Queensland the **Smart State**

Turf for tough times

Keeping grass cover with less water

Proceedings of a seminar held at Cleveland, 6 June 2007

Queensland Government
Department of Primary Industries and Fisheries

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—keeping grass cover with less water

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Edited by Cynthia Carson

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Acknowledgements

A seminar of this nature is only made possible by the considerable research efforts of scientists and technicians who have collected the data on which presentations are based. A debit of gratitude is held to all these unseen hands.

To the seminar speakers, thank you for giving of your knowledge and time to share your insights with a wider audience. By saying “yes” to being on the programme you have made this project possible. Our speakers were (in order of their appearance on the seminar programme): Dr Don Loch, DPI&F Cleveland; Craig Henderson, DPI&F Gatton; Dr Rachel Poulter, DPI&F Cleveland; Keith McAuliffe, Sports Turf Institute, (Australia), Cleveland and Matt Roche, DPI&F Cleveland.

The Queensland Turf Producers Association, Parks and Leisure Australia and the Golf Course Superintendents Association of Queensland were invaluable in advertising the seminar to their members. A special thanks to Kylie Crocker, Department of Local Government, Planning, Sport and Recreation, who also sent information about the seminar to her broader network.

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Cynthia Carson
Seminar coordinator and proceedings editor

Senior Extension Horticulturist—Turf

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About the Speakers

(in alphabetical order of surname)

Craig Henderson

Craig works as a Principal Horticulturist with the Department of Primary Industries and Fisheries, based at their Gatton Research Station, 100 km west of Brisbane. Craig leads DPI&F research and extension in water management in horticultural systems, including the non-food sectors, such as flowers, turf, nursery products and urban open space. He has been researching agricultural plant and soil management since finishing university, just over 25 years ago.

During the past 3 years, Craig has led a collaborative sports field R&D project. The now-completed project is a successful joint venture between Horticulture Australia, DPI&F, AFL Queensland, Brisbane Lions, and several smaller partners. As part of the project, ways of improving community sports fields were investigated. Methods included using better irrigation and soil management and participatory learning with curators, service industries and sporting administrators. The project team intends to publish several sets of training manuals as a result of the project.

Dr Don Loch

Dr Don Loch was involved in broad-based research on pastures and pasture seed production with the Queensland Department of Primary Industries for 30 years from 1970 to 1999. His work was instrumental in developing technology to support the commercialisation of many new tropical herbage grasses and legumes during an exciting pioneering period with these species in northern Australia. At the same time, he bred two new Rhodes grass cultivars and registered several other new pasture cultivars.

Since moving to Redlands seven years ago to initiate and lead the Department's new turf research program, Don has been instrumental in developing a wide range of research projects with the turf research group. These cover water use, bioremediation, stress tolerance (salt, shade and temperature), diseases, nutrition, weed control, characterisation and improvement of sports surfaces, DNA fingerprinting, and breeding. Don's own research interests centre on the development and commercialisation of improved varieties of exotic and native grasses, including their propagation, drought, salt and shade tolerance, nutrition, weed control, and general management—in fact, many of the same areas that he worked on successfully for many years in pastures.

Keith McAuliffe

Keith is the Chief Executive Officer of the New Zealand Sports Turf Institute, a role that he has had since 1988. In January 2005, Keith relocated to Redlands Research Station to work in the broader Australasia Pacific region.

Prior to joining the Sports Turf Institute, Keith lectured in the Department of Soil Science at Massey University, where he'd undertaken both a degree in Agricultural Science and a post-graduate Masters degree.

Keith's areas of expertise include: include turf management, environmental science, water management and soil science. He has considerable experience in sports field consulting and has been involved in many research projects including: the distribution patterns of irrigation systems, work with cricket pitches and soil properties in sports turf.

Dr Rachel Poulter

Rachel Poulter graduated from the University of Tasmania in 1992 with a Bachelor of Agricultural Science, with Honours and completed her PhD through the University of Western Australia. Her thesis, 'Investigating the role of soil constraints on the water balance of some annual and perennial systems in a Mediterranean environment', assessed the impact of both chemical and physical soil constraints on the root growth and water use of various annual and perennial pasture species.

Rachel joined the turf research group here at Redlands in late 2003, where she has been involved in a variety of trials including: amenity grasses for salt affected parkland, investigating the efficacy of soil surfactants, determining the physical characteristics of potting media and investigating the value of soil amendments (water crystals) in hastening the establishment of new turf.

Matt Roche

Matt Roche joined the Department of Primary Industries turf research group in 2002, during his final year of studies at the University of Queensland (UQ), Gatton Campus. During his time within Australia's leading turf research group, Matt has been actively involved with a wide array of turf agronomic studies of significant benefit to the turf industry. Currently his interests include genetics and breeding, with a focus on the commercialization of improved warm-season turfgrasses and the characterisation of vegetative *Cynodon* within Australia. The morphological and agronomic study of known and "off-type" *Cynodon* cultivars is being undertaken part-time as part of his MPhil studies at UQ. Matt is actively involved in sports field research and benchmarking, at both local and elite levels, to improve turfgrass quality, playability and most importantly player safety.

Developing Tough Turf—An Overview

Dr Don Loch
Department of Primary Industries and Fisheries, Redlands Research Station, Cleveland

Australia is the driest inhabited continent on earth. In size, it is around 80% of the USA's land area; but supports a population of only 21 million people compared with just over 300 million in the USA. Our population is concentrated in the limited areas with higher rainfall along the eastern, southern and south-western coasts. Water (or lack thereof) is the major reason for Australia's low population density. The wide brown land has:

- ***1% of the world's surface fresh water resources***
- ***only a few snow-fed rivers***
- ***<300 mm average annual rainfall across 60% of the country (while another 20% receives 300-600 mm)***
- ***highly variable rainfall from year to year***
- ***experienced 12 major droughts in the past 150 years***

Australia's Water Crisis

In a dry continent currently in the grip of one of the worst droughts on record and with unprecedented water restrictions (and likely to increase further in most cities and towns from southern Queensland through to South Australia), making better use of our water must be our **ABSOLUTE** priority.

At Redlands Research Station, water use is a theme that runs through much of the Department of Primary Industries and Fisheries (DPIF) turf research program on warm-season grasses. It is critical that we conduct long-term research commencing now into better and more water effective solutions to apply during drought, if not for this one, then for the next in the ongoing cycle of droughts in Australia.

No 'Silver Bullet' Solution

Homeowners and the media want a quick fix: "Just give us your most drought tolerant grass" is the usual request. But even the most drought tolerant grass will not survive in a few centimetres of soil over rock—a not unusual situation in new housing developments. One major building company actually promises their customers 300m^2 of lawn laid on just 5 cm of topsoil around their new house. This amount of topsoil is grossly inadequate, but is actually being promoted as a positive marketing tool!

If we think about it logically, the plant used sets the potential drought tolerance that is possible. What happens in terms of the soil profile in which it is grown and the management practices applied then determines just how much of that potential is actually achieved.

Drought tolerant turf is built from the ground up by making a series of incremental improvements, not through one simple solution that will somehow fix everything. The basic steps are to:

- put a good soil profile in place;
- ensure that water can enter the soil and be stored there for the plants to use;
- plant a well adapted turfgrass, bearing in mind other site restrictions such as shade, wear or salinity; and
- check water quality, particularly in the case of alternative irrigation supplies.

Water Use Efficiency or Drought Tolerance?

Firstly, we need to be clear about our objective: are we looking for better water use efficiency in our turf or the ability to survive for longer periods while losing water through evapotranspiration? The answer depends on climatic conditions and the chances of rainfall.

In a desert climate where there is very little chance of rainfall any time soon, the turf is reliant on total irrigation. In this context, water use efficiency is important, even though recent research in Arizona by Kopec *et al.* (2006) showed only small differences among the various species and cultivars used.

In a humid subtropical climate like Brisbane, where there is much higher probability of rain in the near future, irrigation is generally used to supplement rainfall on turfed areas. This means that drought-tolerant turf that can go for longer between drinks (by which time rain may have fallen anyway) can make substantial savings in irrigation water use.

Start With the Soil Profile

When grown on a properly constructed soil profile in south-east Queensland, warm-season turfgrasses will survive long periods of drought without any irrigation in the case of the most drought-tolerant species—green couch (*Cynodon dactylon* and hybrids) and blue couch (*Digitaria didactyla*)—and with no more than an occasional strategic watering to save the life of the less drought-resistant ones.

For turf to cope with extended dry periods, the soil profile should be a minimum of 10 cm (and preferably 15 cm or more) deep to provide adequate soil water storage. Where the profile depth varies, shallow patches will dry out more rapidly and the turf on these may even appear dead by the next fall of rain. But with moisture in the profile once again, many such apparently "dead" patches of blue and green couch can stage a rapid and complete recovery.

Not only is the depth of topsoil under the turf important, so is the quality of that topsoil. For example, second-rate soil stripped from a building site will not give the desired result. Increasingly, soil suppliers are mixing components to create artificial soils as sources of good natural topsoil become scarcer. Products with raw compost that is still decomposing should be avoided. Additionally, soil mixes with high organic matter (>25%) will eventually slump to lower levels as the organic matter decomposes. This is an area where more research and more regulation are required to improve the quality of topsoil used under new turf plantings.

Soil Water Entry and Storage

At low moisture levels, many soils will become water repellent, a problem caused by organic acids coating the sand/soil particles. Rainfall and irrigation are then much less effective; water tends to run off or through the soil; and it does not easily wet up again. While this is a problem regularly seen on golf greens, it is not widely recognised that soil water repellency is also a common condition on the extensive areas of infertile forest soils found in urban areas around Brisbane.

The normal treatment for soil water repellency in high quality turf areas is to make regular applications of surfactants, which improve water entry by reducing surface tension. Our research on new generation surfactants has demonstrated their effectiveness in improving infiltration. By maximising the amount of water captured in the soil during short, high intensity storms, improved infiltration in areas treated with surfactant translates into visibly better turf quality.

Newly-laid sod of all turfgrasses has only a very limited root system and is vulnerable to drying out. Water use during turf establishment is also highly visible to politicians, administrators and the general public because regular irrigation is needed until deeper roots have grown through the turf underlay. A number of soil amendment products (e.g. cross-linked polyacrylamides, water-absorbent foam) have been developed to improve soil water-holding capacity. The role of these products in turf establishment is currently being assessed by the Redlands turf team under a research grant from the International Turf Producers Foundation.

Plant a Well-Adapted Turfgrass

There is no such thing as the perfect turfgrass, or one that will grow everywhere and under all conditions. Drought tolerance is not the only attribute to be considered when selecting a turfgrass.

For example, some 25% of turfgrass sites are affected by shade where the most drought-tolerant species, green and blue couch, do not perform well. Buffalo grass (*Stenotaphrum secundatum*), Manila grass (*Zoysia matrella*) and sweet smothergrass (*Dactyloctenium australe*) grow much better than green and blue couch under shade, and also maintain green healthy turf much longer than they would in full sunlight.

While larger differences in drought tolerance are found among species, differences within species also occur and will help maximize water savings in the future. The Redlands turf team through collaboration with University of Queensland (UQ) scientists has recently received a national government grant to develop more drought-tolerant turfgrass cultivars for a range of uses. Over the next four years, this exciting new joint UQ-DPIF project will focus on collecting and evaluating Australian *Cynodon* genotypes for turf quality and drought tolerance.

Water Quality

Using poor quality alternative water sources, including greywater, invariably means that salinity will be an issue. On-going research at Redlands has been directed towards growing turf on salt-affected soils, and has identified salt-tolerant turfgrasses that can also be used with poor quality water.

To date, 41 turfgrass cultivars from 9 different species have been screened hydroponically to assess their tolerance to salt levels up to 40 dS/m, which is 74% of the salt level in seawater. In addition to confirming the high levels of salt tolerance in seashore paspalum (*Paspalum vaginatum*) and Manila grass (*Zoysia matrella*) shown in US work, we found considerable variation in salt tolerance among buffalo grass and green couch cultivars, enabling the more tolerant cultivars to be specified for future use on moderately saline sites.

Turf vs. Landscape Water Use

Garden commentators promoting shrubs and trees in the media often describe turf as a high water user. This could not be further from the truth.

