

Best management practices for sustainable and safe playing surface of Australian Football League sports fields

Craig Henderson
Department of Employment,
Economic Development & Innovation

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Best management practices for sustainable and safe playing surface of Australian Football League sports fields

Final Report

Craig Henderson *et al.*

Queensland Department of Primary Industries and Fisheries



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This report summarises the process and outcomes of a four year project, investigating and demonstrating best-practices for providing safe, and sustainable community-standard sports fields. It provides a review of world practices; sports field assessment processes; recommendations for field improvement priorities; investigations of irrigation systems and practices; studies on potential soil profile and turf amendments; and a report on industry capacity building. It also provides recommendations for further research, extension and commercialisation of project results.

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Media summary

In a 4 year project (trademarked Sureplay®), Department of Primary Industries and Fisheries (Queensland) and AFL Queensland staff worked together, to improve community sports fields. These are the fields that junior footballers invade on Saturday mornings, and where future AFL stars strut their stuff in League fixtures on Sunday afternoons.

Through regular scientific assessment of project fields, the Sureplay® team identified ground hardness as the No. 1 problem. Applying project results, AFLQ now regularly audits affiliated fields several times per year, using a specific instrument. AFLQ closes grounds that don't pass muster.

Throughout the project, the Sureplay® team concentrated on regular ground aeration, and effective irrigation practices. The eventual result - playing conditions on many AFLQ grounds approach elite, national fields. AFLQ team member Nick Jeffrey is now constantly being approached for assistance by other sports, and local/state government agencies.

The Sureplay® team audited irrigation across project grounds. Most fields had less than 65% of sprinklers operating properly. Re-adjusting sprinklers, and fitting more appropriate nozzles, significantly improved irrigation evenness. The team investigated weekly watering, and waiting longer after rain before re-starting automatic systems. These strategies reduced irrigation by more than 30%, compared to non-project fields. This was a critical finding given the current drought. It helped convince authorities to still allow sports field irrigation, despite harsher water restrictions.

Sureplay® investigated subsurface incorporation of organic materials (e.g. composts), before laying turf in high wear areas (e.g. goal mouths). The results - softer playing surfaces in dry soils. In a regular football season, top-dressing turf with crumb rubber helped grass persist into early winter. However, neither process could stop loss of turf following consistent heavy wear. Research into managing high wear sections of community sports fields is a priority.

As well as DPI&F and AFLQ, the Sureplay® project received substantial financial support from Horticulture Australia Limited and the Brisbane Lions Football Club. Apart from enabling research and ground improvements, project funding helped publish more than 80 articles, and hold 100+ industry events, with several thousand participants. A structured curator training program, with accompanying resources, may be commercialised.

Technical summary

In 2002, AFL Queensland and the Brisbane Lions Football Club approached the Department of Primary Industries and Fisheries (Queensland) for advice on improving their Premier League sports fields. They were concerned about player safety and dissatisfaction with playing surfaces, particularly uneven turf cover and variable under-foot conditions. They wanted to get the best from new investments in ground maintenance equipment and irrigation infrastructure.

Their sports fields were representative of community-standard, multi-use venues throughout Australia; generally 'natural' soil fields, with low maintenance budgets, managed by volunteers. Improvements such as reconstruction, drainage, or regular re-turfing are generally not affordable. Our project aimed to: (a) Review current world practice and performance benchmarks; (b) Demonstrate best-practice management for community-standard fields; (c) Adapt relevant methods for surface performance testing; (d) Assess current soils, and investigate useful amendments; (e) Improve irrigation system performance; and (e) Build industry capacity and encourage patterns for ongoing learning.

Most global sports field research focuses on elite, sand-based fields. We adjusted elite standards for surface performance (hardness, traction, soil moisture, evenness, sward cover/height) and maintenance programs, to suit community-standard fields with lesser input resources. In regularly auditing ground conditions across 12 AFLQ fields in SE QLD, we discovered surface hardness (measured by Clegg Hammer) was the No. 1 factor affecting player safety and surface performance. Other important indices were turf coverage and surface compaction (measured by penetrometer). AFLQ now runs regularly audits affiliated fields, and closes grounds with hardness readings greater than 190 G_{max} .

