points to trigger decisions. Having discussions early about what to do during a flood and extreme weather will help you make clear decisions in an emergency.

Some information to include in an emergency plan is:

1. An agreed meeting place for all people from the household.
2. An alternative place to stay including contact name, phone number and address.
3. Any current medications and where they are in case someone else needs to get them.
4. Phone numbers of support networks.
5. An important items list and a plan for where these items will go, i.e. if machinery needs to be moved somewhere else, has the location been identified and is permission granted.
6. If people have to be evacuated or equipment needs to be transported off the farm, make sure the evacuation plan includes the flood levels that cut access to roads and low-level bridges, and alternative access routes.
7. Emergency information such as Medicare number, tax file number, and driver's licence.
8. Account numbers and contact details of services such as electricity, water and phone.
9. Insurance details including the insurer, contact details and policy number.

Some essential things to have in your flood plan include:

- Have an adequate amount of non-perishable foods and ensure access to clean drinking water.
- If possible, make sure your insurance covers flood damage.
- Store important documents and photos in an emergency kit that is waterproof. Include a torch, batteries and first aid kit.
- Anchor fuel tanks and relocate waste, chemicals and poisons to high areas.
- Move equipment where possible e.g. tractors, farming equipment, and other vehicles.
- Remove pumps from waterways and relocate them to high ground.
- Store electrical tools in the highest possible places.
- Know the safest escape routes for when you need to leave.
- Plan for flash floods and/or slow-moving floods (depending on your location), as these are likely to require different responses.
- Make sure you have essential documents at hand such as an emergency contact list, legal documents and accounting records.
- If possible, clean and/or mow drains so that water can flow more easily.

Local Land Services has developed a *Farm flood readiness kit* that will help you get your property flood-ready (https://www.lls.nsw.gov.au/__data/assets/pdf_file/0007/798901/LLS-flood-readiness-091122-web-final.pdf).

Cleaning-up phase

During the clean-up phase, it is crucial to prioritise safety and emotional well-being. Ensure that flooded areas are only accessed when safe to do so and take time to be with family and friends. Here are some tips on looking after yourself and your friends.

Tips for looking after yourself and others

Doing things every day to take care of yourself is important. It will help you to deal with stress, make clear decisions and support loved ones. It is important to:

- maintain social networks and speak openly with friends and family about what you are feeling
- maintain routines with a good diet, exercise, quality sleep and sufficient rest
- have some down-time to remove yourself from the stresses of the farm
- focus on the things you can control
- seek information from reliable sources to ensure you are well-informed
- remember that challenging times will pass
- get help early; it can make a difference to how you feel in the long run.

If you are not feeling yourself, there are plenty of support services to help. Taking care of yourself is the first step in taking care of your family and your farm.

Telephone support

- NSW Mental Health Line, 1800 011 511
- Lifeline, 13 11 14
- MensLine Australia, 1300 78 99 78
- Rural Aid Counselling Line, 1300 175 594

Online counselling and information

- Rural Adversity Mental Health Program (https://www.ramhp.com.au/) informs, educates and connects people living and working in regional, rural and remote NSW to mental health support.
- Rural Aid (https://www.ruralaid.org.au/) offers free, confidential counselling to farmers and their families.
- Beyond Blue (https://www.beyondblue.org.au/) can help you chat to a counsellor, connect you with peers, and find mental health professionals in your area.

Assess and plan

- Assess the damage and record the evidence, i.e. take photographs as you assess the damage.
- There is an online form to report damage on the NSW Primary Industries natural disaster damage assessment (PiNDDA) webpage. If you are unable to submit this form yourself, call your local NSW DPIRD office (https://www.dpi.nsw.gov.au/contact-us/local-office), and someone will submit it on your behalf.
- Create a plan for how you are going to approach the clean-up.

Clean-up

- It is highly likely that flooded growing sites will have been contaminated by floodwaters that could contain sewerage, decaying vegetative waste, animal waste and dead animals; safety is paramount.
- People conducting clean-up activities in these areas should be equipped with personal protective equipment (PPE), i.e. long sleeves and long pants, sturdy boots, gloves, eye protection and dust masks.
- Where debris, waste, vegetative matter or rubbish are being collected, this should be segregated (if possible) to contain its decay/disease spread potential. It could be some time before all rubbish can be removed.
- After handling any contaminated soil, rubbish or water, wash your hands thoroughly with disinfectant soap and use a hand sanitiser.
  - Ensure thorough hand washing practices include full coverage of hands to wrists, underneath nails, and between fingers for 20–30 seconds, followed by effective drying until hands are completely dry.
  - Repeat this often, even if hands appear visibly clean.
- Mosquito activity can also increase in extreme wet weather, so a strong repellent product is recommended to help avoid contracting mosquito-borne viruses.
- Be aware of risks associated with rodents, snakes and spiders that might have taken refuge in unusual places.

