Best Practice Sporting Fields

A guide for turf surfaces in the Lower Hunter

Book 3: Drainage

Cover Picture: Inundation on Macquarie Field due to surface water run-on from the surrounds.

Published by Hunter Water

36 Honeysuckle Dr, Newcastle West 2300, Australia

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ACKNOWLEDGEMENTS

These guidelines were developed as part of an EPA Waste Less Recycle More grant, with Hunter Water commissioning and co-funding the project. The guidelines describe the best practices needed to construct, amend and maintain open space turf areas within the Lower Hunter.

The authors wish to acknowledge the contributions to these guidelines from the reviewers as well as industry leaders and representatives such as:

- Graeme Logan (Head Curator at Bankwest Stadium)
- Chris Chapman (President, NSW Sports Turf Association)
- Matthew Plunkett (Turf NSW).

The guidelines have also been enhanced through the direct and indirect contributions of our colleagues in the sector, including many current and former Council staff.

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Brief biographies for authors and reviewers are contained in Appendix A of Book 1.

INTRODUCTION

There is an urban myth that all existing fields require drainage and automatic irrigation systems. This is untrue for the Lower Hunter as:

- there are many sporting fields with low levels of wear that perform well despite not having an automatic irrigation system
- about two thirds of fields drain within an acceptable timeframe, with most of these fields not having a slit drainage system. Waterlogging on many of the fields that drain slowly can often be overcome using techniques that do not require slit drainage (stopping run-on, amending the soil, etc).

The lifecycle cost to install irrigation and drainage in all the existing sporting fields in Lake Macquarie City Council for example would be around $33 million over 20 years and increase potable water use by 320 ML pa. Instead, best practice involves installing irrigation or drainage only at the sites where these works are needed to meet the playing surface benchmarks described in Table 3.1 (Book 1).

For greenfield (new) sites, a holistic and integrated approach involves consideration of soils, turf, irrigation and drainage to meet the playing surface benchmarks described in Table 3.1 of Book 1. This may entail the provision of irrigation and drainage infrastructure according to best practice to meet these benchmarks.

This book focusses on best practice elements for managing excess water and reducing waterlogging. It includes a discussion on slit drainage systems. Irrigation is covered in Book 4.

Figure P.1: Lydon Oval drains within an acceptable timeframe after rain and is often playable within best practice benchmarks despite not having a slit drainage system.

CHAPTER 7: WATERLOGGING ON LOWER HUNTER SPORTING FIELDS

Waterlogged sporting fields have too much water within the soil profile. When this occurs, turf growth is typically impeded due to low levels of oxygen in the rootzone. Councils will often close waterlogged fields to prevent the damage that occurs if they are trafficked when wet. The damage includes:

- increased wear damage to the turf
- compaction of the soil
- smearing or sealing of the soil surface due to migration of fine particles so the infiltration rate of the soil is reduced
- footprints or ruts in the surface if fields are trafficked when they are very wet (Figure 7.1).

If waterlogging occurs for prolonged periods, it can result in anoxic conditions developing in the soil. This makes healthy turf growth very difficult to achieve due to chemical toxins and imbalances in the soil.

Figure 7.1: Damaged caused by trafficking a field when it is waterlogged.

Occurrence of waterlogging

Major stadiums with sand profiles such as McDonald Jones Stadium (home of the Knights, Jets) often return to play within minutes following rain. However, the skills and maintenance budgets required for effective maintenance of these surfaces are beyond the realm of community facilities.

To comply with the best practice requirements, described in Book 1 (Table 3.1), community sporting fields should be playable within the following timeframes after significant (40mm) rain:

- 30 minutes for regional fields aiming for elite surfaces (e.g. Maitland No. 1)
- 3-6 hours for regional fields
- 6-12 hours for district level fields
- 12 to 24 hours for local fields.

In addition, these fields should not become waterlogged following small rainfall events, so most of the time rain has minimal impact on play. A survey of 256 playing fields in the Lower Hunter by Dr Mick Battam found 31% had significant waterlogging problems, with the remaining 177 fields draining within the best practice timeframe.

Common causes of waterlogging

Most of the waterlogging problems on the Lower Hunter sporting fields were caused by two or three contributing factors, with the most common being (Figure 7.2):

- surface water running onto the field from surrounding areas (run-on)
- an uneven surface, resulting in water ponding in depressions
- layering (particularly impermeable layers) within the soil profile.

Given this level of complexity and the expensive nature of on-field works to overcome waterlogging, it is recommended that independent advice be obtained. With soils playing a key role in contributing to waterlogging problems, it is recommended that advice be obtained from an independent expert with knowledge and industry certifications in soil science (Certified Professional Soil Scientist). The independence of the person(s) providing advice is crucial. For example, a sporting field in central Australia that receives 25mm of rain around 3 days a year had problems with turf cover, yet it was recommended that slit drainage be installed.