Aerating every two months was the primary mechanical practice improving surface condition and reducing hardness levels to $< 110 G_{max}$ on the renovated project fields. With irrigation installation, these fields now record surface conditions comparable to elite fields. These improvements encouraged many other sporting organisations to seek advice / assistance from the project team. AFLQ have since substantially invested in an expanded ground improvement program, to cater for this substantially increased demand.

In auditing irrigation systems across project fields, we identified low maintenance (with $< 65\%$ of sprinklers operating optimally) as a major problem. Retrofitting better nozzles and adjusting sprinklers improved irrigation distribution uniformity to 75-80%. Research showed that reducing irrigation frequency to weekly, and preparedness to withhold irrigation longer after rain, reduced irrigation requirement by 30-50%, compared to industry benchmarks of 5-6 ML/ha/annum. Project team consultation with regulatory authorities enhanced irrigation efficiency under imposed regional water restrictions.

Laboratory studies showed incorporated biosolids / composts, or topdressed crumb rubber, improved compaction resistance of soils. Field evaluations confirmed compost incorporation significantly reduced surface hardness of high wear areas in dry conditions, whilst crumb rubber assisted turf persistence into early winter. Neither amendment was a panacea for poor agronomic practices.

Under the auspices of the project Trade Mark Sureplay[®], we published > 80 articles, and held > 100 extension activities involving $> 2,000$ participants. Sureplay[®] has developed a multi-level curator training structure and resource materials, subject to commercial implementation.

The partnerships with industry bodies (particularly AFLQ), frequent extension activities, and engagement with government/regulatory sectors have been very successful, and are encouraged for any future work. Specific aspects of sports field management for further research include: (a) Understanding of factors affecting turf wear resistance and recovery, to improve turf persistence under wear; (b) Simple tests for pinpointing areas of fields with high hardness risk; and (c) Evaluation of new irrigation infrastructure, 'water-saving' devices, and irrigation protocols, in improving water use and turf cover outcomes.

Introduction

Project background

Non-elite, local sporting grounds are usually multi-use venues managed by voluntary club members. In the majority of cases, they lack the appropriate technology, equipment or training to manage the facility to same level as high profile stadiums.

As part of its commitment to the Brisbane Lions, Australian Football League Queensland (AFLQ) manages a player development program through its state league competition. State league sports fields are mostly community fields, managed by volunteers. Low budgets and limited turf management skills meant the quality of most State level fields in 2002 were poor. Therefore, there was a growing concern regarding the risks to player safety. Under the limited investment constraints of State league clubs, reconstruction of soil profiles, installation of sub-surface drainage, and replanting of new turf cultivars (normally associated with re-establishment of grounds to optimum condition), was not considered viable.

AFLQ and the Brisbane Lions initially approached staff from the Department of Primary Industries and Fisheries for assistance in assessing irrigation systems AFLQ were installing in 5 State League grounds. The rationale for installing these new irrigation systems were: to improve the quality of playing surfaces; to sustain increased use of fields; and to reduce the injury levels of contracted Brisbane Lions players.

Discussion between DPI&F staff and AFLQ discerned that there were no appropriate standards available to assess the impact of irrigation systems, field construction, field renovation, and maintenance processes, on the quality of the AFLQ playing surfaces. It also became apparent that there were no appropriate training packages to promote competence in sport turf management, or deliver accredited field standards.

Under the AFLQ Strategic Plan (2000-2004), a risk management policy was developed to ensure all clubs provide quality environments for spectators, officials and players. Within this policy, AFLQ intend to set minimum standards for venues, based on an AFL-accredited ground scheme, with the primary goal to reduce sports injury and accidents at venues. They have also established "Volunteer Accreditation & Training" programs that primarily target coaches and umpires, but are extended to curators.