Facilities, equipment and tools

- Businesses should also ensure thorough cleaning and disinfection/sanitation of all surfaces, equipment and tools that have been in contact with floodwater.
- Cleaning should start from the top down, rinsing all surfaces first to remove gross debris and soil, then cleaning with a food-grade detergent and hot water (where available), followed by applying a suitable sanitiser and leaving to air dry.
- All food contact surfaces should be cleaned with a food-grade detergent.
- For water tanks, chlorine is considered an effective disinfectant. The NSW Health website (https://www.health.nsw.gov.au/environment/water/Documents/chlorine-ready-reckoner-tables.pdf) has a fact sheet to help you calculate how much chlorine to use and how to apply it.
- All drains within facilities should be flushed to prevent re-contamination of cleaned areas.

Check agricultural chemicals

- In a flood, chemical containers, fertiliser and soil additives might be immersed, bags soaked, or products contaminated.
- Where labels and product identity are lost, or the chemicals are damaged beyond use, the chemicals should be separated and disposed of through ChemClear (https://www.chemclear.org.au/) or registered collection agencies.
- Empty drums should be carefully and appropriately emptied of any floodwater, segregated and disposed of through drumMUSTER (https://www.drummuster.org.au/).

Check fresh produce

Fresh berries that have come in contact with flood water are considered adulterated and cannot be sold for human or animal consumption. If the crop comes in proximity to, or is exposed to a lesser degree, a thorough risk assessment should be conducted involving factors such as the floodwater

hazards, type and stage of crop growth, degree and duration of crop exposure to floodwater and related conditions, and the likelihood for crops to absorb or internalise potential contaminants. The major hazards associated with floodwater are shown in Figure 12.