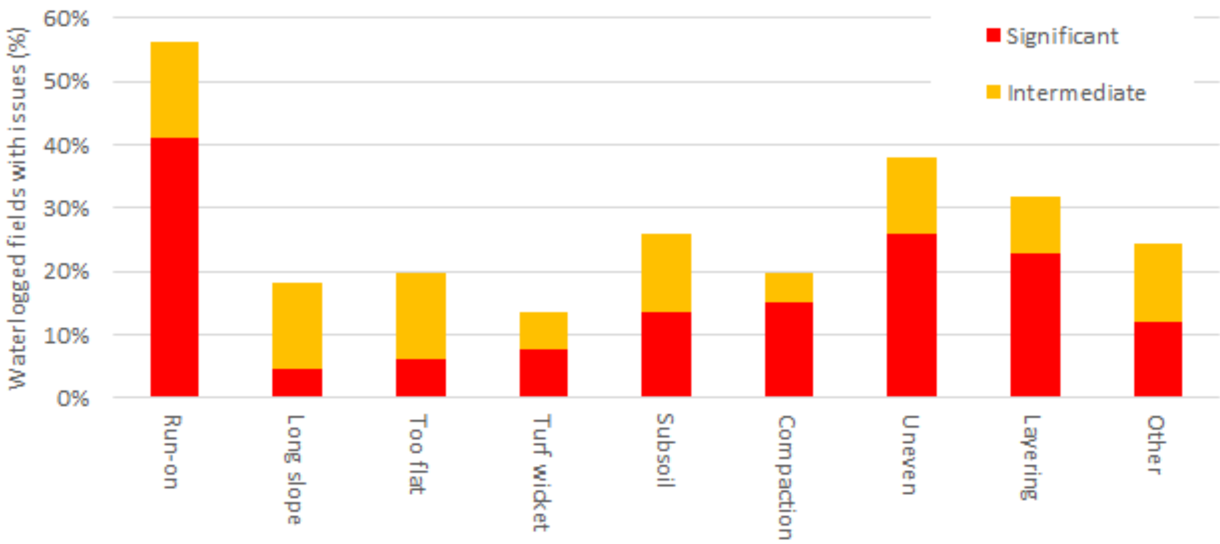

Figure 7.2: Causes of waterlogging on fields in the Lower Hunter where it is a significant problem, with most sites having multiple issues. Turf cricket wicket tables are constructed from clay and run-off from these areas can result in localised waterlogging in the surrounding areas. (AgEnviro Solutions 2020)

Figure 7.3: An example of a blocked drain leading to surface water running onto a field and a clay layer in a soil profile (clay from a turf roll).

CHAPTER 8: REMOVAL OF EXCESS WATER

Excess water can lie on the surface or on top of any layer in the soil that hinders the downward movement of water. Overcoming waterlogging problems involves using gravity to:

- prevent water from running onto the field
- ensure the field can shed surface water by having a suitable cross-fall and being free of depressions so water cannot lie in localised areas
- ensure the topsoil and subsoil are reasonably matched to prevent excess water collecting within the soil profile.

Each of these principles will be discussed in greater detailed below, with some of the common scenarios resulting in waterlogging in the Lower Hunter presented in Figure 8.1.

	**Scenario 1:** Water pooling in depressions. • more common on sites that are compacted, especially on flatter sites • filling these depressions with sand will not overcome the problem as it will pond on the relatively impermeable material beneath (see scenario 3)
	**Scenario 2**: Surface wet whilst soil below is dry • often caused by laying turf with clay attached or surface crusting • in sand profiles it can also be caused by ryegrass oversowing • minimal water enters the rootzone so the turf is often thin and wears out rapidly • rootzone often becomes water repellent
	**Senario 3:** Water pooling on impermeable subsoil • made worse if the topsoil is very sandy as more water enters the profile • in extended rain the water can fill to the surface so the field takes many days to dry • common on fields where the sub-base was heavily rolled

Figure 8.1: Common waterlogging scenarios observed in the Lower Hunter.

Prevent water running onto the field

No water from upslope areas should flow onto sporting fields, with surface water run-on contributing to waterlogging issues on more than half of the wet sporting fields in the Lower Hunter (Chapter 7, Figure 7.2). This includes run-on from:

- roads, carparks and other impermeable surface such as netball and tennis courts
- embankments and upslope landscape areas
- building roofs.

Instead, this water should be conveyed to stormwater or diverted around the field using structures such as gutters, concrete dish drains, contour mounds and swales. These structures must be appropriately sized and have adequate numbers of drainage pits, otherwise they will overflow, so the problem persists (Figure 8.2). A stormwater engineer may need to assist in sizing these structures if they capture run-off from large areas.

The design of swales and contour mounds may also require input from maintenance and asset management teams to ensure they can be maintained using existing equipment and resources. Swales or mounds that are too steep or too narrow cannot be readily maintained and may create additional problems.

Figure 8.2: Waterlogging on Hunter Barnett fields (upper) which is caused by a combination of run-on (lower left) and the thin clay layer attached to turf rolls, with the underlying soil relatively dry (lower right).