Other organisations are also highly interested in the development of safe playing fields for reasons similar to those discussed above. They included:

The Sports Federation of Queensland

In 2002, the Sports Federation of Queensland represented ten field sports associations, local government, School Groundskeepers Association, and the Queensland Department of Sport and Recreation. The two reasons central to the initial formation of the Sports Federation of Queensland was a need by six of the major sports code associations, as users of turf sports fields, to address both sports turf issues and the relationship of associations with the administrative owners of the fields. Another common issue for all members of the Federation is the construction and maintenance of non-elite sports fields. The Sports Federation field sports sector was concerned with the variable standard of the grass surfaces, the lack of commitment by various groups and authorities to upgrade the standards and the consequent impacts of variable surfaces on player safety.

Local Government

Local Governments are the major supplier of sports turf venues in Queensland. The amount of construction and maintenance assistance supplied varied considerably from a fully funded construction, maintenance and renovation service (e.g. Gold Coast City Council, Caboolture Shire Council); to a "peppercorn lease" (typically \$1 per year) with interest free loans or grants for minor capital works (Brisbane City Council, Pine Rivers Shire Council).

Annual maintenance budgets vary greatly between authorities, locations and organization ranging from \$3,000/ha (according to the Queensland Local Government benchmarking Survey, conducted in 2000), to \$40,000/ha for Alan Border Field (Harris 2002). In addition, local governments are under increasing pressure to conserve potable water through improved water-use efficiencies and increased use of recycled water. Environmental waste management legislation/requirements are also driving some local authorities to recap and renovate sports fields built over landfill sites and to incorporate bio-solids in the construction and maintenance of sports fields.

State Government

In common with most voluntary curators and some paid curators of sporting association fields, most school groundskeepers have had little or no training in sports turf maintenance.

The Queensland Department of Sport and Recreation has two primary interests in sports field standards. One is to increase the participation of Queensland's population in active sport to maintain the general fitness of the population with minimal injuries. The second interest is in developing benchmarks for assessing cost-benefits of capital investment in sports fields. Prior to this project, this Department allocated \$5.2 million of capital grants to 173 organisations for playing field improvements (Anonymous 2001). It could readily utilise appropriate benchmarks to assess applications from clubs, and evaluate the value of these grant investments.

Project aims

The project sought to demonstrate potential best practice management strategies for sporting grounds associated with Australian Rules football in Queensland. An initial literature review would investigate and document aspects of sports field renovation and management that influence playability, sustainability and cost-effective management. Benchmark quality standards were to be developed by rating participating playing fields against a range of parameters designed and quantified within the project.

With a plethora of problems associated with establishing best practice management of grounds in subtropical regions, this project intended to focus on soil profile and irrigation management. It was to be achieved through the establishment of soil profile management strategies and irrigation systems at selected grounds, with objective assessment of technology by industry.

Through delivery of workshops, seminars, training events, field days and publications, the project sought to develop industry self-help capacity building, as a key to ensure self-sustainability of the project outcomes.

Related research

Sport in Queensland

In 2002, there were more than 1,000 non-elite grassed sports fields played on regularly by more than 400,000 registered players (Cummiskey 2002) in Queensland. In addition, more than 750,000 school children regularly use sports fields in Queensland. While a few fields are privately owned, most fields are in public ownership through local or state Government bodies.

One of the most common reasons for not playing sport was injury or illness. Men were more likely than women not to play sport because of a sport's injury, whilst women were more likely than men not to play sport because of an illness.

Elite versus non-elite sports fields

Elite sport fields are classified as those which regularly host rounds of one of the various National sports competitions. They are characterised by high levels of capital investment, are subject to intensive management inputs and have very high levels of resource inputs. These grounds are subjected to limited use (up to 50 matches plus 30 training events per annum) and very limited / no open public access.

In contrast, non-elite sports fields are defined as those which host events no higher than at regional level, and are more commonly used for local competition only. They tend to be multi-use venues, catering for several different sports across the year. They are subject to much higher use, often in the order of 250 matches plus 150 training events per annum, and usually have no restriction to public access. They are characterized by having minimal management and resource inputs, generally only at the maintenance level, and have very low level & irregular capital investment. Typically, these grounds are managed by volunteer or untrained curators working with very limited resource budgets. Some are managed by local authorities with access to greater resources, but these are most commonly applied to maintenance of community structural facilities rather than production of a high quality sporting surface.