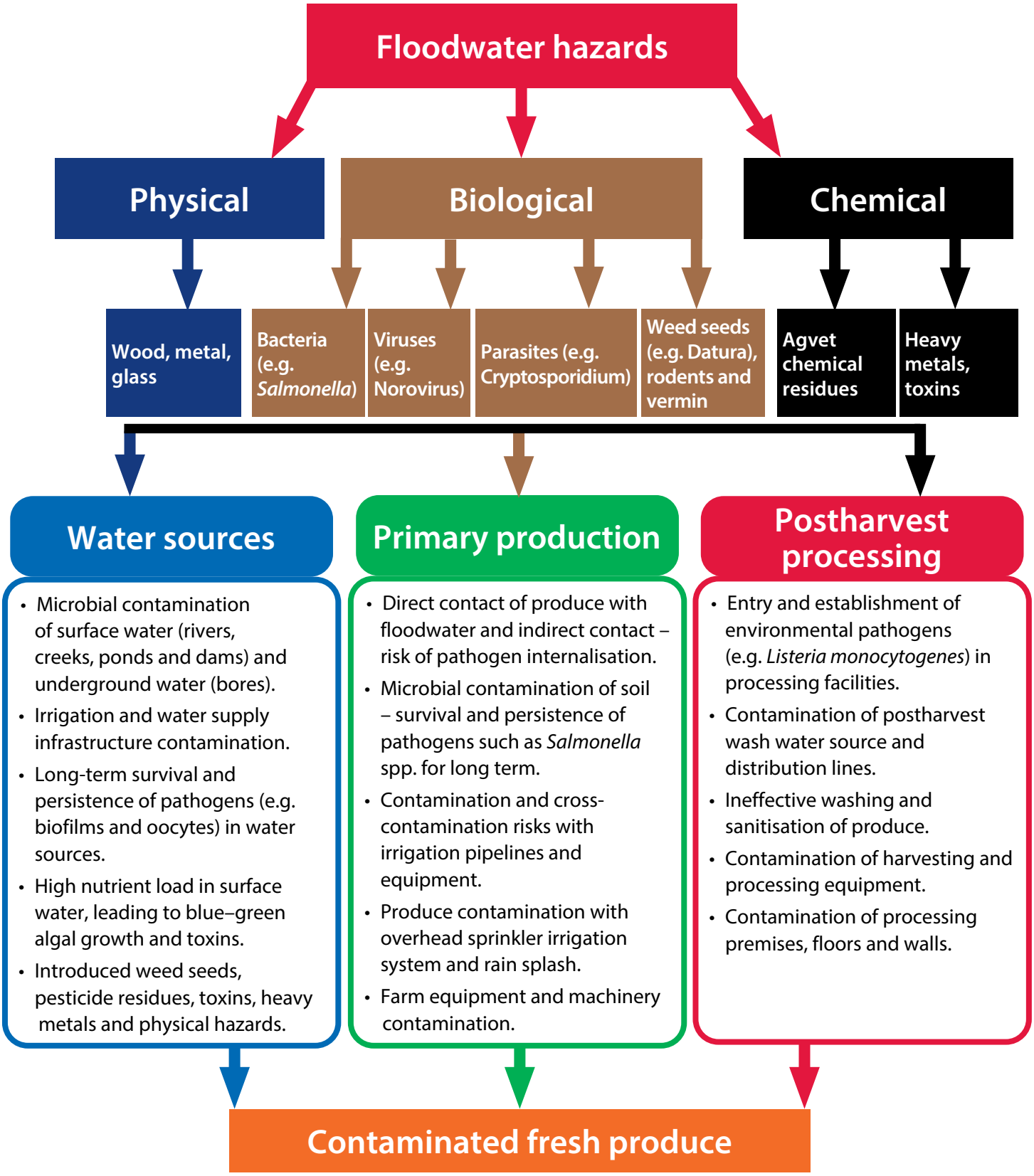


Figure 12. Floodwater as a source and route of microbial contamination in fresh horticultural produce adjacent to livestock, industrial and residential areas. Source: Singh (2023).

Microbiological testing of fresh produce for faecal indicators and foodborne microbial pathogens (e.g. *Salmonella*, *Listeria monocytogenes*) should be the objective and an integral part of food safety risk assessments. A NATA-accredited laboratory must be used for testing (https://nata.com.au/find-organisation/). For more details, refer to *Flooding adversely affects fresh produce safety* (https://www.publish.csiro.au/ma/MA23054).

Growing site

- When safe to do so, inspect the orchard/production field as soon as possible and mark (e.g. with coloured pegs) areas affected by poor drainage. If possible, immediately take steps to improve the drainage of these areas so the water can disperse, e.g. dig drains to let the water get away quickly or pump the water away. Flowing water will reduce the effect of anoxia (absence of oxygen) and draining flood levels quickly will reduce damage to roots.
- For perennial orchard production systems, a risk assessment for soil contamination from flooding is recommended. Foodborne pathogens such as *Salmonella* spp. can survive in the soil for months depending on soil type, moisture and climatic conditions.
- Enhancing hygiene practices during harvesting, processing, and transporting fresh produce, along with regular testing and monitoring of water sources used in preharvest and postharvest operations, are among the practical management options.
- Poor drainage is further exacerbated by wheel ruts created by tractors and implements operating on wet soil; this should be avoided.

Check water sources

The nature and location of the water source determine the influence of extreme wet weather on water quality and suitability for various purposes. Surface waters (e.g. rivers, creeks, ponds and dams), which are more exposed to the environment and run-off, are more susceptible to contamination after extremely wet weather. The following key factors should be considered while conducting risk assessments of water sources:

- Livestock activity on-farm and its surroundings, including the run-off direction and management.
- Upstream microbial contamination of water sources (e.g. rivers, creeks) due to the proximity of animal operations (e.g. pigs, poultry, cattle) and wildlife in the region.
- Other on-farm factors such as compost yards, manure storage areas, and septic tanks should be considered for their potential role in water contamination.
- All water source equipment and infrastructure that has been affected must be completely cleaned and disinfected before being used. This includes all irrigation lines, storage tanks, pumps, taps and other equipment.

Water sources should be sampled and tested to ensure their suitability for irrigation (*Escherichia coli* <100 cfu/100 mL) and cleaning and handwashing (*E. coli* <1 cfu/100 mL). Should irrigation water come in direct contact with fresh horticultural produce to be consumed raw, the quality of irrigation water, if used within 48 hours of harvest, should be the same as for postharvest cleaning and handwashing (*E. coli* <1 cfu/100mL). Any results outside these parameters indicate the water is unsuitable for use, and treatment or alternate sources must be used. Some examples of places that carry out this type of water testing include NSW DPIRD (https://www.dpi.nsw.gov.au/about-us/services/laboratory-services/water-quality) and Envirolab (https://www.envirolab.com.au/). For more details, refer to *Flooding adversely affects fresh produce safety* (https://www.publish.csiro.au/ma/MA23054).