Savings in water use on community-level sportsfields are still possible without compromising turf quality or playability. Our AFL project team looked at the year-round water use across a number of soil-based community sportsfields in Brisbane. Under normal frequent irrigation scheduling, the average field uses around 5 ML/ha. Strategic weekly irrigation (applied only when no rain had fallen in the previous week and surface soil moisture was rapidly declining) still maintained good turf quality and a safe playing surface, but on average required less than half the irrigation water, about 2.4 ML/ha. By comparison, tree crops like citrus typically require 5.0–7.5 ML/ha.

These and other facts about water use should be publicised by the turf industry now, in addition to commissioning further research to compare reticulated water use on turf and on shrubs and trees. In Florida, Park and Cisar (2006) showed that, after the first year when more water was used to establish the turf, their shrub landscape used more water than the turfed landscape, and water use by the shrubs continued to increase as they grew larger whereas turf water use stabilised.

We need studies of this kind in Australia to help in getting the message across to the public that turf is not a high water user—but rather a sustainable and environmentally-friendly option as the pressure on urban water supplies increases.

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Improving sports field irrigation during drought— lessons from research and development on AFL premier league sports fields in Queensland

Craig Henderson[a], Kaylene Bransgrove[b], Greg Finlay[a], Larry Cooper[b]; Nick Jeffrey[c] and Craig Moffatt[c]

[a] *Department of Primary Industries and Fisheries, Gatton Research Station, Gatton*
[b] *Department of Primary Industries and Fisheries, Redlands Research Station, Cleveland*
[c] *AFL Queensland, Coorparoo*

Irrigation is a major infrastructure and operating cost for community standard sports fields. A major function of a project run in conjunction with the Australian Football League, Queensland (AFLQ) was to demonstrate the proper utilisation of irrigation resources in the context of these sports fields. In our initial benchmarking, it was apparent that irrigation management was a key contributor to the main factors affecting the surface standard and safety of sports fields, i.e. surface hardness and turf coverage.

At the same time, as south east Queensland was plunged into the worst drought in recorded history, potable water sources became scarce. Councils and water supply authorities (through voluntary and regulatory means) insisted on reduced usage of potable water, and better overall irrigation management, in landscape and sports field applications. To support this endeavour, a considerable amount of money is becoming available for new turf irrigation infrastructure. State and Commonwealth bodies are administering some of the funds as grants, while improvement programmes administered by local councils are also providing means to upgrade or install irrigation systems. Considering new irrigation systems are worth $30 000 and upwards, and represent a sizeable increase in the capacity of a club to provide a quality turf surface; it was certainly a high priority within the project to investigate the various aspects of irrigation management.

System auditing

Methodology

Optimising the operating efficiency of an irrigation system is a key step for effective scheduling, which will contribute to saving water and effective, appropriate management of the irrigated space. Within our research project, we examined the irrigation infrastructure on nine of the project fields.

After completing the Irrigation Association of Australia (IAA) certification requirements for landscape irrigation auditing, our team used the majority of the audit procedures recommended under that certification (Cape 2006). The key difference was that our minimum catch can spacing was 3 m. This is more in line with agricultural irrigation audit procedures.

The fields were audited after 9 pm at night to match normal irrigation times. Most fields utilise reticulated supplies, and are therefore operated at night to use the higher available night time pressure. Three sprinklers were audited per field. One was in an area closest to the mainline entry; one farthest from the mainline entry; and one somewhere between. We used a 12 x 13 catch can grid at 3 m spacings around each sprinkler. To conduct the audit we measured the static and operating mainline pressure, the static and operating flow rate at the mainline meter, operating pressure and condition of all sprinklers and the precipitation in catch cans. The station containing the audited sprinkler and the two adjacent stations were included in the audit and were run for 30 minutes each.

Using the precipitation measurements (transformed to mm), we calculated the lowest quarter distribution uniformity (DU) for each of three sprinklers per field, assessed head to head coverage and constructed a precipitation map to visually illustrate the precipitation pattern across the audited area. Using the operating sprinkler pressures, we calculated the estimated variation in pressure due to the design of the system and to non-design (maintenance) issues. Where available, we used rates notices to calculate field water use per annum. When rate notices were unavailable, we estimated water use on the remaining fields from sprinkler precipitation rates and likely irrigation regimes.

Results and discussion

Our findings from auditing the nine fields were consistent with the results of researchers and irrigation audit experts across Australia—most irrigation systems on community based sports fields are operating at significantly less than optimum efficiency.

Sprinkler operation

An example of one of our irrigation audit sprinkler maps is shown in Figure 1. Points to note are the diagrammatic representations of the sprinkler layouts, including direction, and numbers of sprinklers per station. Also on the diagram are measures of water pressures at the mains and individual sprinklers. We have also identified any functional problems with the sprinklers, as well as the location for the three specific catch can precipitation analyses.

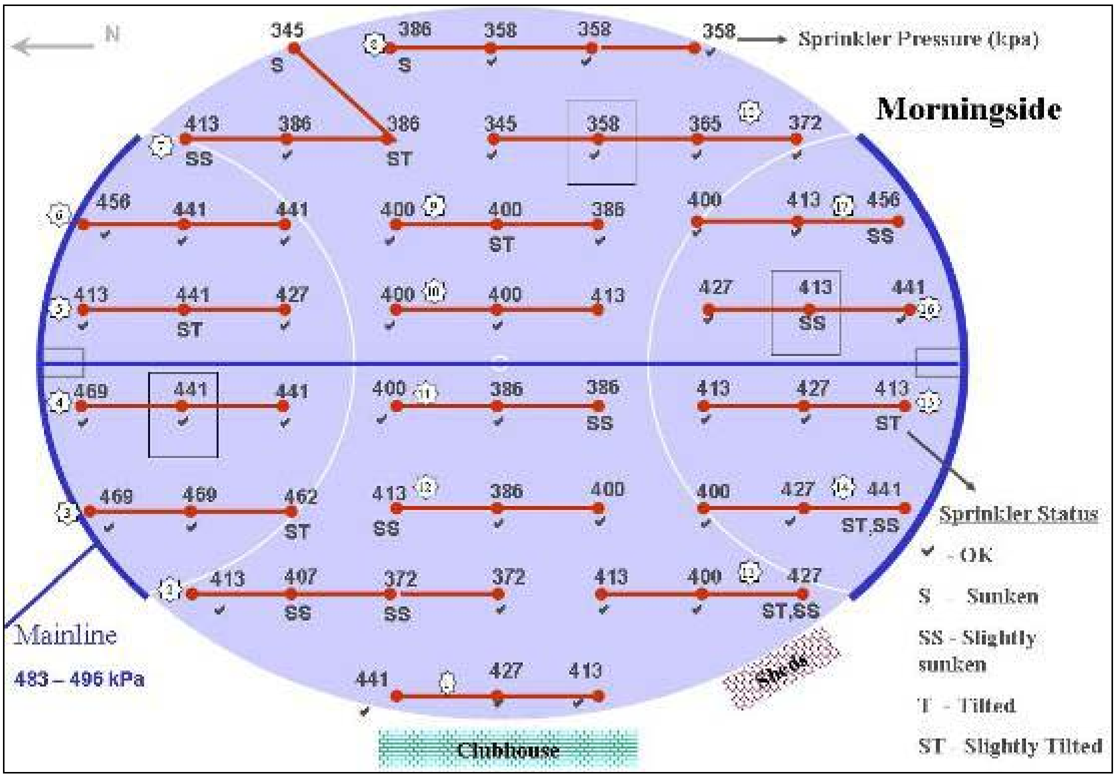

Figure 1: Sprinkler audit map for Morningside sports field.

A need for significant sprinkler maintenance was identified across eight of the nine fields. It was in fact unusual if more than approximately 65% of the sprinkler heads were in optimal working order (Figure 2), with that value as low as 40% (of sprinklers functioning properly) on one field. Pressure at sprinkler heads varied considerably within and between fields (Figure 3).

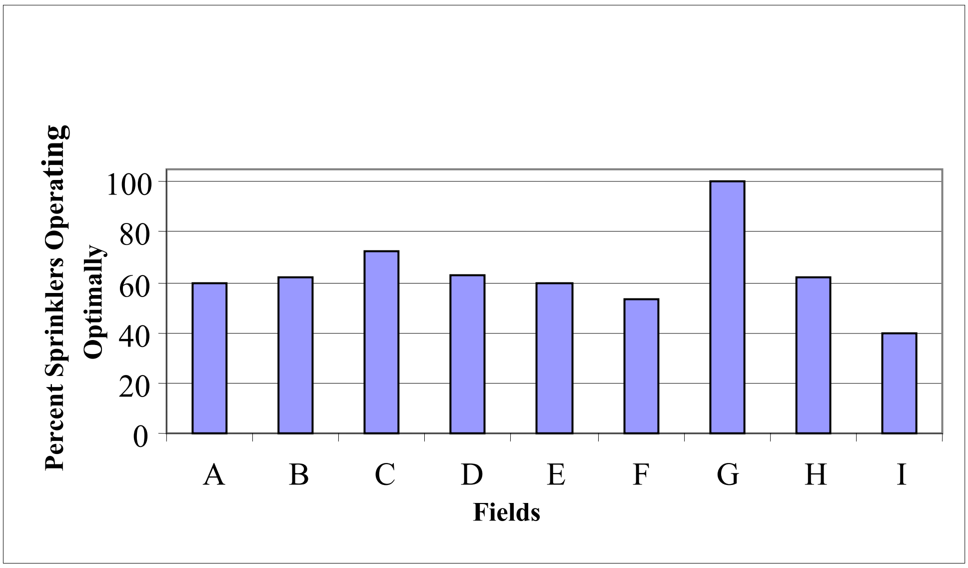

Figure 2: Percent sprinklers operating optimally on audited AFLQ fields. Only two of nine fields had more than 65% of sprinklers functioning optimally.

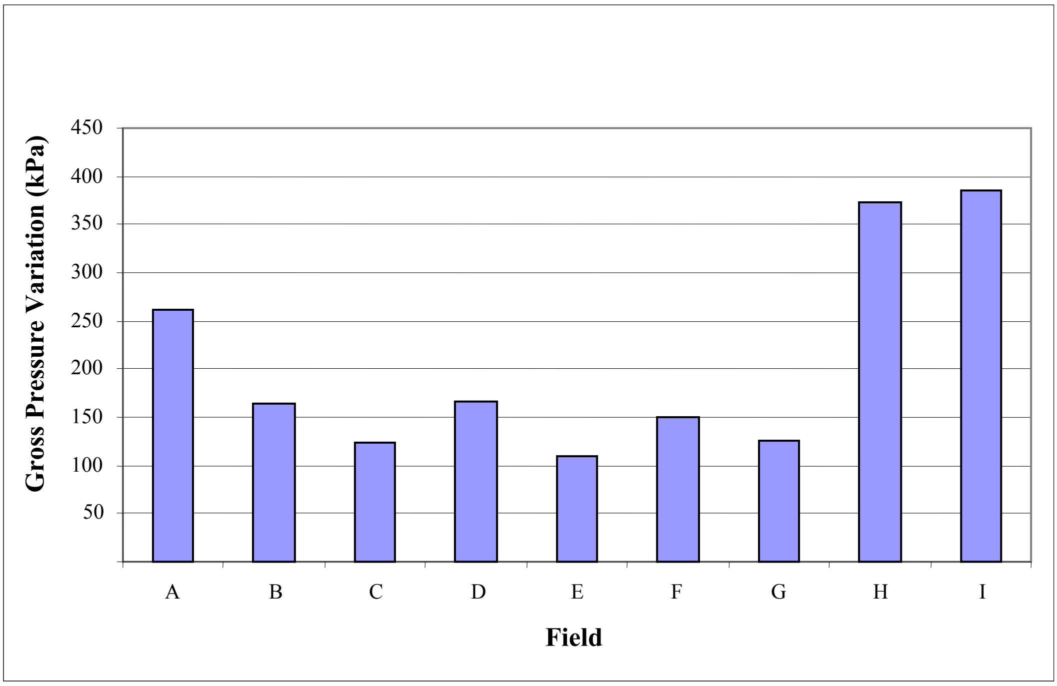

Figure 3: Gross pressure variation across audited AFLQ fields. Sprinkler pressures across fields varied enormously.