Playing surfaces and sports injury

Sports injury generally originates from physical causes and develops when the imposed forces on the playing surface are greater than those that biological structures can tolerate (Ekstrand and Nigg 1989). The incidence and severity of sports injury can be linked to the quality of a playing surface. A review by (Nigg and Yeadon 1987) of sport injury epidemiological studies suggests a strong link between the quality of the playing surface and the aetiology of injuries. (Ekstrand 1982) found that 24% of the injuries in soccer were correlated to the playing surface, mainly due to an uneven or slippery surface or alteration in the training surface. An AFL study linked increased risk/incidence of anterior cruciate ligament (ACL) injury with the occurrence of high evaporative rates and low rainfall periods (Orchard 2002; Orchard, Seward *et al.* 1999).

Improper traction between the shoe and the playing surface may result in injury. (Nigg and Yeadon 1987) discussed how the fixation of the foot on the ground is a critical component in the mechanism of injuries. For example, the incidence and severity of knee and/or ankle injuries are significantly reduced by shoes with lower friction properties. Excessive traction may also produce a foot fixation injury (Warren and Mallette 2002).

Shoe-surface interactions are influenced by a number of surface characteristics such as ground hardness, soil moisture content, grass type and density (McNitt, Middour *et al.* 1997; Orchard 2002). Surface hardness is mainly controlled by moisture content whereas traction is more related to grass cover (Baker 1991). As reduced hardness is positively correlated to increased soil moisture (Baker 1991), altering irrigation management practices through increased application amount and frequency may reduce ACL injury incidence (Orchard, Seward *et al.* 1999).

Grass type and length affect surface traction. Couch grass (*Cynodon dactylon*) provides high surface traction and may lead to a higher risk of ACL injury than perennial ryegrass (*Lolium perenne*) that grows better in winter conditions, and in addition, provides a more slippery surface (Orchard, Seward *et al.* 1999). Reduced grass mowing height (Mooney and Baker 2000) and removal of verdure (Rogers and Waddington 1989) can significantly lower traction. However, grass mowing height may have only minimal effect on playing surface hardness (Rogers and Waddington 1989). Shoe design, specifically cleat style and configuration, may also affect the traction response between player and surface.

Playing surface assessment

Player surface interactions can be separated into two main components (Neylan 1999): friction / traction; and hardness / resilience. Friction and traction relate to player movement, and the interaction of shoe and surface. Examples of relevant testing procedures include: a torsional traction test, which uses a loaded studded plate rotated on the surface (Canaway and Bell 1988); a sliding traction test, which measures the distance a weighted studded boot travels when supported on a trolley, such that the studs just contact the surface of the turf (Baker 1989); or a rotational and linear friction of a leg and foot assembly (McNitt, Middour *et al.* 1997).

The hardness and resilience relate to the response of a surface to an applied vertical force (Neylan 1999). Two main technologies used to evaluate surface hardness are the penetrometer and Clegg hammer. The penetrometer is an internationally recognized instrument to measure hardness, which is objective and reliable. The Clegg hammer, also highly recognized as a technique to measure surface hardness, is being adopted by the American Society of Testing Materials (ASTM) as a standard procedure for determining the shock-attenuation characteristics of turfgrass surfaces (Neylan 1999).

Sports field renovation and maintenance

In tropical and subtropical Queensland, many non-elite fields are constructed on reformed clay soils that have been subjected to compaction and poor water management. Many of these grassed surfaces have been subjected to extreme wetting and drying cycles, and highly variable traffic and wear. The management of these surfaces, however, is often limited to sporadic irrigation and fertilizer additions with occasional top-dressing. Anecdotal evidence suggests that many of these surfaces and underlying profiles suffer from structural degradation, with compaction, infiltration, drainage and aeration problems. These adverse soil physical conditions interfere with turf grass management by limiting water movement, reducing soil aeration, and decreasing root/shoot growth.

Importantly, soil profile construction and maintenance are the major factors affecting playing quality (Baker 1990) and therefore influence the incidence of surface-related sports injury. Altering soil moisture, bulk density and turfgrass cover can improve surface quality. Proper construction and maintenance, coupled with managed use, will contribute to development of a good playing surface (Rogers, Waddington *et al.* 1988).