High volumes of run-off water during wet weather can wash sediment into dams used for irrigation. This can cause:

- sedimentation in pipes, tanks, and other equipment
- clogging of spray nozzles and irrigation systems
- chlorination systems becoming ineffective
- reduced herbicide performance.

Coagulants and flocculants can be added to water to help particles clump together, forming larger particles that settle more easily. Alum, available in liquid or solid form, is one of the most common flocculating agents to clarify water. Ferric alum is also widely used, as the small amount of iron it contains increases the effectiveness of alum over a wider pH range.

Recovery phase

General advice

Prioritise blocks: it might be tempting to try and get to the worst blocks first, but consider prioritising the blocks that will require less effort and give a better return on investment.

Plants that have been fully submerged in flood water might have dying or dead leaves and potentially branches. Check branches by scraping back the bark; if it is green, it is still alive, but if it is brown, it has died. Remove dying or dead branches as they can become an entry point for disease organisms or a breeding ground for insect pests.

Diseases and pests

Many diseases are more active in wet, humid conditions. Where water is ponded or soil is waterlogged, the humidity will increase, adding to disease pressure. This should be factored in when considering disease control programs.

As part of the plan for disease control, implement a monitoring program that is based on identifying areas infected by pests and diseases, and have thresholds for control.

More information on crop monitoring tools can be found in *Monitoring tools for crop protection* (https://ausveg.com.au/biosecurity-agrichemical/crop-protection/monitoring-tools-crop-protection/).

Diseases likely to occur after prolonged wet weather or flooding

Anthracnose

Anthracnose affects blueberries and is caused by *Colletotrichum* species fungi, mainly *Colletotrichum simmondsii*. Anthracnose develops in moist conditions with temperatures between 20 °C and 27 °C. Spores are released during warm, wet weather and are spread by rain splashing onto blossoms and green berries.

Infection on fruit begins during flowering, but the fruit can appear symptom-free until berries ripen. The first symptom will usually be berry shrivelling, and then the characteristic sunken lesions will develop, particularly during warm, moist conditions. On ripe fruit, orange–pink spore masses form during humid conditions (Figure 13). Symptom development is often delayed until after harvest.

Regular pruning allows air circulation in the canopy and reduces drying time after the bushes have become wet. Removing all dead twigs, fruit and pruned material from blocks also helps reduce the disease level in the field. A biological fungicide containing a naturally occurring fungus, *Aureobasidium pullulans* (Botector®), is registered for the suppression of anthracnose in blueberries.

Figure 13. Orange spore masses characteristic of anthracnose. Photo: Carolyn Teasdale, ES Cropconsult (https://fieldguide.bcblueberry.com/anthracnose/).

Blueberry rust

The fungus *Pucciniastrum minimum* (syn. *Thekospora minima*) causes blueberry rust. Spores spread from old infections to infect new tissues. Infected leaves remaining on the plant after pruning can become an inoculum source for new infections. Young leaves are most susceptible to infection. Periods of leaf wetness (e.g. 7 hours at 21 °C) are required for infection.

Early blueberry rust signs will appear as small chlorotic (yellow) spots on upper leaf surfaces. As the disease develops, the spots become larger and turn dark red–brown (Figure 14), then merge and become necrotic. Yellow-orange pustules develop on the corresponding lower leaf surface (Figure 15).

Figure 14. Progressive blueberry rust symptoms.

Figure 15. Orange pustules on the underside of the leaf.

Cultural practices should be used to minimise conditions favourable for blueberry rust infection and spread, and to improve spray deposits on foliage. These practices include:

- Orientating rows in the direction of prevailing winds or northern facing slopes to encourage airflow and using appropriate planting densities to help minimise crowded canopies.
- Pruning to open the canopy will promote ventilation and reduce the time that leaves remain wet and conditions are favourable for rust infection. Opening the canopy can also improve fungicide contact and penetration.
- Preventing water from pooling in the orchard as this leads to high humidity, which can encourage blueberry rust infection. Ensure that wet and boggy areas are eliminated via better drainage.

Botrytis (grey mould)

Botrytis cinerea is a fungus that causes blossom blight during flowering and fruit rot during postharvest handling and storage. Infections occur in the field during flowering, so this is the most effective time to implement control. *Botrytis cinerea* is always present but causes serious losses when the weather is wet and cool for several consecutive days. Infection is favoured by high relative humidity, fog and long wet periods.

Blossoms are the most susceptible tissue, turning brown when infected (Figure 16) after only a few days of high relative humidity. In continued humid conditions, masses of grey mycelia and spores are produced on blighted blossoms.