The percentage variation in sprinkler pressure across each field was divided between the variation due to the system design (e.g. length and diameter of piping, distance from mainline entry and number of sprinklers in a station) and the variation from system malfunctions (e.g. sprinklers sunken or broken and line blockages). On most fields, the variation due to system malfunction was equal to or greater than inherent systemic pressure drops, indicating system efficiencies could be improved simply by conducting regular sprinkler maintenance checks (Figure 4). This does not take away from the need to insist on within-specification 'at-head' pressures when commissioning and reviewing an irrigation installation.

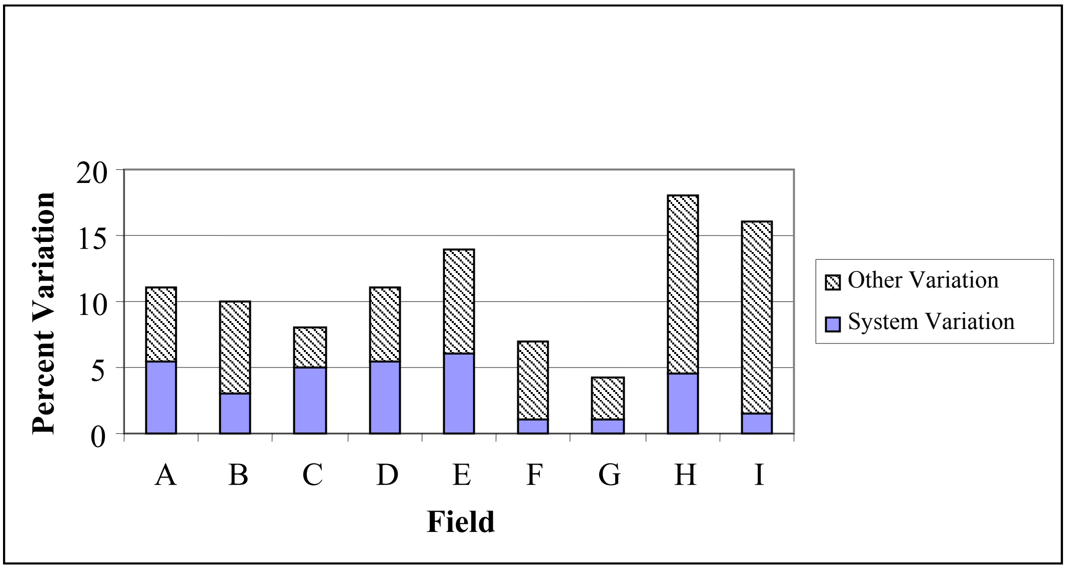

Figure 4: Variation in sprinkler pressure due to system design and other constraints on audited AFLQ fields. Variations are due to both systemic pressure drops, and individual sprinkler malfunction.

A key consideration of system installation is the pressure available from the water source. Clearly if a pump and tank system is used, available pressure should not limit system efficiency. Where the AFLQ irrigation systems were operated on town pressure, even at night, a general lack of operating pressure was identified. The mainline supply on two of the nine fields was insufficient to raise sprinkler operating pressures to the manufacturer's sprinkler specifications. Under-pressurised sprinklers contribute to low distribution uniformities and decreased precipitation rates. Unfortunately, most water supply authorities will not permit the double pumping of reticulated water into a holding tank for redistribution. Nor will they permit the addition of a booster pump to increase the pressure of reticulated water.

Another important issue is the reduction in reticulated water pressure across many water supply systems, as a method of reducing leakage from old pipe systems. This will further compromise the efficiency of systems currently reliant on town pressure. At this stage many of the sports fields will have to look at redesign of their current infrastructure, to cope with lower pressures, or look to additional, independent water supplies.

Distribution uniformity

Calculating distribution uniformity (DU), a measure of how evenly the water applied is distributed over the turf surface, is useful when investigating the efficiency of irrigation systems. High DU indicates the water is being applied evenly to the surface and increases the ability of the system operator to apply specific amounts of water to field surfaces and to produce a surface of even quality. Therefore, the higher the DU of one's system the better, though realistically, a DU of 85% is the highest currently expected DU of a pop-up, rotor sprinkler system.

While it seems low, the reality is that few installed systems reach 70 or 75% DU. The average DU values of the audited AFLQ fields ranged from 51 to 72%, with most between 55 and 65% (Figure 5). The irrigation system of one of these fields was only months old (DU 55%), underscoring the need to check new systems.

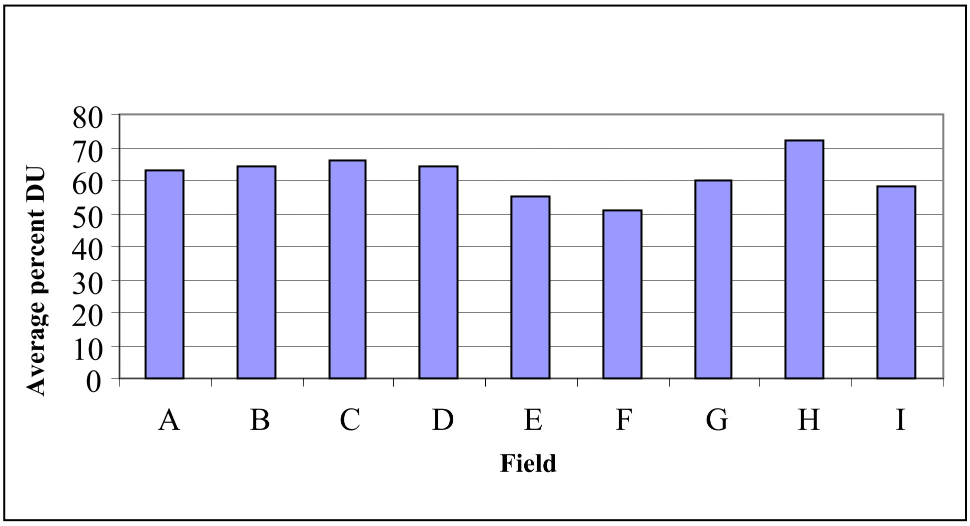

Figure 5: Average percent Distribution Uniformity (DU) of audited stations on AQFL fields. Average DU's across eight of nine fields were less than 67%.

In addition to DU, the catch can (precipitation) data was plotted to visually represent precipitation around each sprinkler. The patterns of precipitation for a dysfunctional sprinkler (ceased rotating occasionally), and systemic problems with sprinkler coverage, are clearly demonstrated in Figure 6. The plots illustrate classical dry areas around sprinklers and wet areas where all the contributing sprinklers overlap.

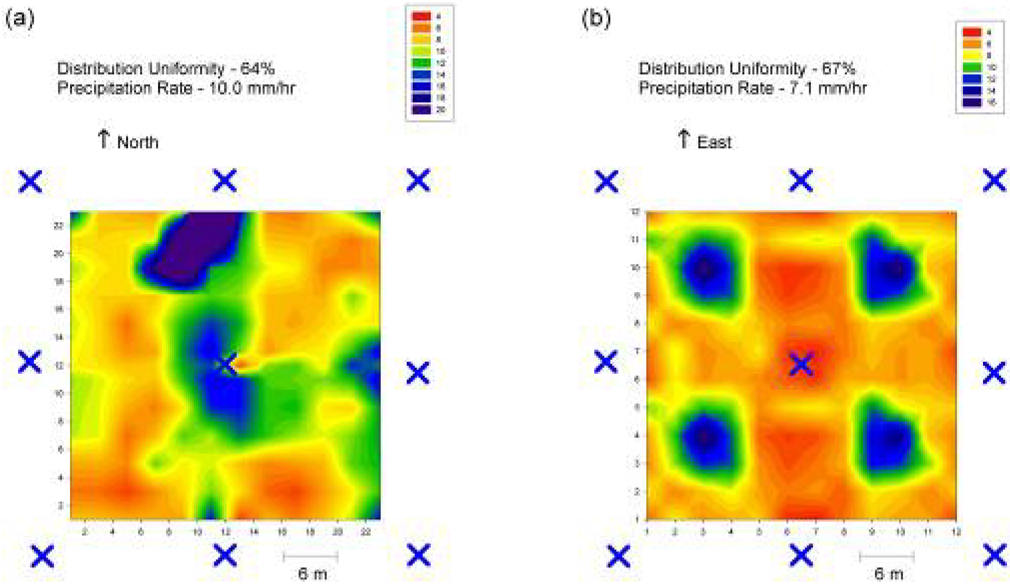

Figure 6: Precipitation patterns with (a) faulty sprinkler rotation or (b) systemic problems with sprinkler coverage. Each cross marks a sprinkler location. Darker areas are wetter.

Average precipitation rates for each of the nine fields ranged from approximately 6.5 mm/hour to 15 mm/hour. The variation within fields was smaller and usually in the order of 1 to 4 mm/hour. In no instance was the precipitation rate more than the field surface could adequately absorb (given a total application of 15 mm or less). Of more concern were low precipitation rates. Even under normal conditions, the whole field surface should be able to be adequately irrigated in a 10 hour period (Cape 2006). With some fields having as many as 16 stations, this would mean each station only operates for 40 minutes. At a 7 mm/hr precipitation rate, this is only 4 mm irrigation. This is particularly problematic as Councils and Water Authorities impose restricted irrigating hours. At the very least, sports field irrigators need to understand the implications of their precipitation rate for managing the scheduling of their stations. It may mean sequential irrigating of different sections of the field over several nights, to ensure adequate application volumes.

Water use per hectare per annum was quite good, with the majority of the nine fields in the range of 3 to 6 ML/ha. Calculated crop factors varied considerably between fields and seasons, from 0.16 in cool seasons to 1.5 in warm seasons. This compares with suggested benchmark minimums of 0.4-0.45 for acceptable performance of turf surfaces (Connellan 2005).

We conclude that irrigation infrastructure should not be under capitalised. We found that over half of the variation on some fields was due to under investment, providing a system that would never meet pressure and DU targets.

An audit of the system needs to be conducted prior to the implementation of any serious scheduling or water management regimes. This is irrespective of the age of the system. Our results highlight the need for new systems to be audited, whether by the supplier or the owner, to ensure the system meets the required criteria.

Regular maintenance is essential and without it significant losses in system performance and DU can occur.

System improvement

We conducted a small experiment to investigate the effect on DU of levelling and fixing sprinklers and of replacing nozzles with those more appropriate to the available pressure. This is analogous to a low-cost retro-fit and maintenance option following an irrigation audit.

An initial catch can analysis on a representative sprinkler location at Mt Gravatt gave a DU of 68%, with an initial dry spot in the south-east corner. The sprinklers (Hunter grey nozzles) were running at 520 kPa, with only a 25 kPa variation between the highest and lowest pressure. Theoretically these should have been throwing a 17.5 m radius and delivering 60 L/hr at that operating pressure. However, five of the nine sprinklers were tilted, and whilst the DU was reasonable, there were obvious drier areas.

We changed the nozzles to higher volume/radius (Hunter brown nozzles), which immediately dropped the operating pressures at the sprinkler head to 425 kPa, varying by 35 kPa from lowest to highest. Theoretically these should be throwing 20.1 m and 71 L/hr at that operating pressure. We re-levelled several sprinklers to the best of our ability. Unfortunately a south-easterly blew up to 15 km/hr during the follow up evaluation, but nevertheless there was a more even application following the retro-fit and maintenance and the DU value of 76% reflects this.

After conversations with irrigation designers on commercial design realities, we did some quick research on the sprinkler systems, and theory behind the spacings, based on industry recommendations. Most systems are being recommended on a 'head to head' design, that is, sprinklers are spaced (square or triangular) so that the sprinkler throw just reaches the closest neighbouring sprinkler.

An initial analysis using sprinkler pattern optimisation software, using a square, head to head design, showed the best DU achievable using the installed system was 75%. This replicated the pattern we observed in our best re-run at Mt Gravatt, where the wettest areas were in the zones in between each of the sprinklers. For this design, 75% was the best DU achievable in an optimised model with the ideal distribution profiles provided by research studies and no wind.

These analyses suggested DU improvements would be limited to around 75%, because of the designs and equipment, and these are the best that industry is currently installing. This was not saying that irrigation designers and installers were doing a bad job—they are simply providing the quality that the users are prepared to pay for. Commercial experience suggested a reluctance to pay higher prices for more effective systems.

The results of this short study suggested:

We could lift the performance of current systems—although low pressures may limit where nozzles can be replaced.