Soil profile

Previous studies (e.g. (Hacker 1987)) suggest that the most important factor influencing grass establishment, and tolerance to wear, is soil profile construction. The over-riding influences are water infiltration and drainage rates. The majority of the existing research has been directed towards elite, constructed profiles with high sand contents, due to their higher infiltration rates. However, much of this research is inappropriate for the high clay profiles found in the subtropical and tropical areas of Queensland.

Drainage from even sandy loam soil profiles has been found to be inadequate, with infiltration rates falling to 0.5 mm/h after only one season of wear (Baker and Canaway 1990). Similarly, soil profile mixes with less than 60% added sand, which were subjected to simulated foot traffic, produced infiltration rates and air filled porosities which approached zero (Rashid, Amin *et al.* 1988). Attempts to correct this problem are usually directed at soil amendment, in an effort to increase soil pore sizes. Amendments may be either physical or chemical, aimed at improving infiltration and drainage rates, and reduce compaction, with benefits for turf establishment and resilience. The most common physical amendments are sand and peat, while common chemical amendments include gypsum and polyacrylamides. The physical amendments act by increasing the average particle and pore size within the profile, whereas the chemical amendments encourage particle aggregation and/or reduce aggregate dispersion. Other physical amendments, which have recently been trialled, include crumbed rubber and light expanded clay.

Crumbed rubber additions to the soil profile enhance the physical properties of soils susceptible to compaction and add resilience to sports turf (Groeneveld and Grunthal 1998). Admixtures of 20% or less of crumb rubber maintained total porosity values, while 10-20% added crumb rubber significantly reduced surface hardness. No deleterious effects to the environment, due to the inclusion of rubber crumb in turf grass root zones, were identified. Light expanded clay amendment (LECA) has been used on clay loam profiles, and found to be similar to the addition of non-porous river sand or gravel, because the internal water is not readily available for plant use (Spomer 1998).

The benefits of top-dressing are also highly variable, with some treatments not affecting turfgrass quality (e.g. (Dunn, Minner *et al.* 1995)). Annual top dressing with a soil material similar to that of the growing site may enhance root development. However, inappropriate topdressing materials may reduce infiltration, internal drainage, aeration and root penetration.

Soil structural degradation

Compaction of the soil surface and the use of excessively fine-textured (i.e. high in clay and silt content) soil profiles have been shown to be the most common limiting factors in turf maintenance (Carrow 1990). Soil compaction reduces oxygen diffusion, total water use and moisture extraction in the soil profile (Agnew and Carrow 1985). The proportion of pore spaces >200 microns in diameter within the top 10-90 mm of the soil profile reduces over time due to compaction (Lodge and Baker 1993). Rapid physical deterioration of sporting field soil profiles has been observed, even with high levels of spiking and sand top dressing (Gibbs and Baker 1989). High wear areas on sporting fields have been identified as suffering from inadequate infiltration and drainage due to compaction. High wear also leads to micro-topographic depressions, which encourage surface ponding and exacerbate both aeration and root growth problems.

Deterioration occurs through both man-made (e.g. intensive use) and natural causes (e.g. an accumulation of organic matter arising from under-use) with large differences being found between high and low wear areas. Similarly, declining turf quality under hot, humid summer conditions is exacerbated by poor soil aeration, excessive subsoil wetness, high temperatures and turfgrass diseases (Bigelow, Bowman *et al.* 2001).

While soil amendments have been shown to improve establishment of turf, due to improved water and nutrient retention in the amended root zones, cultivation is often regarded as the primary means of alleviating structural problems. However, the benefits of cultivation are often either not significant, or short lived.

Neither a Verti-drain nor a deep aerating rotovator produced a long-term loosening effect, or any change in puddle formation, or playability on sporting fields, in the Netherlands (Zwiers 1987). Similarly, a range of cultivation treatments failed to improve oxygen diffusion into soil profiles assessed on golf courses in the USA (Carrow 1990) and failed to have any long-term effects on the density or colour of the turf in the UK as measured by reflectance ratio (Baker, Cook *et al.* 1999). In Australia, aeration using Verti-drain reduced surface hardness and soil strength and improved infiltration rate and volumetric soil moisture in a clay loam profile. However, the effectiveness was short term, and much reduced with active play (Aldous, James *et al.* 2001). Verti-slicer and Hydro-Jet treatments have a variable effect with either no influence on soil physical properties and rooting (Carrow 1990) or only short term reductions in surface firmness (Baker, Cook *et al.* 1999) and improvements in infiltration rates (Baker, Cook *et al.* 1999; Lodge and Baker 1993).