Remove infected fruit (Figure 17) and plant material from the orchard, as each infected fruit with spores can infect more flowers and fruit. Blueberries should be pruned annually to keep the canopy open and improve air circulation. This will help the plant dry after it has become wet from dew or rain. Several biological and traditional fungicides are available for controlling botrytis in blueberries and Rubus. Never apply the same fungicide twice in a row and choose mixtures with different modes of action whenever possible.

Figure 16. Blueberry flowers infected by *Botrytis cinerea*.

Figure 17. Raspberry fruit infected by *Botrytis cinerea*.

Downy mildew

Downy mildew, caused by *Peronospora* spp. oomycetes, is mainly a problem in blackberries. It overwinters inside roots, crowns and canes. Downy mildew favours warm, humid areas and is most prevalent during wet weather with temperatures between 18 °C and 22 °C. Spores can be carried by insects, wind, rain, people, and equipment.

Figure 18. Symptoms of downy mildew on blackberry leaves. Photo: Paul Bachi, University of Kentucky Research and Education Centre.

Symptoms appear on the upper leaf surface with light green to yellow discolouration, progressing to red and purple (Figure 18). Lesions are usually angular and restricted by veins. On the underside of the leaf, light pink to tan areas will appear directly below the blotches on the upper surface. Spore masses are produced only on the lower leaf surface and are initially white but become light grey with age. Infected green fruit will redden prematurely and the berries will shrivel and harden.

Management includes using pathogen-free planting stock and ensuring good airflow through the canopy to promote quick leaf drying. Prune, train and thin out canes early to reduce humidity in the canopy. Remove and destroy old and infected pruning material to reduce inoculum build-up. Fungicides are available for controlling downy mildew in blackberries. Never apply the same fungicide twice in a row, and choose mixtures with different modes of action whenever possible. Refer to the APVMA PubCRIS database for registered controls (https://portal.apvma.gov.au/pubcris).

Phytophthora root rot

Phytophthora spp. cause phytophthora root rot in blackberries, raspberries, and blueberries. Moisture is required for disease reproduction and spread. Fine feeder roots are infected, compromising water and nutrient uptake. Phytophthora root rot develops when soil temperatures are higher than 12 °C, where there is poor drainage, water ponding, heavy soil types or low levels of organic matter.

Symptoms mostly occur during warm weather, often in plant clusters spread along drainage lines. In blackberries and raspberries, primocanes wilt and shoot tips dieback. Floricanes will have weak lateral shoots. Leaves wilt then become yellow or brown from the margins until the leaf dies. Roots will be discoloured (black to brown; Figure 19), and fine feeder roots will be missing. Affected plants are easily pulled from the soil. If cut open, the centre of the main root will be brown.

In blueberries, early symptoms are often above ground and include leaf yellowing and wilting, resembling drought or water stress (Figure 20). As the disease advances, stunting of terminal growth, leaf necrosis and plant dieback can occur. Below-ground symptoms include young rootlet and crown necrosis, with the main roots turning reddish–brown. Disease symptoms might follow drainage lines as the pathogen can be spread by water.

Management for phytophthora root rot includes:

- Sourcing new planting material from phytophthora-free nurseries.
- Prepare new sites by mounding and improving soil organic matter using cover crops and manure. Ammonia and volatile organic acids released by decomposing organic material reduce phytophthora spores and stimulate beneficial microorganisms. Incorporating gypsum into planting sites might help as it acts as a weak fungicide and reduces the number of spores in the soil.
- In heavy soil types or high rainfall areas, grow blueberries on mounds with good drainage in the inter-row. In high rainfall areas, blueberry mounds should run up and down the slope for quick drainage rather than across the contours.
- Avoid planting in poorly drained sites or improve the drainage before planting.
- Grow rooted cuttings or nursery plants on raised beds and avoid over-irrigating and ponding.
- Monitor irrigation to avoid over-watering and waterlogging.

Figure 19. Root symptoms of phytophthora root rot (brown roots on the right).

Figure 20. Foliar symptoms of phytophthora root rot. Photo: M Rocchetti, Costa Berries.

Insects likely to occur after prolonged wet weather or flooding

Monolepta australis (red-shouldered leaf beetle)

Red-shouldered leaf beetles are 6 mm long and yellow, with a dark red band across the shoulders (Figure 21 and 2 purple spots on the ends of their wing covers).

Adult beetles attack leaves, fruit and flowers. High populations will shred leaves and strip plants of flowers (Figure 22). Hatching occurs from grassed rows in spring through to autumn after rain. Infestations are likely after heavy rainfall (20–40 mm) in spring and summer.