Drainage pits, gutters and dish drains must receive adequate maintenance, or they will become blocked over time (Chapter 7, Figure 7.3). This was observed on numerous fields in the Lower Hunter.

Facilitate surface water run-off from field

Unless constructed using a rapidly draining sand, surface water run-off is a primary means for removing excess water from sporting fields during storms. The amount of run-off that occurs and the time that it takes for water to be shed from the playing surface depends on factors such as:

- Slope angle (steeper slopes result in more water being removed as water moves faster under gravity)
- Slope length (shorter lengths means less time for water to travel across the playing surface)
- Soil infiltration rate (the lower the infiltration rate, the less water that infiltrates into the soil, with more water moving across the surface, rather than down into the profile).

To drain within an acceptable timeframe, sporting fields should generally be constructed with adequate cross fall and in a manner that minimises slope length and ensures water cannot pond in any location. Fields constructed with minimal cross fall are at greater risk of waterlogging. Reducing the cross fall from 1 in 100 to 1 in 200 increases the time taken for water to move across the field by 23%.

Best practice sporting fields should have a cross fall ranging from 1 in 70 (local fields) to 1 in 100 (elite fields). Major stadiums such as the SCG and ANZ Stadium have a cross-fall of 1 in 100 to assist field drainage (Graeme Logan, pers. comm). Best practice is to ensure the slope length for fields is minimised, and ideally less than 70 metres.

Examples of possible shapes for sports field surfaces are provided in Figure 8.3.

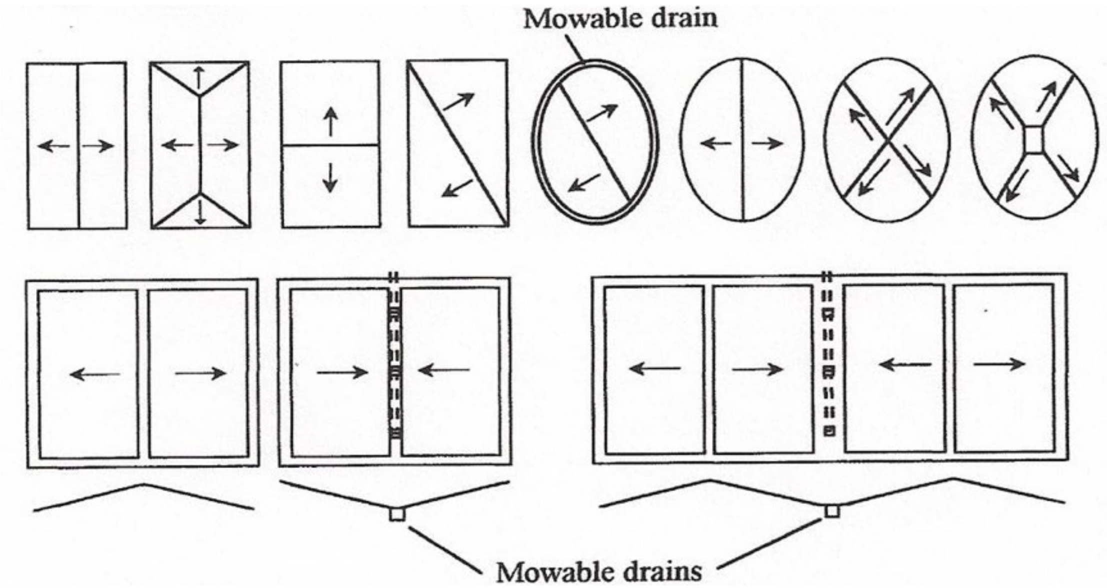

Figure 8.3 Possible shapes for sports field surfaces (from McIntyre 2004)[16].

Once the runoff water reaches the downslope edge of the field it must have somewhere to go. It should either be allowed to continue beyond the field boundary or be removed in appropriately sized drainage structures. As with any drainage structures, these will require maintenance to ensure blockages do not develop (Figure 7.3).

Ensure soil layers do not cause waterlogging

Any layer within the soil profile that can impede the downward movement of water has the potential to cause waterlogging problems. Layering within the soil profile contributes to waterlogging on about 32% of the wet fields within the Lower Hunter. Ideally the topsoil should be constructed so it is free from distinct layers, such as those associated with:

- turf underlays which are generally NOT suitable for the construction of sporting fields
- turf rolls, with the attached soil often having a clay texture
- topdressing, with the materials often used in the industry often very different to the underlying soil
- hardpans and seals that can develop due to aeration practices or trafficking surfaces when wet.

Some aeration methods can assist in breaking up layers within the soil profile, with the effects of individual aeration events generally small. Instead, more extensive works are often needed to address waterlogging associated with soil layering. Given the science involved, if soil layering is suspected as a cause of waterlogging problems, it is advisable to seek the professional recommendations of an independent Certified Professional Soil Scientist specialising in sports turf.

Figure 8.4: The soil profile on a site where turf patching of the same area is performed almost annually (upper). With all these layers, the water and roots struggle to penetrate into the profile. Amending the soil prior to patching resulted in these areas draining rapidly (lower).