Slit tyne aeration had no effect on water infiltration rate and no measurable effect on hardness (Baker, Cook *et al.* 1999) and did not provide adequate aeration and drainage between the slits on sporting fields in the UK (Gibbs and Baker 1989). However, the performance of the slits depends very much on the method of profile construction and tyne spacing. (Aldous 2002) suggested the need for further assessment of the effects of Verti-drain timing, frequency, depth and spacing on the longevity and effectiveness of tyne hole under Australian environmental and cultural conditions.

Many studies (e.g. (Baker 2001; Baker, Mooney *et al.* 1999; Newell and Wood 2000)) have shown strong relationships between the physical soil properties of moisture content, penetration resistance and surface hardness. Similarly, watering of sporting fields prior to use, reduced surface hardness and influenced ball rebound (Mooney and Baker 2000). This suggests that irrigation management is important in managing firmness and playability of the soil profile surface. A major factor in playability is the identification and maintenance of an appropriate soil moisture content for the soil profile properties and the sport being played.

Implications for industry and potential impact

The project was targeted to provide information on best management practices for: irrigation management, soil profile management, turf surface management, and overall field facility management. The information was to be available as accredited extension and training packages, and delivered during the project by the project team, and post-project by an ongoing, negotiated communication process.

The targeted outcomes were:

- Internationally-recognised, scientifically-based sports field management protocols and quality assured benchmarks.
- Increased technical and professional proficiency of paid and voluntary sports field curators.
- Increased sport participation, in player numbers, facility access and reduced level of sports injury.
- Improved water use efficiency and environmental stewardship.
- Export of sports field management and technical expertise for tropical and subtropical sports fields.
- Cost-effective and sustainable management of resources allocated to sports field construction and management.

The target project audiences were:

Paid and volunteer grounds managers and curators of AFL sports fields.

- Sports facility managers and grounds people for soccer, rugby union, rugby league, cricket and other sports requiring grass playing fields.
- Sports turf construction and maintenance contractors.
- State and local government sports field managers and curators.
- Sport clubs and association administrators.
- Players and affiliated associations.
- Industry trainers and educators.
- Sports institutes.
- Sports medical practitioners.

The adoption priorities were:

Immediate term

All AFL clubs & fields in Queensland; representing some 110 fields located in tropical & subtropical environments. Involvement was either to be as participatory stakeholders, or via delivery of project outcomes through the AFLQ structure. The involvement of AFLQ as major project partner provided a substantial adoption opportunity. At the conclusion of the project, via a field accreditation process, AFLQ may require all participating clubs to address benchmarked standards, and to participate in the training program and development of a ground remediation plan for their own facility. This provides an immediate uptake audience of sports fields currently controlled or managed (for at least part of the year) by clubs affiliated with AFLQ.

Medium term

As part of the AusKick program operated by AFLQ in State Schools in Queensland, awareness training is delivered by & through the AFLQ structure. With all local school coordinators of the AusKick program required to participate, this provides access to a further 180 fields currently controlled by Education Queensland. Delivery of basic field management training modules to AusKick school coordinators provides a major entry point to the State Department of Education system, which currently controls several hundred fields across the State. As many of these are also accessed by local junior sporting organisations, linkage to and impact upon these other organisations are also likely during the project and ongoing delivery of the project outcomes.

Longer term

Education Queensland (Non-AFL field sports) – 550 Ovals

Community-standard grounds used for other field sports – 1200 Ovals

These groups are the longer term target audience, who will become aware and involved in benchmarking and best practice implementation, through their association with other grounds and other clubs with whom this process has been implemented. There is also awareness via communication strategies implemented during the life of the project. In addition, this is the target audience for the commercial delivery of best practice manuals and associated training sessions.