The immediate DU target is confirmed at 70–75%.

There is a longer term requirement for extension work with clubs, funding bodies, councils, Irrigation Association Australia and irrigation suppliers, to try and improve the standard of performance of new irrigation system installations.

System operation

Introduction

During the irrigation auditing process, we discovered most fields were being irrigated 2–3 times a week, mostly with less than 45 minutes per station. As a result, at each irrigation, most fields were only receiving 2–4 mm of water—enough to wet the leaves and some of the thatch, but probably insufficient to penetrate to any depth in the turf root zone. We felt this would mean a greater proportion of the irrigation water would be lost to evaporation, as opposed to transpiration through the leaves to drive effective photosynthesis and turf growth/recovery.

We hypothesised that, provided it could be fitted in with training and play schedules, a weekly irrigation would be more efficient (8–10 mm per irrigation). We also reasoned that strategic irrigations of 15–20 mm would be even more effective, getting water deep into the turf root zone. This would require irrigating not to a calendar schedule, but as a result of some measure of surface condition, such as moisture content or surface hardness. The thought was that these less frequent, higher volume irrigations would mean less proportional loss to evaporation, more chance to store rain in the root zone, and encourage deeper root growth.

Methodology

We evaluated our ideas at Morningside and Mt Gravatt ovals between July 2005 and June 2006. We compared the irrigation practices of experienced ground curators at these grounds, with two alternative strategies targeted at potentially improving irrigation efficiency. We selected three comparable sites on each field; generally low wear areas away from the centre corridor and dressing sheds.

Site 1 was irrigated by the curator, representing the bulk of the field. This constituted the standard irrigation treatment. The actual amounts were 2.5 to 3.5 mm twice weekly at Morningside, and 3.5 to 4.5 mm three times per week at Mt Gravatt. The amounts at Morningside were limited by the requirements of the Queensland Water Commission's reticulated water supply restrictions enforced at the time. Irrigation at the Mt Gravatt field was not restricted, as they sourced their irrigation from a groundwater bore.

Irrigation at Site 2 was also scheduled, but limited to once per week. We set the irrigation controller to use the equivalent of 75-80% of the weekly water volume applied by the curator. Thus the actual amounts were 4.2 to 5 mm once per week at Morningside, and 9 mm once per week at Mt Gravatt.

Site 3 was irrigated at our discretion. This was our strategic irrigation treatment. We tried to irrigate 15–20 mm per time to promote deep wetting and turf root growth. With strategic irrigation, we maximised the period between watering by monitoring turf and soil surface condition, after discussing with the curators what field condition they were comfortable with. Between July 2005 and February 2006, Site 3 at Morningside and Mt Gravatt received five and ten irrigations respectively. For reasons discussed later, the strategic irrigation treatment was discontinued in March 2006.

On each field, we measured surface hardness (Clegg Hammer), and surface water content (Theta probe) twice a week between June 2005 and February 2006. Between April and June 2006 we reduced the frequency to weekly. Once a month, we conducted penetrometer measurements (not reported here), ratings of turf cover and composition, and took photographs of the turf. As in the benchmarking exercises, we took nine measurements with each of the instruments at each of the three sites within each field.

We calculated irrigation volumes from recorded sprinkler run times at each site. Daily rainfall was measured by the curator at Mt Gravatt; daily rain at Morningside, and pan evaporation at both fields, was estimated using the Queensland Department of Natural Resources and Water's SILO database.

Results and discussion

<u>Rain, irrigation and turf condition</u>

From June until mid-October 2005, only 50 mm of rain fell (Table 1), with one event on each field over 10 mm. This compares with evaporation of around 400 mm (SILO estimate of Weather Bureau Class A Pan data) for the corresponding period. By late September 2005, the rain, irrigation and stored soil moisture at both fields was not enough to keep the turf fully transpiring. By mid-October all treatments were showing water stress, with the irrigation strategy having little impact on turf condition at either field.

Between mid-October 2005 and February 2006, between 550 and 600 mm of rain fell on the fields, of which we estimate about 100 mm was ineffective (that is, rain that ran off the surface, or drained beyond the turf root zone). This compares with evaporation of around 940 mm for the corresponding period. For several significant two-three week stretches during this time, the standard and weekly irrigations were switched off by the automatic rain sensor, or the curators manually ceasing watering.

By this time it became evident that we were not reducing total irrigation requirements in the strategic treatment (Table 1). We always seemed to be applying 15-20 mm just before an unpredicted summer storm! Because of the complexity of trying to manage this treatment, and the lack of any apparent advantage, we decided not to persist with it for the rest of the evaluation.

There were two 30–50 mm rain events at the start and finish of the portion of the evaluation from April through June 2006. In between those rains, the irrigations in both the standard and weekly irrigation treatments were sufficient to keep respective areas on both fields in good condition.

In late December, the grass was growing well in all treatments; benefiting from the summer rain. This good growth persisted into June 2006. There was no difference in turf cover between the irrigation treatments for that whole period.

Table 1: Evaporation (Evap'n), rainfall and irrigation values (mm) for Morningside (M'side) and Mt Gravatt (Mt Grvat) sports fields July 2005 through June 2006.

Period	**Evap'n**	**Rainfall**		**Standard irrigation**		**Weekly irrigation**		**Strategic irrigation**	
		M'side	**Mt Grvat**	**M'side**	**Mt Grvat**	**M'side**	**Mt Grvat**	**M'side**	**Mt Grvat**
July - mid Oct.	402	51	46	64	105	51	89	45	74
mid Oct. - Feb.	942	547	586	59	106	26	62	60	123
April - June	340	90	149	104	93	80	77	-	-
TOTAL	**1684**	**688**	**781**	**227**	**304**	**157**	**228**	**-**	**-**

Surface hardness

Reviewing the surface hardness values from Morningside oval (Figure 7), we can see that hardness gradually increased from late June until the 10 mm rain event in early September, however values remained at an acceptable level for a community field (<130 G_{max}). There were no differences between irrigation treatments in surface hardness. During hot dry spells in early October, late November and late December, hardness levels on all irrigated areas at Morningside rose as surface moisture levels dropped. The site receiving the standard irrigation treatment was particularly sensitive to increased hardness as moisture levels fell, peaking above 130 G_{max} on two occasions. Following the heavy rainfall in January 2006, surface hardness at Morningside remained low for the rest of the evaluation period, irrespective of irrigation treatment (Figure 7).

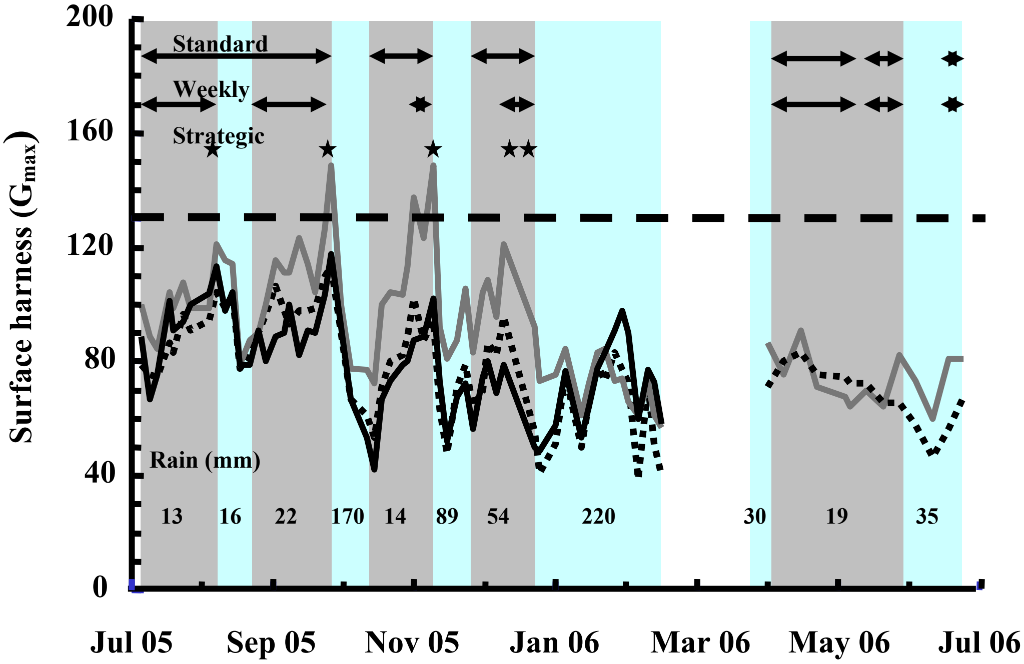

Figure 7: Impacts of irrigation treatments on surface hardness at Morningside sports field, between July 2005 and June 2006. Arrows for standard and weekly treatments show periods when irrigation was operational (otherwise turned off by rain sensor or manually). Stars for the strategic treatment show the irrigation event. The horizontal dotted line shows the current acceptable hardness level for community fields. Background shading shows low rainfall periods. The solid black line represents the strategic irrigation treatment readings. Standard irrigation surface hardness readings are in light grey. The dotted dark line gives readings for the weekly irrigation treatment.

At Mt Gravatt (Figure 8), the standard irrigation kept the site uniformly moist, and hardness remained constantly low for the whole period. The surface of the weekly irrigation site dried out slightly during the early October dry spell, with hardness gradually increasing, but only reached a value of 130 G_{max} just before the October rain. From then on it remained at less than 110 G_{max}.

At Mt Gravatt the strategic irrigation site was interesting and informative. The curator had previously suggested this was a ‘difficult’ area, which always seemed to dry out and need watering before other parts of the field. Our results confirmed that this site did behave differently, with a very strong relationship between soil moisture content and surface hardness. Its surface water content was always lower than other parts of the field, and it had concerning levels of field hardness on several occasions between irrigations.

As an example, the field was waterlogged by 75 mm of rain on 6 November 2005. Eight days later, following a week of fine weather, 50 mm of evaporation and no irrigation, hardness on the strategic irrigation site reached a level of 110 G_{max} (even though the turf was not showing any signs of stress), compared to 80–90 G_{max} on the other two irrigation sites.

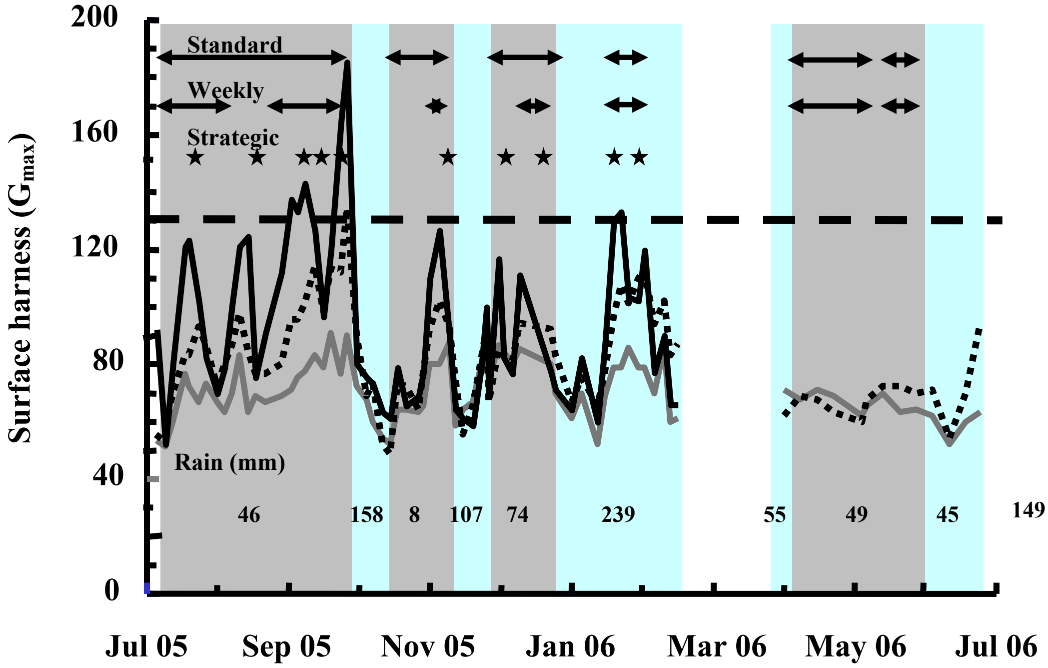

Figure 8: Impacts of irrigation treatments on surface hardness at Mt Gravatt sports field, between July 2005 and June 2006. Arrows for standard and weekly treatments show periods when irrigation was operational (otherwise turned off by rain sensor or manually). Stars for the strategic treatment show the irrigation event. The horizontal dotted line shows the current acceptable hardness level for community fields. Background shading shows low rainfall periods. The solid black line represents the strategic irrigation treatment readings. Standard irrigation surface hardness readings are in light grey. The dotted dark line gives readings for the weekly irrigation treatment.