Ensure the subsoil does not cause waterlogging

Water that enters the topsoil profile will move downwards under gravity and accumulate on top of the subsoil. If the subsoil is impermeable, under sustained wet conditions, the whole soil profile can become fully saturated and unable to drain. The subsoil is contributing to waterlogging issues on about 27% of the wet fields within the Lower Hunter.

To prevent this from occurring, excess water reaching the subsoil (from the topsoil) needs to be removed in an acceptable timeframe. This is best achieved during construction/reconstruction, when the subsoil must be shaped to have adequate cross-fall, and appropriately amended to facilitate downward water movement through the subsoil.

For existing fields that have been constructed without amending the subsoil it may be necessary to install subsoil drains to assist in removing this water. This is an expensive option as these drains will often need to be installed close together (no wider than 2 m apart), with some sites requiring an even closer spacing. Before committing to a drainage installation, engage an independent expert that specialises in sports turf drainage to design an appropriate solution.

When seeking drainage advice, be aware that drainage installers have a conflict of interest and often use similar layouts for all installations. This cookie cutter approach often works poorly on sites with impermeable subsoil, with about 6% of fields in the Lower Hunter that have slit drainage still experiencing waterlogging problems.

Figure 8.5: Saturated areas between sand slits that won't drain as the slits were installed too far apart for the conditions at the site. However, this drain spacing may have been effective if other soil amendment works had been implemented first.

Understanding the role of topsoil infiltration

To minimise the rain interruptions to play, many elite stadium fields are constructed from sand (K_{sat} >150 mm/hr) overlying a gravel base. Utilising a similar sand for local sporting fields very often results in these fields being prone to:

- extended periods of waterlogging due to the sand allowing most of the rain to infiltrate, with the removal of this water from the profile slowed by the subsoil (often clay). By contrast, more run-off (and a faster return to play) would have occurred on a soil-based field with appropriate cross-fall
- drying out and becoming water repellent, resulting in thin turf that has limited resilience and carrying capacity.

As can be seen from the above example, the commonly espoused idea to prefer high infiltration rates is not always appropriate for overcoming or preventing waterlogging.

What is saturated hydraulic conductivity

Saturated hydraulic conductivity (K_{sat}) is a measure of how fast water infiltrates into saturated soil. Figure 8.6 shows – the drier the soil, the faster water infiltrates, which is why some fields drain better in warmer months. As the soil gets wetter, the infiltration decreases to a steady rate where gravity is the main driving force. This rate is referred to as the saturated hydraulic conductivity (K_{sat}).

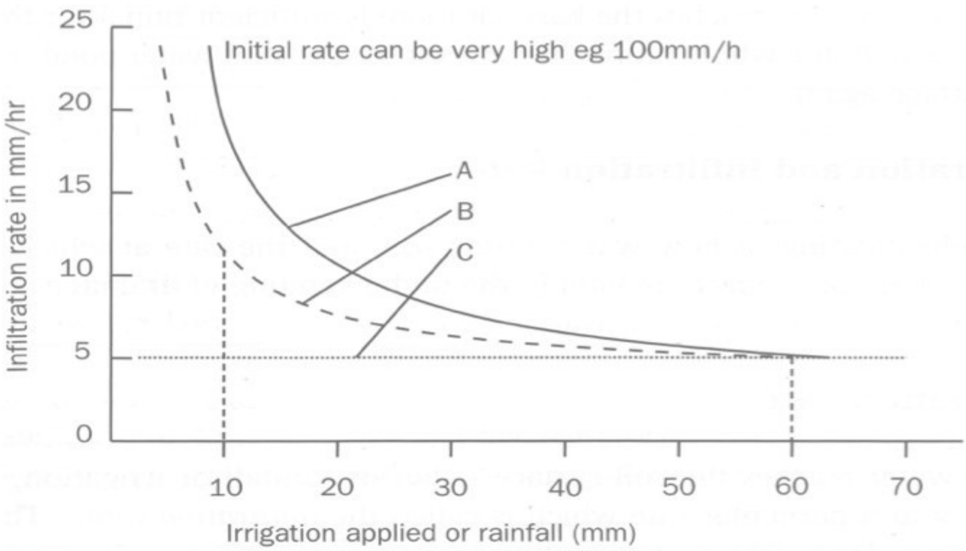

Figure 8.6: Infiltration rate of a loam soil varies with moisture status at the time of rainfall or irrigation. Curve A is the soil when the grass is stressed. Curve B is the soil at field capacity and Curve C is when the soil is saturated (McIntyre 1998, p22)[17].

Achieving a suitable saturated hydraulic conductivity

It has been found that designs for community fields have required the soil profile to have K_{sat} of at least 70-150 mm/hr. This is excessively high for all but elite fields, with most slit drainage systems only producing an effective infiltration rate of 2-15 mm/hr over the entire field surface.