Prior to the project, an estimate of the human resources allocated to managing community-level, Queensland sports fields were categorised as:

- Volunteer curators (35%) – untrained, under resourced, limited time, unrecognised;
- Part-time unqualified curators (20%) - untrained, under resourced, limited time, unrecognised;
- Part-time qualified curators (5%) – no specialist sports field training, some training (Certificate level), under resourced, limited time, unrecognised;
- Full-time unqualified curators (15%) - no specialist sports field training, untrained, limited resources, unrecognised;
- Full-time qualified curators (5%) - no specialist sports field training, some training (Trade level), limited resources, recognized;
- Contractors (5%) - no specialist sports field training, some training (Trade or Certificate level), limited resources, unrecognised;
- Local Government (15%) - no specialist sports field training, some training (Trade or Certificate level), limited resources, unrecognised;

Capacity building for the various groups was to range from participation in all aspects of the project outcomes, to awareness raising via communication processes such as magazine articles and media events.

A core group of curators associated with the project were intended to act as an initial 'promotion team' for the project as they communicated with their peers. The project curator was to become a core resource for all AFLQ clubs (and, potentially, clubs in other sporting codes) in undertaking benchmarking and implementing BMP. With their assistants, they would also form part of the resource used to commercially deliver the project outcomes beyond the life of the project.

Beyond the AFLQ structure, the intention was to also deliver the project's Benchmarks and Guidelines through various other networks, such as including the Local Government Association (Queensland network); the Amenity Horticulture Industry Development Council; Parks and Leisure Australia; the Queensland Turfgrass Foundation; and the Queensland Golf Course Superintendents Association.

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Project research

Because this project involved a broad range of component activities, each of these is described sequentially. They are presented roughly in the order they were done during the project; however there was significant overlap between several of the project components, with aspects being conducted concurrently. The research is only summarised here; they are described in more detail in the reports associated with each of the project components. These reports (where not confidential), are available from the project team, either singly, or as part of a more comprehensive project package.

Literature review

Between August 2003 and March 2004, project team member Kaylene Bransgrove reviewed the international literature on world's best practice relating to sports field surface management. Most of the scientific literature concentrated on elite fields, and sports at the elite level. This review covers that literature, as well as material on non-elite fields, and also provided guidelines on constructing, maintaining and monitoring non-elite fields to stimulate discussion.

Introduction

Concern for the occurrence of injuries and the overall safety of athletes has risen over the last few years. Injuries have been linked with the quality of the playing surface, with, for example, up to 24% of soccer injuries correlating with the playing surface (Ekstrand 1982; Nigg and Yeadon 1987). Playing quality is an overall product of player-surface interactions and ball-surface interactions (Neylan 1999), the common factor in each being the playing surface.

The need clearly arises to establish playing surfaces that will reliably provide a surface on which the risk of injury from player-surface interactions is low and the ball-surface interactions are acceptable. For field managers to provide such conditions, the individual factors that collectively constitute the overall quality of the field must be defined and numerical ranges that denote player safety for each parameter must be developed.

To do this the status of field surfaces under current management regimes must be determined. This is called benchmarking and is the process where current management practices are documented and outstanding management practices from elsewhere are identified, adapted and adopted where possible. These 'best management practices' are continually used as a measuring stick for ongoing local practices and outcomes.

Managers who use the process frequently reduce wastage of resources (water, fertiliser) and further comprehend activities needed to achieve expected standards and to negotiate reachable standards if budgetary and resource constraints are imposed.

Objective assessment of sports field condition and performance

A number of parameters are currently measured on sports surfaces and are related to factors that impact most upon the player-surface interaction. These factors are friction and traction, hardness and resilience and ball-surface interactions (Neylan 1999; Rogers and Waddington 1990b). Other parameters include moisture, surface evenness, ground cover, compaction, ball bounce, sward height, and wear.

In elite sports, standards for the parameters have been developed in conjunction with player feedback, correlating numerical measurements of surface parameters (such as hardness, grass, moisture levels) with player likes and dislikes.