Key discussion points

In our study, we found weekly watering was as effective as irrigating 2–3 times per week, in providing a suitable playing surface for AFL football. Between July 2005 to January 2006, we used around 0.7 ML/ha less irrigation by weekly watering, compared to more regular scheduled irrigation. Although there were some savings from the intrinsically lower water allocation, the bulk of the difference came through not turning the irrigation back on as soon after rain. This suggests there is scope for improving irrigation efficiency by increasing the sensitivity of the automatic rain sensors supplied with most irrigation controllers, and also 're-tuning' the curators eye, to be able to hold off irrigation that little bit longer.

In our experience, some sites on natural soil playing fields may become hard following 7–10 days without rain, even if the soil profile was fully moist (not waterlogged) before the drying period, and a good turf cover exists. On sand-based fields, this interval may be shorter.

A strategic irrigation strategy is initially difficult to implement, as sports turf surfaces appear to behave somewhat differently to 'standard' irrigation situations. We speculate that dry soil surfaces—even where there is sufficient deep moisture to provide reasonable turf persistence—can result in potentially hard playing surfaces, and reduced turf recovery from wear. Our other major problem was the difficulty in second guessing the weather! It seemed that when we held off irrigation, and applied it in one efficient dollop, it was always just before a summer storm, and we ended up applying more water than the other regular irrigation strategies.

In the weekly treatment from April 2006 onward, we attempted to supply just enough irrigation (say 8–10 mm once a week) to maintain turf recovery and surface hardness at acceptable levels. We relied on rain to provide the water to rewet the full turf root zone at regular intervals (say at least once a month). If, within a month, no rain reached the root-zone, then we planned to initiate one major irrigation to rewet it. This was not required during our demonstration period.

A combination of a sufficiently sensitive rain sensor on the irrigation system, and responsive curator behaviour in reaction to rain, may further increase our water saving.

Irrigation recommendations

The following is a summary of recommendations included in the majority of talks and forums, presented to numerous turf managers and sporting bodies in various guises during 2005-2007.

Why do we irrigate?

- It promotes persistence of turf cover, by increasing turf recovery rates, and potentially improving wear tolerance
- It can reduce hardness—the primary risk factor for closing community sports fields
- It aids turf survival and growth during prolonged drought

Reduce irrigation requirement by:

- Not depending on irrigation to keep the surface soft—this is a vicious circle, as surfaces are **most** prone to compaction if wet!
- Improve soil structure to reduce irrigation needs. Good structure gives:
  - Lower ground hardness for a given moisture content
  - Better turf growth and wear tolerance/resistance
  - Deeper turf roots and therefore access to stored soil water (particularly from rain, but also some derived from irrigation)

Getting the irrigation equipment right

- Make sure the system design can deliver good sprinkler pressure, and at least go 'head to head[1]'. Aim for distribution uniformity of 75% or better.
- Try for capacity of at least 8 mm per irrigation event (e.g. over a 10 hour period). With a lower system capacity, work out how to irrigate alternate areas of the field on different nights. This will require coordination with the potential users.
- Make sure the system is working properly! Poor system maintenance is a major problem.
- At installation, try and ensure the stations run **with** the usage pattern, not across it. For example, on an AFL field it is ideal to have stations that just irrigate around the goal mouths, and the remainder running parallel to the centre corridor. In that way, the high wear areas can be irrigated more frequently, and the low traffic areas (e.g. the flanks) irrigated sparingly. Figure 9 shows the Morningside design is more useful in this regard than the Coorparoo design.

[1] A design where each irrigation sprinkler head throws water as far as the sprinkler heads to the left and right (and any others within it's throw path). This provides even water coverage.

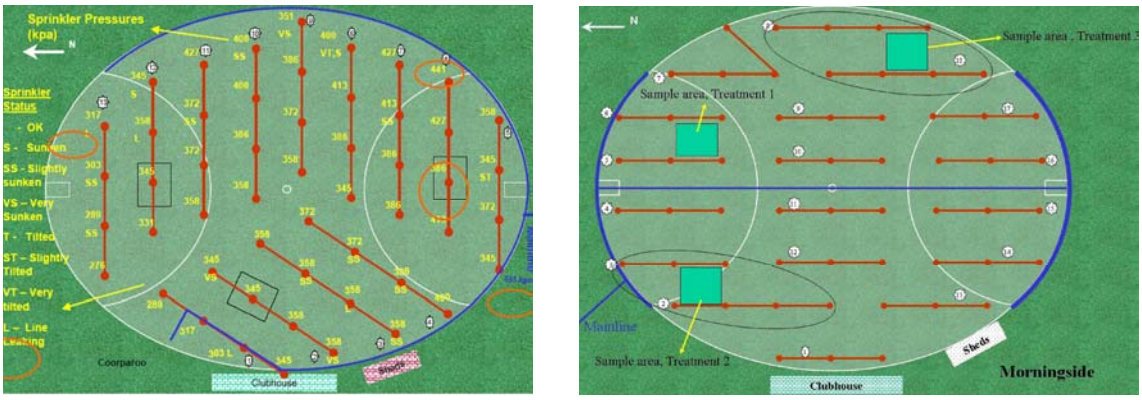

Figure 9: Comparison of irrigation designs, non-compatible (left) and compatible (right), with differential irrigation of high wear areas.

Irrigation schedules

- Turf can go several weeks between irrigations without significant long term effects. However, wear recovery may be reduced, and surfaces can get hard
- In our trial work weekly irrigations provided the best compromise
- Recommend a run time of **at least** 30 minutes per sprinkler (assuming a delivery rate of 8-10 mm/hr)
  - Shorter runs are too inefficient
  - Runs of 1 hr are preferable

The main messages

- Get the people things right—awareness, communication, training, agreed action plans
- Avoid obvious faults! Examples are leaking or broken pipes/sprinklers, overgrown sprinkler outlets and malfunctioning controllers
- Manage soil structure! Hardness is the key turf/soil risk factor
- Make sure the person responsible for administering irrigation understands both irrigation concepts **and** the specific equipment
- Make sure access to the irrigation controller is secure, so that:
  - It comes on when you want it on
  - It stays off when you want it off
- The **key** to water saving is how often the irrigation is **not** active!
- Ensure the rain sensor is sensitive and functioning
- Install and use a rain gauge. Keep your own records. Rain can vary significantly over a distance of just a few hundred metres, particularly during storm events
- Maximise the benefits of any rain with good soil structure, which will promote strong root systems and good turf growth.
- Test yourself—how long can you comfortably hold off irrigation after rain?
- If really stretched for water (through absolute volumes available, or imposed water restrictions), prioritise to irrigate the most actively used areas

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Using recycled water for irrigation—valuable resource or risk for soil and turf?

Dr Rachel Poulter
Department of Primary Industries and Fisheries, Redlands Research Station, Cleveland

Introduction

In this discussion, recycled water is that produced from wastewater and stormwater after treatment and filtering. The resulting water is generally suitable for irrigation and other purposes, but is unsuitable for human consumption. Recycled water is available from various central collection sites under the jurisdiction of local councils. The subject of greywater (that is, individual household waste water) is not covered by this paper. However, greywater derived from the hand basin, shower, bath, washing machine, and laundry tub, can now be used for irrigation following approval from local councils.

Recycled water is already being used in the United States, Israel and Australia for irrigating a range of crops and gardens. In fact, irrigation of various crops with recycled water has been practiced around the world for more than 50 years (2007, National Coordinator for Recycled Water Development in Horticulture, http://www.recycledwater.com.au).

Hazards

Not all plants and soils can be safely irrigated with recycled water. There are hazards that users need to understand to ensure that the use of recycled water is sustainable for turf irrigation. Councils generally provide a detailed report from the analysis of water samples from each source. These documents provide valuable information in helping consumers decide on the suitability of water for irrigation. However, there are some complexities in the interpretation of the data presented.

Interpretation of water analysis reports

Water analysis reports provide information on factors such as: salt concentration, mineral composition, and pH. However, various parameters that indicate whether the applied water is likely to cause soil structural problems usually have to be calculated from the presented data by the end user or consultant interpreting the data.

Total salt concentration

The total salt concentration of the tested water is one of the most important pieces of information presented in the water analysis report. High levels of soluble salts can induce physiological drought in the plant. Turf roots may have an adequate water supply, but are unable to absorb the water due to osmotic pressure[2].

The total salt concentration can either be expressed as total dissolved salts (TDS) or Electrical Conductivity (EC). Both measures may be presented on the report. The units of TDS are parts per million or milligrams per litre (ppm or mg/l), while electrical conductivity has the units of deci Siemens per metre or milli-mhos per centimetre (dS/m or mmhos/cm).

[2] In this case: the pressure exerted by the external saline water, preventing the movement of moisture into the interior of root hairs.

It is possible to convert between the two using the following equation:

TDS in ppm or mg/L = 640 X EC_w in dS/m or mmhos/cm

Table 1 lists the levels at which the salt concentration poses a hazard when considering the water for an irrigation source.

Table 1: Salinity levels posing a hazard in irrigation water.

TDS ppm or mg/L	**EC** dS/m or mmhos/cm	**Salinity Hazard**
<500	<0.8	Low
500-1000	0.8-1.6	Medium
1000-2000	1.6-3	High
>2000	>3	Very High

Plant tolerance to high salinity is species specific. Knowing the salinity tolerance of turf species allows confident use of lower quality water sources for irrigation. Table 2 is a summary of findings from turfgrass salinity tolerance screening conducted at Redlands Research Station (Loch *et al*, 2005). Detailed results are included in the final report for the project, which is available from Horticulture Australia, <http://www.horticulture.com.au/main.asp>.

Table 2: Salinity tolerance of turf species.

Salinity Hazard	**Effect on Turf**	**Suitability**
Low (EC <0.8)	No detrimental effects	Suitable for all turf species
Medium (EC =0.8–1.6)	Sensitive plants show salt stress.	Not suitable for blue couch or kikuyu. Sensitive varieties of green couch and buffalo grass (St Augustine grass in U.S.A.) may show signs of stress.
High (EC = 1.6–3.0)	Salt tolerant plants only	Not suitable for green couch or buffalo grass. *Zoysia matrella* may start to show signs of stress.
Very High (EC >3.0)	Very salt tolerant plants only	Halophytes such as seashore paspalum (*Paspalum vaginatum*)*;* marine couch (*Sporobolus virginicus*) and; *Distichlus spicata* are the only grasses likely to survive. Sensitive varieties may show signs of stress reducing the quality of turf at these sites.

Using a salt tolerant grass is not a silver bullet when it comes to using salt laden water for irrigation. It is important to be aware that salts in the water can build up due to evaporation and damage both plants and soil.

It is possible to ensure that salt levels in the soil do not exceed that of the irrigation water by leaching the salt beyond the root zone. Adequate drainage is needed to ensure that this salt laden water does not cause further environmental damage.

The fraction of irrigation water that must pass through the root zone to control salts at an acceptable level is described as the leaching requirement (LR) or leaching fraction. It is derived from the following equation.

$$LR = \frac{EC_w}{5EC_{ec} - EC_w}$$

Where:
EC_w = irrigation water salinity (dS/m)
EC_{ec} = threshold soil salinity at which growth starts to decline for the turfgrass on the site.

Specific ions
Concentrations of various dissolved ions in water are also available from the analysis reports.
Soluble salt ions found in recycled irrigation water are:

- **Cations**
  Calcium (Ca^{+2})
  Magnesium (Mg^{+2})
  Sodium (Na^{+1})
  Potassium (K^{+1})
- **Anions**
  Carbonates (CO_3^{-2})
  Bicarbonates (HCO_3^{-1})
  Chloride (Cl^{-1})
  Sulfate ($S0_4^{-2}$)
  Nitrate (NO_3^{-1})
  Borate ($B0_3^{-2}$)
  Phosphate ($P0_4^{-3}$)

Specific ions can be toxic to plants and/or detrimental to the soil physical structure. Certain salt ions (sodium, chloride and boron) can cause direct root injury, accumulate in shoot tissues and cause shoot toxicity problems, or cause direct foliar toxicity on plant leaves. These problems are almost always present when high total salinity is present. Other ions cause management problems. Bicarbonates and carbonates precipitate calcium and magnesium ions, leaving sodium to degrade soil structure. Sulphates can enhance the development of black layer and iron, carbonates and bicarbonates can produce unsightly stains or foliar deposits.