To put K_{sat} values in perspective, consider the 2007 Pasha Bulker storm event. This East Coast Low resulted in 350 mm of rainfall, with a maximum one-hour downpour of 75 mm. Assuming no run-off, a sporting field with a saturated hydraulic conductivity of:

- 70 mm/hr is equivalent to the largest one-hour rainfall rate from this storm
- 25 mm/hr would have dealt with 350 mm of rainfall in roughly 14 hours
- 15 mm/hr would have managed to remove the 350 mm of rain in roughly 24 hours.

The speed at which fields return to play after rain will also be determined by the amount of surface run-off and the permeability of the subsoil. As such, if the field was constructed using a suitable cross-fall and suitably amended subsoil, then a field constructed with soil that has a saturated hydraulic conductivity of 15 mm/hr would have likely been playable within 24 hours of the 2007 Pasha Bulker storm.

Measuring saturated hydraulic conductivity

Methods for measuring K_{sat} are described in the Questions and Answers section at the back of this book. Be aware that inappropriate tests have been specified and used to measure K_{sat} in soils, such as the USGA method which was developed:

- for sands
- NOT for soils (ASTM 1815-11, 2018)[18].

If the USGA method is used inappropriately to measure K_{sat} in soils it can be misleading, and often ends up with the expensive recommendation to import large amounts of sand. As such, it is recommended to engage a certified professional soil scientist.

Figure 8.7: The Pasha Bulker.

CHAPTER 9: SLIT DRAINS

Slit drainage systems consist of a series of trenches that are backfilled all the way to the surface with sand. Typically, ag-pipe is installed in the bottom of these sand filled trenches (Figure 9.1), with the run-off water they capture conveyed to a collector pipe or mainline that discharges to the stormwater system.

Slit drains are primarily used to remove surface water[17] and rely on the sand being connected all the way to the soil surface (Figure 9.2). If the slits are installed close enough together then they can also function effectively as subsoil drains (see Chapter 8). Slit drains facilitate run-off by dramatically reducing the slope length to the spacing between the slits (often 2-3 metres), instead of the width or length of the field (Chapter 8).

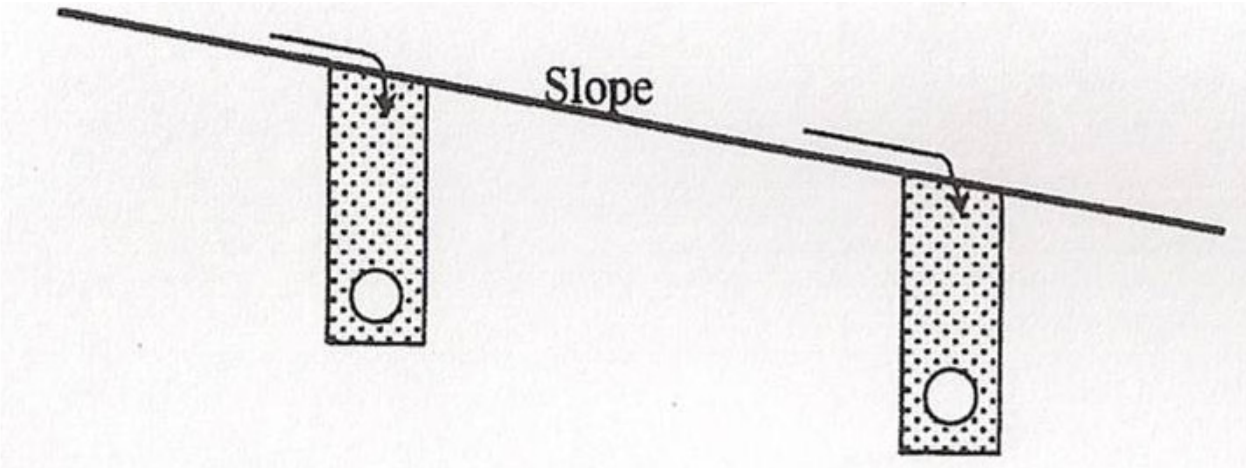

Figure 9.1 Cross section of slit drains (from McIntyre 2004)[16]. The steepness of the slope has been exaggerated for visual clarity

Figure 9.2 Recently installed slit drainage system showing the sand extending all the way to the surface. The turf will grow across the slits from the adjacent areas, so they are less visible over time.

Do all fields require slit drainage?

Contrary to popular belief, slit drainage is not always required (Figure 9.3). In an assessment of 256 sporting fields in the Lower Hunter:

- 38 have a slit drainage system
- 218 sporting fields do not have slit drainage, with 65% of these fields draining within an acceptable timeframe. Of the remaining fields, often waterlogging could be significantly reduced or overcome fully by implementing the measures discussed in Chapter 8.

However, slit drainage is often required to assist in removing excess water on sites with turf cricket wicket tables and longer slopes, especially if they have been constructed with insufficient cross-fall or impermeable subsoil (slits are also then functioning as subsoil drains). Slit drainage may also be used to accelerate the return to play if higher levels of service are justified at individual sites.

What about new fields?