Figure 21. Adult *Monolepta australis*.

Figure 22. Damage to blueberry flowers and young flush caused by *Monolepta australis*.

Effective control can be achieved if incursions are discovered early and are spot-sprayed before they disperse to the rest of the orchard. Check crops after heavy rainfall as populations greater than 20 beetles per square metre will cause significant damage. *Eucalyptus torelliana* is highly attractive to red-shouldered leaf beetle and is useful for early detection and control. Yellow sticky traps in boundary trees provide an early indication of beetle presence.

Blueberry stem girdler

Idiophantis habrias were reported to be causing damage in blueberries around Corindi, NSW, in 2015. After the extreme wet weather on the Mid-North Coast in 2022, this pest started to cause damage in other areas of the region.

The adult moths have brown forewings, each with a white area near the base, a dark triangle on the middle of the costa, and a network of yellow lines along the margin (Figure 23).

Figure 23. Adult *Idiophantis habrias*.

The first symptom of *Idiophantis habrias* damage in blueberries is discolouration of the bush and frass on the crown (Figure 24). Branches might also easily detach from the plant. This is because *Idiophantis habrias* ringbark the crown of the bush, producing callused tissue and killing off branches.

There are very few control methods available for this pest. An *Ichneumonid* wasp has been found to be a potential biological control.

Figure 24. Typical damage caused by *Idiophantis habrias* includes ring-barking and calluses at the crown of blueberry plants.

Re-establishing phase

Extreme wet weather and flooding can lead to significant changes in your farm. If you are re-establishing, it is the best time to undertake significant remediation work to prevent problem areas from becoming worse.

Some of the key issues associated with extreme wet weather and flooding to be aware of when re-establishing are:

- changes in soil structure and compacted soil
- soil erosion, nutrient loss and depletion
- soil pH imbalances
- reduced soil organic matter and microbial activity.

Assessing site suitability and mitigating limitations

If sections of your farm require replanting due to plant decline or death from submergence or waterlogging, keep in mind that some areas might be more suited to having the plants removed and the area used for another crop or purpose.

Before replanting, it is best to determine the limitations to the site, whether these can be overcome, and what is needed to correct them. While there are many factors to consider, some of the most common ones are drainage, erosion, soil health and nutrients.

Drainage

Lidar mapping uses pulse lasers to map topographic elevations. Lidar can pinpoint elevation changes and determine which areas are more prone to flooding. It can also help identify areas around blocks that require better drainage to protect them from flooding.

Drains should be constructed to carry water away on a suitable grade from the orchard. The best practice for creating surface drainage consists of laser-guided machinery or a survey with an optical level to establish an accurate grade in the surface drains.

Managing erosion and sediment

Intense rainfall can accelerate erosion, which contributes to soil degradation and water quality issues if left unmanaged. To respond to erosion caused by intense rainfall, you can:

- Construct flumes (Figure 25) to divert water away from slopes vulnerable to erosion and onto stable ground.
- Use coir logs, silt fencing, or hay bales to capture loose sediment from exposed slopes or paddocks or divert run-off away from areas of active erosion. Place silt fencing or coir logs across exposed slopes or drainage lines, or uphill of active erosion points. Secure these with stakes that are cut level with the coir log or hay bale to reduce the risk of flood debris being caught.
- Use gravel compacted and sealed on main roads to reduce erosion on the main tracks (Figure 26).
- Use mulch on bare ground or plant cover crops to provide temporary ground cover and prevent erosion. Avoid applying mulch too heavily on regenerating areas to enable natural regeneration.
- When laying jute (Figure 27) or coir mesh over exposed slopes, make sure to anchor the mesh down securely using timber pegs, metal staples or rocks. Make holes in the mesh for planting seedlings to increase vegetation cover and stabilise the slope.
- Steep slopes are particularly vulnerable to erosion. Hydro-mulching and aerial seeding are approaches to revegetate exposed slopes (Figure 28) quickly with minimal disturbance.

Figure 25. A concrete flume to divert water away from vulnerable slopes.

Figure 26. A compacted gravel driveway used to reduce erosion on the main track.

Figure 27. Jute mesh used to line a cross drain. Grass will grow through the mesh and break down afterwards. Photo: C Colmer, Soil Conservation Service.

Figure 28. Grassing slopes helps to reduce erosion in extreme wet weather.

Soil structure and nutrients

Healthy soil has a good structure with a crumbly texture and a good balance of air, water, and pore spaces. This allows water, nutrients, air, plant roots, and microorganisms to move through the soil freely. Soil organic matter additions can help improve soil structure, encourage healthy root development, promote microbial activity, and assist in preventing phytophthora. Soil organic matter can be incorporated into the soil before replanting, with compost, mulch and manure being common materials.