Risk parameters for soil structural degradation

Some background
Colloidal or clay particles are surrounded by a “diffuse double layer” where charges on the mineral surface attract cations from solution. This layer is often referred to as the exchange complex. Soil structural degradation occurs when sodium ions replace the more charge dense ions such as calcium. The diffuse double layer expands in the presence of hydrated sodium so that particles repel each other, filling pore spaces and consequently reducing the ability of the soil to absorb and transport water. This process is illustrated in Figure 1.

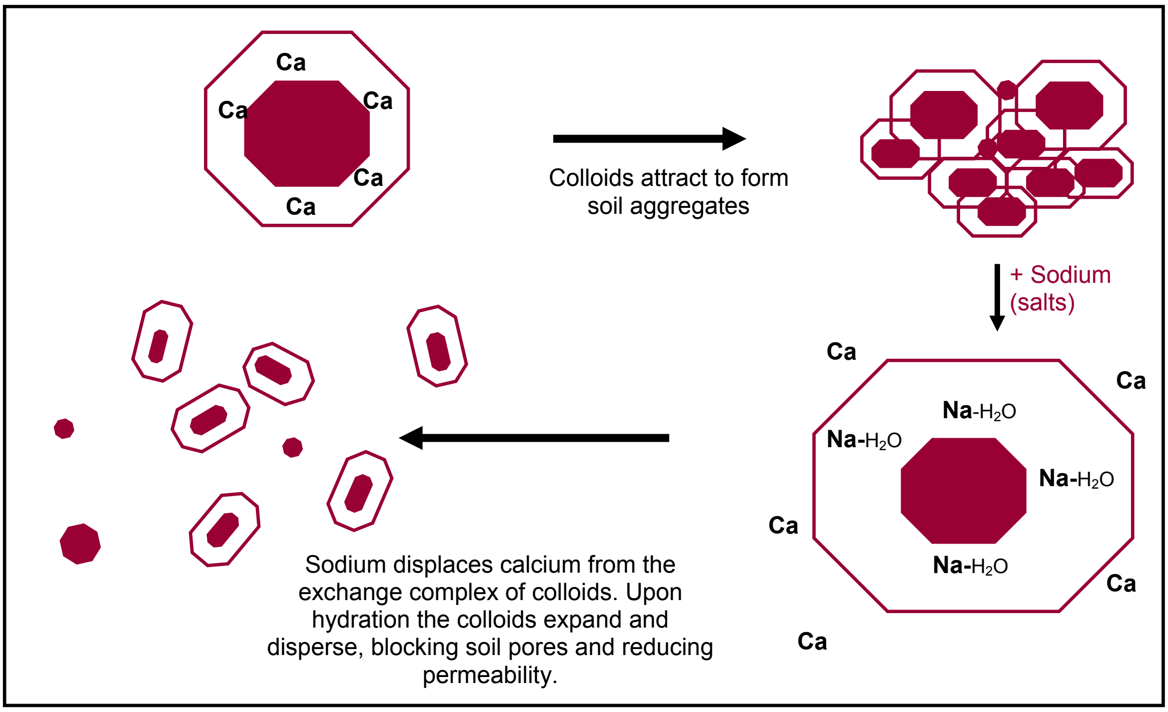

Figure 1: The process of structural degradation of soil particles when sodium dominates the exchange complex.

Sodium Absorption Ratios and Residual Sodium Carbonate

Parameters calculated from ion concentrations in the water analysis report help to determine the risk of susceptible soils becoming dispersed.

First, all concentrations must be converted to milliequivalents per litre (meq/L).

1. The following equation converts parts per million or milligrams per litre to milliequivalents per litre:

$$meq/l = \frac{ppm \cdot (mg/l)}{Equivalent \cdot weight}$$

Where equivalent weights are:
Calcium = 20
Magnesium = 12.2
Sodium = 23
Sulphate = 48
Potassium = 39
Bicarbonate = 61
Carbonate = 30
Chloride = 35.4

2. The sodium absorption ratio (SAR_w) is calculated using the following equation, where sodium, calcium and magnesium levels are given in meq/L:

$$SAR_w = \frac{Na}{\sqrt{(Ca + Mg)/2}}$$

SAR$_w$[3] quantifies the ratio of sodium to calcium and magnesium in terms of the ability of sodium to dominate the exchange complex of the soil. The lower the SAR$_w$ the less likely the water is to cause structural degradation of susceptible soils. Table 3 outlines the levels at which the SAR$_w$ indicates a hazard to soil structure. The susceptibility of differing soil types to degradation is then further quantified in Table 4.

Table 3: Hazard levels for SAR$_w$

SAR$_w$	Hazard
<10	Safe to irrigate with no structural deterioration but, may affect salt sensitive plants depending on EC/TDS (see Table 4)
10–18	Hazard on fine textured soils with a high cation exchange capacity. OK on coarse textured soils with good drainage (Table 4)
18–26	Hazard on most soils. Need to manage with amendments and drainage i.e. leaching.
26	Not suitable for irrigation.

Table 4: SAR$_w$ limits based on soil type

Soil	No Hazard	Slight to moderate hazard	Severe hazard
2:1 clays	<6	6-9	>9
1:1 clays	<16	16-24	>24
Sand: EC$_w$>1.5 dSm^{-1}	<16	16-24	>24
Sand: EC$_w$<1.5 dSm^{-1}	<6	6-9	>9

2:1[4] clays such as montmorillonite, illite and smectite are the common clay minerals found in black earths and yellow solodic soils. 1:1 clays such as kaolinite are commonly found in self mulching red-brown earths (krasnozems). The SAR$_w$ at which a 2:1 clay is at risk is lower than for a 1:1 clay, as the bonds holding the 2:1 clay platelets together are more unstable in water than those of a 1:1 clay mineral.

The overall electrical conductivity of the water also has an affect on the level of sodium hazard. From the above table (Table 4) it may seem confusing that a low electrical conductivity in the water poses a risk at a lower SAR$_w$. Where conductivity is high, the presence of ions other than sodium (calcium and magnesium) helps to limit the size of the diffuse double layer. At low conductivity, hydrated sodium can easily move into and expand the diffuse double layer. Similarly pure water applied to a sodic soil can be detrimental to structure.

[3] The subscript $_w$ in the SAR indicates the SAR is for water rather than soil.
[4] The 2:1 and 1:1 ratios refer to platelet layers in the clay lattice and are used as descriptors for particular types of clay.

Table 5 gives a range of SAR_w values from sampled water sources.

Table 5: Example sodium adsorption ratios**.**

Source of water or effluent[5]	**Minimum**	**Mean**	**Maximum**
Town water supplies—coastal	0.2	1.0	2.3
Town water supplies—inland	0.4	1.7	4.5
Groundwater—sedimentary aquifer	0.1	0.9	5.2
Groundwater—granite aquifer	0.5	1.6	3.2
Groundwater—basalt aquifer	0.7	0.8	2.7
Septic tank effluent	0.7	3.6	9.6
Sewage treatment works effluent	2.6	3.9	5.1
Laundry water—powder detergents	1.2	9.2	52.1
Laundry water—liquid detergents	0.02	1.0	4.0

Source: Dr Robert A. Patterson (2006) Consideration of soil sodicity when assessing land application of effluent or greywater. Septic Safe Technical Sheet 01/7 NSW Department of Local Government, viewed on 6 June 2007, <http://www.lanfaxlabs.com.au>/publications.

3. Residual Sodium Carbonate (RSC) predicts the accumulation of sodium in the soil based on the potential precipitation of calcium/magnesium carbonate. This is calculated using the following equation, where ion levels are given in meq/L:

$$RSC = (CO_3 + HCO_3) - (Ca + Mg)$$

A negative RSC indicates water is unlikely to cause structural degradation. An RSC greater than zero indicates a potential hazard to soil structure. Additions of calcium (gypsum) or acidification of the water prior to use may be required.

pH

The ideal range for plant growth is 6.0–8.0, although most turfgrasses can tolerate levels down to pH 5.0. However, changes of soil pH by water are slow. pH has more effect on soils with a low cation exchange capacity[6]. It is generally considered beneficial to correct pH where the RSC is high. Another consideration with an abnormal pH is corrosion or precipitation in irrigation equipment

Soil properties

The cation exchange capacity and constituents on the exchange complex will also determine how a soil will respond to the chemistry of recycled water. It is generally accepted that only soils with clay content greater than about 20% have the potential to disperse.

[6] Such as sands.

Soil analysis reports include a list of concentrations of each of the exchangeable cations and overall cation exchange capacity. From these it is possible to calculate the Exchangeable Sodium Percentage (ESP). This parameter describes the current status of the soil in terms of the dominance of sodium in the exchange complex. It is calculated by:

$$ESP = \frac{ExchNa}{CEC}$$

Where:

ExchNa = Exchangeable sodium (meq/100g)
CEC= cation exchange capacity (meq/100g)

An ESP less than 3 is regarded as having no problems, 3–15 indicates problems are increasing and greater than 15 suggests severe problems and that the soil needs amelioration with calcium. This is usually applied in the form of gypsum. Lime is only used if the pH is also low and there is a requirement to raise it.

Conclusion

Recycled water is a valuable resource provided we match the quality of the water to the soil and plant.

It is essential to understand the potential risks involved in using recycled water—these can be determined by regularly examining and interpreting the water analysis reports of the recycled water. Use the above guidelines and equations. A soil analysis will indicate the suitability of the soil to which the recycled water is applied.

Check regularly for adverse effects on plants and soil, so that problems are found quickly and treated early through amendments or leaching.

For best results, use quality recycled water, supplemented by occasional flushes with very good quality water in a suitable soil.

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So you think you know your soil?

Keith McAuliffe
Chief Executive Officer, Sports Turf Institute (Australia), Cleveland.

Email:Kmc30745@bigpond.net.au
Mobile 04 24634717

Introduction

In SE Queensland the current water crisis has created an unprecedented interest in optimizing water use efficiency and devising alternative water supplies for turf irrigation. Long forgotten are those days of sodden playing fields and unplayable conditions due to water logging. Drought is the challenge of today and will be the focus of this paper.

It would be fair to say that the focus of attention for water use efficiency in irrigation has been on the above ground component—the water supply and distribution system. We talk about coefficients of uniformity as the basis for determining if water is being applied efficiently. However, from my experience, getting water applied uniformly to the surface is only the start of the water use efficiency story; much can happen beyond the point of water application to completely change the picture.

Unlike the hardware of a watering system we can't design on paper how a soil will behave. N**o two soils are the same**. As such, management must be tailored to suit the specific needs of each site.

Further, the **properties of a soil can change dramatically over time**. Take a new sand sports field for example. At the time of construction the field may have an infiltration rate of say 300 mm per hour. Within 12 months this value may have dropped to say 80 mm per hour, as a result of the build-up of organic matter and other fines. Yet further, if nothing is done about the build up we may find the infiltration rate drops to the point where applied water ponds. It could even get down to zero if the surface sand/mat layer becomes water repellent.

To get the best from a soil requires an understanding of the soil properties. It is no use assuming your soil will behave like that down the road.

Two important points:

Every soil is different
Soil characteristics can change with time

Relevance to WEMPS

Those with irrigated sports fields are required to undertake a Water Efficiency Management Plan (WEMP). The WEMP process involves monitoring quantities and frequencies of water application, as well as measuring properties of the watering system, such as uniformity coefficient and system pressure.

The question needs to be asked as to whether sufficient attention is given to the soil and its management. The soil and how water enters and moves through it is going to have a significant bearing on the systems water use efficiency, as outlined below. The soil water distribution phase shouldn't be neglected, simply because it is a little harder to understand than the above-ground phase.

So how do we get a better understanding of our soil?

How much can we tell about a soil from just looking at the surface? Can a doctor tell what a patient is sick from by just surface appearance?