Unlike existing fields, whose performance during and after rain can be assessed, new fields do not have a track record to fall back on. Ideally, new fields would have a slit drainage design developed, but only the slit drainage mains would be installed initially. The drainage laterals would only need to be installed later if return to play benchmarks are not achieved.

In practice it can be very difficult to carry forward existing funding or secure new funding for additional works following construction. Therefore, for new fields, slit drainage would be incorporated in a holistic plan, with an integrated construction able to achieve many best practice outcomes such as:

- high carrying capacity
- field that provides acceptable turf cover throughout the entire year
- drought resilience
- efficient and effective irrigation
- provision for non-potable water
- rapid return to play after rain.

All these outcomes can be achieved by following the principles described in these guidelines.

Figure 9.3: Balcomb field has a soil type similar to that observed on many of the fields in the Lower Hunter. It drains rapidly after rain without a slit drainage system.

Staging the works (when to install slit drainage)

Slit drainage can assist in removing surface water, but generally does not help the grass grow in the space between the drains. As such, if the field currently provides a poor playing surface, then this is likely to remain following the installation of the slit drainage and may even become worse (Figure 9.4).

Improving poorly performing fields typically requires works such as the incorporation of soil amenders, re-levelling, establishing a new turf surface and/or topdressing. All these activities would compromise a slit drainage system by preventing the sand slit from extending all the way to the surface. Whilst it is possible to reinstate the slits later, this will incur significant additional costs that could be avoided by delaying the slit drainage installation until the following issues have been addressed:

- uneven playing surface, this is often an ongoing problem on fields built over old fill sites
- soil problems that are causing the turf to struggle or the surface to remain unacceptably hard
- the wrong turf cultivar
- water running onto the field (addressing this may overcome the waterlogging problem).

The best practice approach is to first address the underlying issues, so an acceptable playing surface is achieved, then install a slit drainage system as required to overcome waterlogging problems.

Figure 9.4: Slit drainage was installed in this field enabling it to be used more often, but the turf cultivar could not handle the wear. As such, the field had to be reconstructed, with additional costs then needed to reinstate the drainage system. Install slit drainage after other works are complete and an acceptable playing surface can be maintained.

Designing slit drainage systems

Slit drainage systems should be independently designed by a suitably qualified person that has experience in sports turf drainage. Analysis of “design and construct” systems installed in the Lower Hunter found many examples that have not met best practice benchmarks. As a general guide, slit drainage systems should:

- be capable of removing surface water over the entire field area at a rate greater than 8 mm/hr
- use sand that will not damage cylinder mowers or present a safety risk with mowers
- allow the effective installation of an irrigation system if the site does not already have one
- be installed following soil amendment and turf works. Laying turf with soil attached over the top of slit drains can completely negate the drainage system (Figure 9.5)
- have additional design requirements if the slits also need to function as subsoil drains. This may require a drainage designer with formal qualifications in soil science. Generally, the slits will need to be installed no wider than 2 m apart if they are to function as subsoil drains.

Once the system has been designed, ask drainage installation companies to bid on performing the works. If budget is limiting, then consider staging the works (install on sections of the field or use a spacing that can be halved later). It is not recommended to undersize the collector or mainline pipes as this will compromise the long-term performance of the system and is very expensive to rectify.

A 100 mm drainage mainline (often used in residential houses) is barely adequate for draining about one third of a soccer field.

There are examples of a single 100 mm drainage mainline discharging water from entire AFL fields. Sections of these fields drain slowly as the water backs up in the system. Had the mainline been correctly sized it would have resulted in 2.5-times the discharge capacity for about 2% extra cost.

Figure 9.5: Turf with clay attached was laid over the top of slit drains (left), rendering the system almost completely useless so the field remained waterlogged (right).

Sock versus No sock

The industry is divided over whether ag-drain pipes (or the “lateral” pipes) in the bottom of the sand slit should be enclosed in a geotextile sock. Drainage installers from both the “sock” and “no sock” camps have strong views and preferences. The proponents of geotextile sock will typically install the pipe on the bottom of the trench and backfill the entire trench with sand. Proponents believe that the sock prevents sand from entering the pipe and gradually blocking it (ag-drain pipes typically have a hole opening size of about 1mm, with the sock hole opening being about 0.4mm). However, this view fails to account for bridging between sand and soil particles which will result in minimal material entering the pipe if an appropriate sand is selected.

In essence, geotextile sock acts as a filter and all filters will block and need replacement at some stage. Once it is in the ground, it is impossible to replace the geotextile sock without reinstalling the entire system. Geotextile sock is at particular risk of blockage from bacterial build up, particularly iron reducing bacteria that are present in the subsoil (Peter McMaugh pers comm). This risk is elevated if the bacteria can receive additional iron to support their growth. Two common sources of iron are sports field fertilisers and groundwater, with numerous fields in the Lower Hunter having the tell-tale signs of iron staining on fences, goal posts and pathways from groundwater use.