Soil chemistry can be affected by extreme wet weather, with mobile nutrients such as nitrogen, phosphorus and potassium being washed out of the profile. The soil's pH and structure can also be affected. Before replanting, conduct a soil test so that any issues can be corrected. For slow-moving amendments (e.g. gypsum or lime), adding these before replanting is advisable to allow incorporation into the soil profile before planting. If damage to the root system after prolonged waterlogging is suspected, it is better to apply small amounts of fertiliser often to avoid burning the roots and allow the root system to regrow.

For more information, refer to *Saving soil: a landholder's guide to preventing and repairing soil erosion* (https://www.dpi.nsw.gov.au/__data/assets/pdf_file/0008/270881/saving-soil-complete.pdf)

Tunnels

Installing a protective covering (Figure 29) is another option that can be used to manage long periods of wet weather. Most diseases rely on leaf wetness to germinate and spread. Having protective covers reduces leaf wetness and, in turn, generally reduces the damage caused by diseases such as blueberry rust and botrytis. It also means fruit can be picked in wet weather.

Figure 29. Blueberries grown under protected covers.

Available flooding assistance in NSW

Several assistance options are available in NSW for when you are affected by significant weather. Some of the most common are:

Local Land Services Flood recovery, https://www.lls.nsw.gov.au/floods/flood-recovery-resources

NSW Government Support to apply for grants, loans or payments, https://www.nsw.gov.au/emergency/recovery/support-to-apply-for-help

Rural Assistance Authority Storm and flood programs, https://www.raa.nsw.gov.au/disaster-assistance/storm-and-flood-programs

Resources

Anon (2017) Blueberry field guide: identification of pests, diseases and other disorders in blueberry fields, https://fieldguide.bcblueberry.com/blueberry-field-guide/

Alt S, Jenkins A and Lines-Kelly R (2009) *Saving soil: a landholder's guide to preventing and repairing soil erosion*, NSW Department of Primary Industries, https://www.dpi.nsw.gov.au/__data/assets/pdf_file/0008/270881/saving-soil-complete.pdf

Bright J (2020) *Considerations for developing and managing macadamia on floodplain soils*. Primefact 1656, NSW Department of Primary Industries, https://www.dpi.nsw.gov.au/__data/assets/pdf_file/0010/823744/Considerations-for-developing-and-managing-macadamia-on-floodplain-soils-second-edition.pdf

Bright J, Alt S, Howard B and Langfield K (2022) *Macadamia integrated orchard management drainage*. NSW Department of Primary Industries, https://www.dpi.nsw.gov.au/__data/assets/pdf_file/0005/731462/Macadamia-integrated-orchard-management-drainage-2022.pdf

Jones DR, Slabaugh WR (1998) Anthracnose and fungal scald. In: Ploetz RC, Zentmyer GA, Nishijima WT, Rohrbach KG, Ohr HD, editors. *Compendium of tropical fruit diseases*. Minnesota, USA: American Pathological Society Press, pp. 4–5.

Local Land Services (2022) Farm flood readiness kit, https://www.lls.nsw.gov.au/__data/assets/pdf_file/0007/798901/LLS-flood-readiness-091122-web-final.pdf

Mancuso S and Shabala S (eds) (2010) *Waterlogging signalling and tolerance in plants*. Heidelberg, Springer, 294 pp.

Manghwar H, Hussain A, Alam I, Khoso MA, Ali Q and Liu F (2024) Waterlogging stress in plants: unravelling the mechanisms and impacts on growth, development, and productivity. *Environmental and Experimental Botany*, p.105824, https://www.sciencedirect.com/science/article/pii/S0098847224001825#:~:text=Waterlogging%20can%20also%20affect%20root%20and%20plant%20growth%2C,gaseous%20exchange%2C%20which%20then%20degrades%20the%20plant%20hormones

NSW DPI (2023) *Managing drought, fire and flood*. NSW Department of Primary Industries, https://www.droughthub.nsw.gov.au/planning/managing-drought-resources

NSW DPIRD (n.d.) Primary industries natural disaster damage assessment (PiNDDA), https://www.dpi.nsw.gov.au/emergencies/emergency/community/primary-industries-natural-disaster-damage-survey

NSW Health (n.d.) Chlorine ready reckoner tables, https://www.health.nsw.gov.au/environment/water/Documents/chlorine-ready-reckoner-tables.pdf

Simpson M and Leong G (2023) *Berry plant protection guide*. NSW Department of Primary Industries, https://www.dpi.nsw.gov.au/__data/assets/pdf_file/0006/566349/Berry-plant-protection-guide-2023.pdf

Singh SP (2023) Flooding adversely affects fresh produce safety. *Microbiology Australia*, 44(4): 185–189, https://www.publish.csiro.au/MA/pdf/MA23054

Acknowledgements

This guide was funded under the Storm and Flood Industry Recovery program, jointly funded by the Australian and NSW governments.