To understand your soil it is important to investigate what is going on below ground. Just like a doctor will call for scans, x-rays and exploratory surgery to get to understand what is wrong, so too do **we need to dig and probe**. We need to examine the soil profile from the surface to the depth. This allows us to evaluate the soil physical properties, such as soil texture, structure and features of the pore system. We need to consider the pores (size, number and continuity) to understand the drainage, aeration and water storage properties. We need to look at the behaviour of the root system and soil properties such as colour, hardness, stone content, organic content, layering and signs of any microbial activity.

A soil examination—what to look for?

Soil texture—Refers to the relative proportion of sand silt and clay in a sample. Sandy soils are generally considered well-drained but droughty, and silts and clay soils can be boggy but are high in water and nutrient retention. The word loam is used to indicate a soil with a similar proportion of sand, silt and clay.

Soil structure—refers to how the individual soil particles are bonded together. Without structure silt or clay soil does not drain internally and lacks the oxygen needed for the development of root systems.

Macropores—Larger visible pores that will allow roots and water to drain, such as: old root channels and cracks. Check for pores that are continuous to depth, such as worm or old root channels.

Root system development—where roots go so too will water. Check the effective rooting depth.

Other factors include: organic matter, soil colour (any discoloration or red staining may indicate poor drainage), soil hardness and stone content.

How water moves through soils

It is natural to assume that applied irrigation water will evenly penetrate into and evenly move through the soil. Theory suggests water penetrates as a neat uniform wetting front, progressively getting deeper.

But in reality this is the exception. The norm is for water to track down through the soil unevenly via larger soil openings—often without actually wetting the root zone. This process is often referred to as "preferential flow".

The mechanism of preferential flow

A driving force for free (ponded) water movement at or near the surface is gravity. Water will find the path of least resistance—often over the surface or downwards into cracks, old root channels, core holes and the like.

Preferential flow, while helping drainage and deep water penetration, can be a major source of water use inefficiency. This is especially true if there are continuous macropores linking into a deeper layer beyond the root zone, resulting in the water being lost to plant growth. Further, preferential flow will lead to poor uniformity of water distribution.

Water repellency—an added cause of poor water use efficiency

Water repellency occurs when the soil becomes hydrophobic and doesn't allow water to soak in. Water repellency can accentuate any water loss via surface runoff of ponded water, or via preferential flow, where water moves through zones that are non-repellent.

The mechanism of water repellency and steps to prevent it from occurring are touched on elsewhere in this seminar.

How do we find out what is happening with water movement in our soil?

We could get some idea of how water moves in our soil by:

- Studying the pore system (size, continuity etc.)
- Dye staining
- We could take plugs out after watering and check moisture content
- We could core sample or excavate

Minimising losses via preferential flow

There are a number of options that can help to minimise water loss through preferential flow, including:

- Avoid irrigation methods which cause ponding. Give preference to low application rate sprinklers.
- Stagger water applications to allow infiltration to occur before the next application of water. This allows ponding to be avoided. Water can then move into the soil by capillary pull between pulsed applications.
- Use surfactants.
- Don't let the soil get too dry before watering, thereby minimising cracking or water repellency.
- Be wary of physical treatments which might cause preferential flow (e.g. deep vertidraining in a gravelly soil or slicing over drain lines).

Summary

To get the best out of your soil requires a sound understanding of the key physical properties of the soil. It will be necessary to take out cores or dig a hole to observe key soil properties such as texture, structure, macroporosity and root depth.

Water movement into and through a soil seldom conforms to ideal theory, and the process of preferential flow is common-place. Preferential flow is a potential cause of poor water use efficiency, so an understanding of it and how it can be minimized is an important part of optimizing water use efficiency.

Wear Tolerance Study on *Cynodon* Cultivars

Matt Roche
Department of Primary Industries and Fisheries, Redlands Research Station, Cleveland

Background

"Traffic stress" is the general term that covers both soil compaction and turfgrass wear components (Beard, 1973). While soil compaction and turfgrass wear may occur simultaneously on a site, one is usually the dominant stress (Carrow and Petrovic, 1992). Wear dominates on high-sand root zones (e.g. elite sports fields) and when moisture becomes limiting on heavy soils, while soil compaction dominates on fine-textured soils at high moisture contents (i.e. field capacity or greater).

Turfgrass wear injury involves direct damage to shoot tissues by mechanical pressure, abrasion, scuffing, tearing, or divoting action. The nature of turfgrass wear injury can vary greatly depending on the type of traffic, for example football, polo, soccer, and other activities such as walking all exhibit specific characteristics of play. Wear tolerance consists of two main components: resistance to wear, followed by recovery from wear. Turfgrass species differ in the relative importance of these two components in terms of their wear tolerance. Species that are resistant to wear use less water, as they do not have to regrow biomass.

Evaluation of turfgrasses for wear tolerance has become increasingly sophisticated over the past 30 or so years, starting with Canaway (1976), who recognised the importance of incorporating a differential-slip (tearing) action into wear studies. Advances on simulating wear were made with the construction of the Brinkman Traffic Simulator, constructed in California (Cockerham and Brinkman, 1989) and the GA-SCW Simulator developed in Georgia. These machines enabled the rapid and uniform application of wear to turfgrass. Studies conducted by Carrow *et al.* (2001) using the GA-SCW Traffic Simulator indicated that wear damage from eight passes is roughly equivalent to one game of American football (National Football League).

Cynodon Wear Experiment

Wear trials were established at the Department of Primary Industries and Fisheries' (DPIF) Redlands Research Station at Cleveland, Queensland. Here, the machine used to apply treatments is based on the GA-SCW design. However, in these studies on *Cynodon* wear tolerance, it was drawn by a small Kubota tractor much like the original Brinkman design. Another major difference is that the DPI&F's wear machine uses smooth rubber galvanised rollers (1 m wide), rather than studded rollers as described by Carrow *et al.* (2001).

The basic experiment was a randomised block design, with individual plots (6 x 2m) allocated at random to eight different *Cynodon* cultivars within each of four blocks (replications). This was situated on an irrigated 15-cm sand profile with internal drainage to remove excess water.

Superimposed over the basic experiment was a two-level strip-plot design to accommodate wear treatments, which of necessity had to be applied in straight lines. Strips within each level were again allocated at random. A 2.4m wide strip of *Cynodon* was over sown with perennial ryegrass (to simulate standard winter management of elite fields), leaving the remaining 3.6m strip as a pure *Cynodon* sward. Two wear treatments were imposed on each of the ryegrass/*Cynodon* strips and three wear treatments were applied to each of the pure *Cynodon* strips.

Within the pure *Cynodon* treatments, this provided a simulated comparison of weekly play versus a fortnightly home-and-away schedule against no wear. For the fortnightly and no wear treatments, this design provided a direct comparison of the effect of ryegrass oversowing.

Winter-Spring Wear Study

Plots were fertilised frequently and mown regularly at 25 mm to simulate the normal management of a football field. Wear treatments commenced on 14 July and ended on 27 September 2006. On the first three wear occasions, both weekly and fortnightly wear treatments received 30 passes with the DPIF wear machine. Subsequently, wear was reduced to 20 passes per week on the weekly treatment, but increased to 40 passes per fortnight on the fortnightly treatment.

Substantial differences in wear tolerance among cultivars quickly became apparent and persisted through to the end of the trial (Plate 1). The four best cultivars (in random order)—TifSport™, 'Grand Prix', Legend™ and Conquest™—continued to produce new leafy growth following each wear event; but after 4-6 weeks, the other four grasses had either stopped producing new leafy growth (especially under the weekly wear regime) or in the case of some 'Wintergreen' plots were producing new leaves at greatly reduced rates.

Turf quality under fortnightly wear did not decline to the same extent as under weekly wear. The recovery potential between fortnightly wear events was also much greater than where there was only a week between wear events, particularly for the top four grasses.

Wear on the oversown sub-plots was more uneven (patchy) and variable than on the comparable pure *Cynodon* sub-plots. Overall, however, ryegrass established more strongly in the more open grasses and these treatments resisted wear and maintained slightly higher turf quality than the denser grasses in both pure and oversown swards, though cultivar differences were generally not significant.

Plate 1. Aerial view of wear damage (6 October 2006).

The percentage of bare ground increased rapidly in the worn treatments before stabilising after about 3–4 weeks of treatment. Up until mid-August, recovery from wear was very slow and the results largely reflected differences among the cultivars in their resistance to wear. However, once growth rates started to increase with the return of warmer temperatures from about mid-August onwards, recovery from wear became an increasingly important component of wear tolerance.

At the end of the trial period, samples of above-ground material (leaf and thatch) were cut for fibre, lignin and ash analysis. Differences in wear tolerance were not associated with shoot moisture content as suggested by Trenholm *et al.* (1999, 2000) and Brosnan *et al.* (2005) for other species, nor were they associated with the levels of minerals (ash), silica (acid insoluble ash) or acid detergent fibre (ADF) present. However, wear tolerance was strongly and positively associated with levels of total cell wall constituents (TCW), lignin and neutral detergent fibre (NDF). Essentially, this confirms the importance of cell wall strength in determining the wear tolerance of different *Cynodon* cultivars, as shown by Trenholm *et al.* (2000) and Brosnan *et al.* (2005) with other warm- and cool-season grasses, although both highlighted other contributing factors as well.

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Rootzone amendments to improve soil moisture relations under newly-laid sod

Donald Loch, Rachel Poulter, Alan Duff, and Craig Henderson
Department of Primary Industries and Fisheries, Redlands Research Station, Cleveland

Background

Turf as newly-laid sod is at its most vulnerable in terms of the need to maintain moisture around the roots until deeper roots extend through the turf underlay medium. Newly laid sod also draws attention as a visible water user. At the community level, there is an increasing need to use water more efficiently as water shortages are encountered more frequently across Australia and in most developed and developing nations around the world. The growth of urban populations, coupled with growing lifestyle expectations and periods of lower than average rainfall, is putting greater pressure on existing water supplies to the point where arbitrary water restrictions are being imposed for long periods by local authorities. In Australia, for example, the period allowed for watering of new lawns varies from 0 weeks (previously 6 weeks under level 2 restrictions) in Melbourne to just 2 weeks in Brisbane (under both level 2 and 3 restrictions), decisions made without any independent research validation.

A number of products have been developed with the aim of improving soil water-holding capacity. Some of these are currently being marketed to enhance the establishment of newly-laid turf sod, but with little or no independent research to support manufacturers/distributors claims. These products include various water-holding crystals (cross-linked polyacrylamides), starch-and organic-based materials, and more recently a water-absorbent foam.

There is some anecdotal evidence locally that shallow placement of products helps establish turf more rapidly and with less water. Depending on the product, recommendations vary from mixing them through the underlay soil to enhance long-term root development to placing product just below the laid sod where the immediate need for moisture is greatest.

Objectives

1. To document the development of the root system of newly-laid sod through to establishment for three warm-season turfgrasses; and

2. To investigate if the early need for regular watering can be reduced and rate of establishment enhanced by placing water-holding amendments below the sod before laying.

Experimental Design

Three short-term experiments each covering the establishment period (approximately 8 weeks) for newly-laid sod were planned. Phase 1 has been completed and Phase 2 recently commenced. In each case, the design is a 2 x 11 x 3 split-split-plot design with four overall replications arranged in randomised blocks.

- ***Main plot*** Two watering regimes (watering daily or every second day with 4 mm of water to give 28 mm and 14 mm per week respectively).

- ***First split*** Twelve soil amendment treatments (untreated control and five soil amendments each applied as two treatments (one product has 2 rates).

- ***Second split*** Sod of three warm-season grasses; green couch (*Cynodon dactylon*) and buffalo grass (*Stenotaphrum secundatum*)—both fast-rooting species, and zoysia (*Zoysia japonica*)—a slow-rooting species).

Methods

Eight independently programmable irrigated plots have been installed to accommodate the eight main plots (2 watering treatments x 4 replications). Within each main plot, weed mat was laid over the native soil and the 7.2 x 7.2 m experimental area surrounded by 10 cm thick sleepers. Split-plots (3.6 x 1.2 m) of each soil amendment treatment were prepared within each blocked-off main plot. Sod of the three grasses was laid on 1.2 x 1.2 m split-split-plots within each of the soil amendment treatments. After laying, each area was then watered to field capacity as per normal turf laying practice, and the two watering regimes then imposed.