It is noted that McIntyre and Jakobsen (1998)[17] regard geotextile sock as unnecessary and likely to "drastically reduce the rate of flow" (p141). They go on to say, "Do not wrap pipes in geofabric or place geofabric over the top of drain" (p142). In instances where "no sock" is specified, then installers will place a layer of gravel below the ag-pipe (followed by sand). The gravel provides a mechanism for any minor amounts of material that enter the pipe to then fall out into the gravel layer below during low flow conditions.

Topdressing fields with slit drainage systems

Once a slit drainage system has been installed:

- general applications of soil based topdress should not be used
- localised topdressing with soil can be used to fill depressions, but the soil must not be applied over the top of slits.

This is because the soil has a much lower infiltration rate than the sand used in the slits and will reduce their effectiveness (Figure 9.6). Furthermore, machines such as recycled topdressing machines should not be used on fields with slit drainage, as the machine uses the site topsoil as a topdress and this will reduce the effectiveness of the slits.

Figure 9.6: Field with a slit drainage system that was rendered useless by topdressing with 80:20. Whilst this material is very sandy, it has an infiltration rate much lower than the sand used in the slit drains.

If a field with slit drainage requires a general topdress then only sand matching the characteristics of the material used to construct the slits can be used. However, the amount of sand topdressing should be minimised as this will generally result in thinner turf when applied to local sporting fields.

Slit drain installation and maintenance

Sports field slit drainage installation requires specialist equipment (e.g. laser guided chain trenchers and whiz-wheel trenching machines). Specialist sports field drainage and construction contractors also have the ancillary equipment (e.g. conveyors and trailers) to collect and remove spoil to minimise damage to the playing surface. As such it is recommended that only specialist sports field contractors with the requisite equipment be engaged to undertake slit drain installation.

For slit drainage systems, the infiltration rate of the sand slits will decline over time. This can be addressed by re-grooving of sand slits to remove the top layer of old material and replace it with new sand. It is important to note that in new slit drainage systems, the design capacity is usually limited by the discharge capacity of the pipes, not the infiltration rate of the sand slits.

Sand grooving does not need to be undertaken routinely at set time periods (e.g. 6 years), but only when the limitations of the slit drainage system are affecting the ability of the field to return to play within best practice benchmarks. Testing of 13 slit drainage systems in the Lower Hunter found significant variation in the performance of the slit drainage systems over time. Site conditions and horticultural practices were factors in determining the frequency of when sand grooving may be needed. Therefore, it is recommended that the infiltration rate on a slit drain system be tested at regular intervals after installation (e.g. 3, 5, 7 and 10 years) to determine performance trends and the likely time sand grooving will be required.

DRAINAGE QUESTIONS AND ANSWERS

Why doesn't my field drain and what do I do about it?

There are several reasons why a field or parts of a field may remain wet for an extended period. These include, but are not limited to:

- water is running on to the field
- water cannot readily infiltrate (e.g. the soil is heavily compacted, or there is a layer of clay in the soil – a common problem is the clay in soil attached to the turf rolls)
- an uneven surface or lack of cross fall (water doesn't shed from the surface and lies in depressions or where the slope changes)
- a long slope length (e.g. a field falls from one end to another over a distance greater than 70m). With a long slope length, it takes a long time for water to move across the surface and off the field
- the subsoil or base for the field drains very slowly (or not at all) so once the topsoil is saturated, the water can only be lost very slowly through either evapotranspiration (very slow in winter) or via infiltration through the base (if it drains at all)
- springs or groundwater movement, with these sometimes being tidal or only having an adverse effect during extended wet periods.

The appropriate measure(s) to improve drainage require correct diagnosis of the problem. Drainage problems are often complex and cannot be considered in isolation (Figure A.1), and expensive drainage infrastructure may not be required in many situations.

TIP: Observe the field during significant rainfall events (e.g. 40mm or more of rainfall). Watch and map where the water is flowing and lying. This will yield invaluable information about how the water is behaving and what measures might be appropriate to prevent or at least reduce the incidence of waterlogging.

Figure A.1: Waterlogging is often caused by a combination of factors and in many cases a Certified Professional Soil Scientist is needed to come up with solutions. Waterlogging on this field for example is due many factors, including: localised depressions, long slope length, hard setting soil, poor soil chemistry and the subsoil having an extremely low saturated hydraulic conductivity. In addition to this large list of causative factors, the soil also requires amendment so healthy turf cover can be achieved.

Why adding sand usually doesn't work

Adding sand to a soil profile often has no effect on drainage. Whilst this may sound like it contradicts common sense, it is obvious if you think about what would happen if you mixed clay and gravel together in a 50:50 ratio. Once you moderately compact this mix, the clay would drain at almost exactly the same rate that it did prior to mixing in the gravel (i.e. slowly). The same is true when you mix sand into most soils, it takes large quantities of sand to change the properties of the soil.

If water is lying in a depression due to the underlying soil being compacted, then adding sand to the surface won't help. The water will continue to lie on top of the same compacted layer, it is just that the depression is now full of sand that becomes easily saturated whenever it rains.