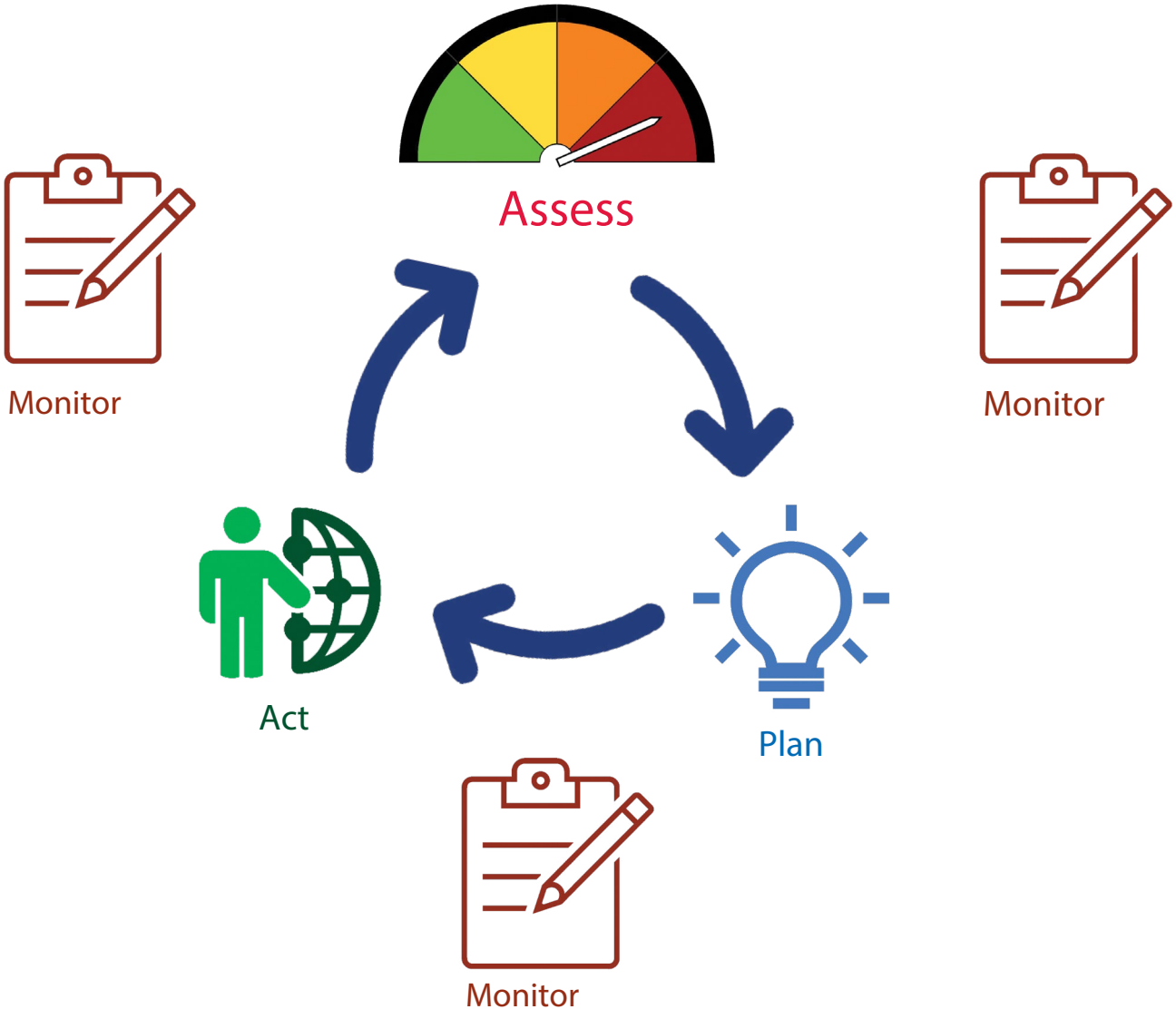
Notes

Notes

Australian Government

NSW GOVERNMENT

Managing berries in extreme wet weather



berries AUSTRALIA