Measurements

- Rooting depth was assessed by measuring the maximum length of roots under each individual split-split-plot. Initially, this was achieved by lifting up a section of a sod roll to assess root growth. As soon as the surface was stable a 50 mm corer was used for these measurements.

- Root dry weights from washed 50mm core samples.

- Weekly measures of soil moisture content using an MP406 soil moisture probe from ICT International.

- Weekly ratings of turf quality and/or death to assess the effectiveness of each watering by amendment combination.

- Soil and air temperatures were logged hourly using Thermocron temperature buttons.

- Additional temperature, rainfall and pan evaporation data are available from the Redlands Research Station weather station approximately 200 m from the trial site.

Proposed Duration and Experimental Timetable

Three short-term experiments (maximum of 8 weeks each) are planned in summer, autumn and spring 2007. Experiment 1 (completed) investigated the placement of each product, and experiments 2 (commenced) and 3 will investigate the effect of the recommended rate and double the recommended rate of each product for the optimised placement method.

Alterations to Methodology Based on Experiences from Experiment 1

Sandy loam soil replaced with a USGA sand with lower water retention.

Irrigation was reduced to impose greater stress on turf. However, current rainfall trends have negated any imposed drought stresses. For the final phase of this experiment some form of rainout shelter will be investigated.

Weed mat has been replaced with damp course plastic sheeting, as roots were found growing through the weed mat and accessing water stored in the native soil profile beneath.

Preliminary Results—Experiment 1

Green couch

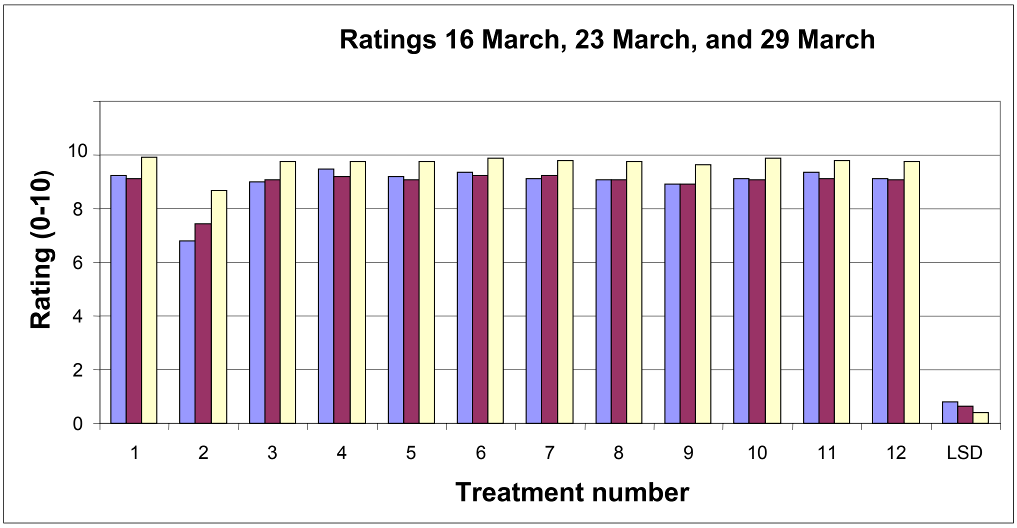

Figure 1: Turf quality ratings per treatment for green couch during March 2007. Treatment 1 had no amendments.

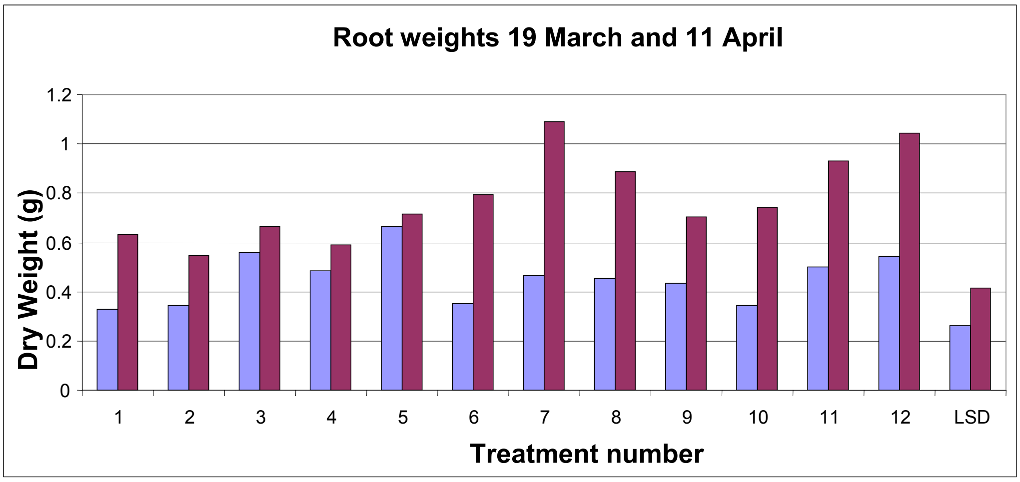

Figure 2: Root dry weights per treatment for green couch in March and April 2007. Treatment 1 had no amendments.

The turf ratings were similar for all treatments (see Figure 1) with the exception of Treatment 2, which was slower to establish due to poor root contact at the sod-soil interface. Treatments 7 and 12 showed best root growth overall (see Figure 2). Treatment 5 showed faster early root growth.

Buffalo

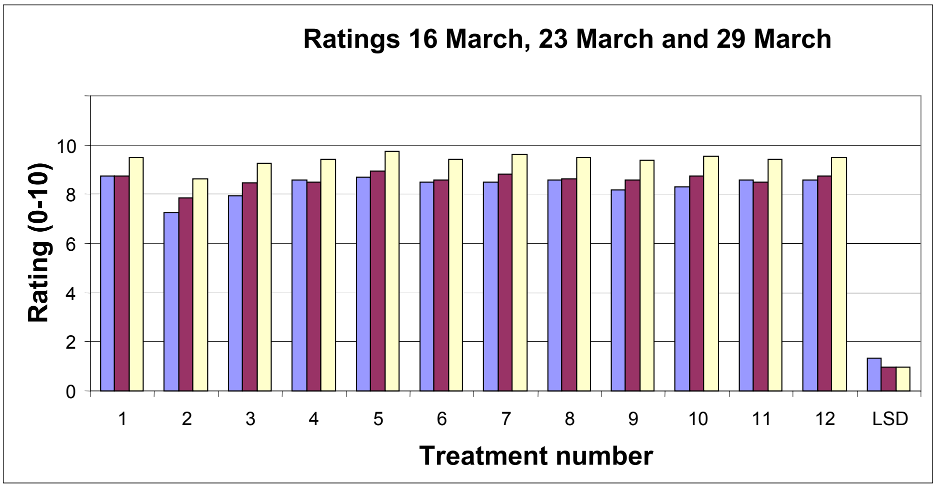

Figure 3: Turf quality ratings per treatment for buffalo grass during March 2007. Treatment 1 had no amendments.

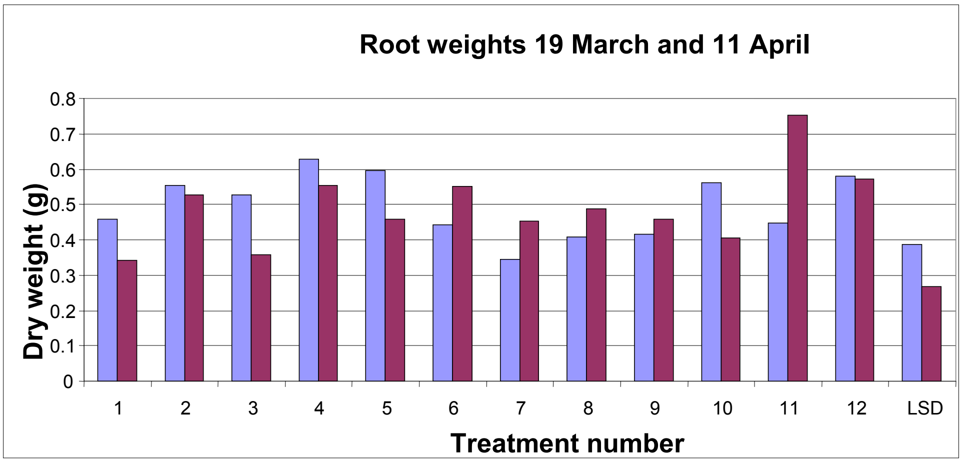

Figure 4: Root dry weights per treatment for buffalo grass in March and April 2007. Treatment 1 had no amendments.

As with the green couch, Treatment 2 slower to establish due to poor root contact at sod-soil interface. Turf quality ratings were similar for all treatments (see Figure 3). Treatment 11 showed best root growth overall (see Figure 4). There was a high level of variability in the data, which prevented any significant differences being detected between treatments.

Zoysia

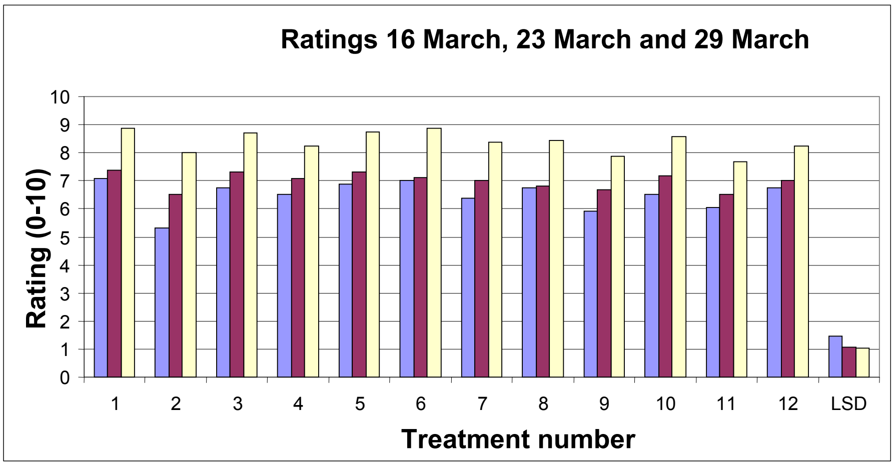

Figure 5: Turf quality ratings per treatment for zoysia during March 2007. Treatment 1 had no amendments.

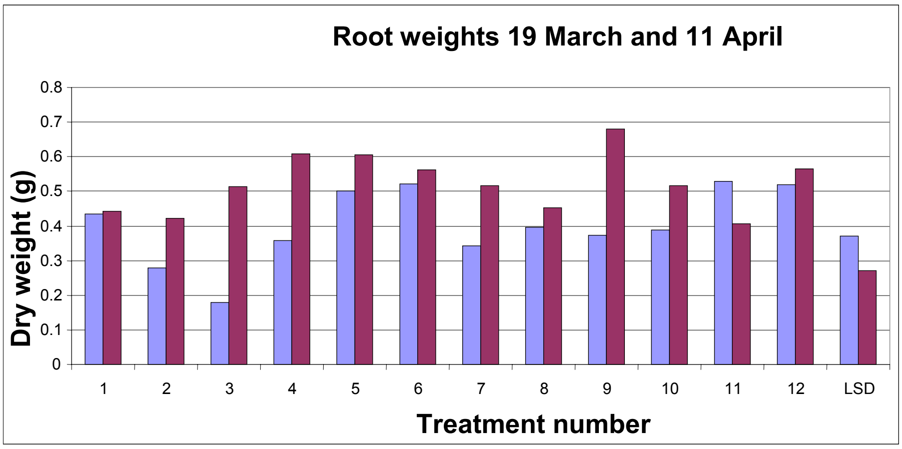

Figure 6: Root dry weights per treatment for zoysia in March and April 2007. Treatment 1 had no amendments.

As for the green couch and buffalo grass, Treatment 2 slower to establish due to poor root contact at the sod-soil interface. For the zoysia, Treatment 9 showed best root growth overall. Treatments 6, 11 and 12 demonstrated fast early root growth. There was a high level of variability in the data, which prevented any significant differences being detected between treatments.

Conclusion

Results from Experiment 1 were inconclusive, with no single treatment providing outstanding results. The early data raises the prospect of differences between green couch, buffalo grass and zoysia in response to treatments, however this requires further investigation.