Fix everything else before slit drainage

Once slit drainage is installed, it is difficult to amend the soil or change the turf cultivar without incurring significant additional costs to re-instate the slit drains. As such, if the turf is struggling then it usually continues to do so following slit drainage installation. Sometimes it becomes worse as the field will receive more wear, from reduced wet weather closures (Figure 12.4). Therefore, as a rule, slit drainage should only be installed once the issues causing poor turf performance are addressed such as:

- preventing water from running onto the site e.g. using strategically placed concrete dish drains, pits and pipes. Turf swales are not ideal as they tend to remain wet and can be difficult to maintain
- any re-grading of the site to achieve a slope shape that does not allow water to pool
- amending the soil to overcome problems such as the soil being too shallow, too sandy, prone to hardsetting, layered and/or having low levels of fertility
- changes to the turf cultivar to one capable of handling the site usage levels.

If performed correctly these works will overcome waterlogging on many sites in the Lower Hunter, but some fields will still require slit drainage. If slit drainage is installed without consideration to site characteristics, then sometimes waterlogging problems can persist (Figure A.2).

Figure A.2: Saturated areas between sand slits that won't drain due to soil issues that were not addressed.

How do I measure the saturated hydraulic conductivity of a soil?

Field measurements

Field measurements are the most accurate way of measuring the K_{sat} because they can account for the major role played by soil structure. These measurements can be performed not only on the surface, but also on individual layers. Measurements are usually performed in the field, but sometimes intact soil cores are collected and taken back to the laboratory. The most common methods of measuring the saturated hydraulic conductivity in the field involve using various version of either a:

- double ring infiltrometer or
- single ring infiltrometer (soil matric suction effects must be accounted for).

As soils are highly variable it is not possible to rely on a single measurement and ideally at least 20 measurements would be performed per hectare. However, this is prohibitively expensive, so in practice fewer measurements are taken by a soil scientist who can then interpret the results.

Laboratory measurements

If soil samples are sent to the laboratory then they are typically crushed, with the soil then re-compacted prior to the K_{sat} being measured. As such, the result is highly sensitive to re-compaction process. In fact, it is possible for even relatively coarse sands to display low values of K_{sat} if they are compacted aggressively. Therefore, it is crucial to use an appropriate method or misleading results will be obtained.

McIntyre drop test method

The McIntyre drop tests have been developed by Dr Bent Jakobsen as a simple and effective test for saturated hydraulic conductivity (McIntyre 1998, p147)[17]. The level of compaction of the sample is important when undertaking the test, with these corresponding to (McIntyre 1998, p40)[17]:

- 8 drops (roughly equivalent to teams of small children playing)
- 16 drops (roughly equivalent to sporting use such as senior football)
- 32 drops (approximately equivalent to racehorses).

It is not uncommon for testing to be undertaken on samples using 8, 16 and 32 drops to assess how a soil behaves under different levels of compaction.

USGA method

The USGA test methods are detailed in the ASTM Standard 1815-11 (2018), "Test Methods for Saturated Hydraulic Conductivity, Water Retention, Porosity, and Bulk Density of Athletic Field Rootzones"[18].

The method involves repeatedly dropping a weight that aggressively packs the sample (Figure A.3). ASTM Standard 1815-11 (2018)[18] states in Clause 1.1: "*These test methods are designed for sand-based mixes and are not intended for use with fine or medium textured soils, for example, sandy loams and loams.*"

As the USGA method is only applicable to sand profiles (not soils), the tests and the results produced are not relevant for most fields in the Lower Hunter.

Figure A.3: The USGA method is only applicable to sand profiles (not soils) and involves heavily compacting the sample by dropping a weight repeatedly on it from a fixed height.[19]

Interpreting the results

With laboratory tests it is important to remember that they cannot replicate conditions in the field such as layering or soil structure. Furthermore, the compaction procedure that is performed in these laboratory tests can result in misleading results if not interpreted by a Certified Professional Soil Scientist.

Unfortunately, when the wrong test method is used and/or the laboratory samples are over-compacted, the K_{sat} values do not represent any conditions that would exist in the field. This often results in recommendations for importing of large amounts of sand for construction, at great cost to the community and environment.

BOOK 3 REFERENCES

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19. United States Golf Association (2002) “Building the USGA Green, Tips for Success”, https://archive.lib.msu.edu/tic/usgamisc/monos/tipsforsuccess-2015.pdf

FIGURE AND TABLE CREDITS

Ethan Battam: Cover photo

Dr Paul Lamble (Peak Water Consulting): Figures P.1, 7.1, 7.3, 8.5, 8.7, 9.3, A.1, A.2

Dr Mick Battam (AgEnviro Solutions): Figures 7.2, 8.1, 8.2, 8.4, 9.2, 9.4, 9.5, 9.6

Keith McIntyre (References 16 and 17 above): Figure 8.3, 8.6, 9.1

USGA (Reference 19 above), Figure A.3

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August 2022