Non-elite fields

Little research and development work has been done regarding non-elite fields and sporting levels. A non-elite field may be defined as a field on which more than one sport may be played, progressively over the season or simultaneously, hours of use are high and typically maintenance inputs are low. Maintenance inputs vary considerably from field to field and may be restricted to mowing, or mowing and irrigation.

Non-elite fields are often situated on unwanted urban land such as landfill sites and their profiles are not constructed for player safety or turf growth. In addition, if a landfill site is incorrectly capped, slumpage can occur for many years and considerable undulation of the playing surface may exist.

Non-elite fields are the focus of the current benchmarking project. Parameters that affect the quality of community playing surfaces are identical to those that affect elite surfaces. The primary difference is that within the bounds of player safety, acceptable ranges for guidelines will need to be achievable with few inputs and therefore be more relaxed than for elite fields.

Field performance and condition parameters

Hardness

Hardness is defined as the ratio of an applied vertical force to the amount of surface deformation. Either a Clegg hammer or a penetrometer can be used to measure hardness. Until Holmes and Bell completed their work (Holmes and Bell 1986), no guidelines had been proposed for Clegg hammer measurement of surface hardness in sports turf. Current standards for hardness are in the range of 30 – 180 g for rugby union and soccer.

A Clegg hammer measures the deceleration of a 0.5, 2.25 or 4.5 kg weight dropped from a set height. Hard surfaces decelerate the weight quickly and have high deceleration values. The units of the deceleration values (and therefore hardness) are G_{max} . Caution should be applied if comparing Clegg hammer results with other authors as while (Rogers and Waddington 1990b) found a strong correlation between the 0.5 and the 2.25 kg hammer, they found a poor correlation between 0.5 and 4.5 kg hammers. The 4.5 kg hammer, however, is rarely used in turf applications.

The two penetrometer types are the flat-tip penetrometer and the cone penetrometer. The flat tip penetrometer measures the distance a rod will penetrate the soil or playing surface upon the impact of a sliding hammer. The weight of, and the distance travelled by, the sliding hammer is constant. The dimensions of the rod are also known and constant. Such penetrometers have been used in agricultural soils for the detection of hard pans (Malcolm 1964). They provide useful information regarding compaction in a turf profile.

The cone penetrometer measures the force required to move through the soil. It can also be used to measure the depth to which the soil can be penetrated at a pre-set maximum force. This is usually 300 psi and is the accepted maximum force that roots can exert to move through the soil (Duiker 2002). The cone penetrometer often measures hardness further through the profile than the flat tip penetrometer. It is also used in agriculture to determine the location and depth of a hardpan or compaction layer. It can be applied to a turfgrass profile in the same manner.

Hard surfaces cause jarring and muscle soreness and increases the risk of injury from falling. Conversely, a soft surface generally causes fatigue (Baker and Canaway 1993; Neylan 1999).

A recent study of the incidence of anterior cruciate ligament (ACL) injury in AFL (played on natural turf) found a positive correlation between increased risk/incidence of ACL injury with ground hardness, the occurrence of high evaporative rates and low rainfall periods (Orchard 1999; Orchard 2002).

Artificial turf is usually considered to be harder than natural turf and injuries sustained on artificial turf are usually greater in number and seriousness than on natural turf (Guskiewicz, Weaver *et al.* 2000; Nigg and Segesser 1988; Orchard 2002).

Hardness is negatively correlated with soil moisture, increasing as soil moisture decreases, and often positively correlated with compaction. Grass cover, type and quality also influences hardness. Thick, dense, stoloniferous grasses usually help soften the surface in comparison to worn, thin areas of grass or weeds. Turf mowing height, however, may have only minimal effect on playing surface hardness (Rogers and Waddington 1989).

Hardness can be managed primarily by irrigation, de-compaction and aeration practices. The frequency of these practices significantly affects the severity of the hardness of the profile. It can also be minimised by ensuring an even coverage of turf is maintained on the field.

Hardness is one of the primary parameters with respect to playing field quality and safety. This is especially relevant to non-elite (AFL) playing fields where de-compaction or other maintenance is infrequent or nonexistent. On grounds where water is limiting, the risk of exceeding recommended hardness limits is increased.

Traction

In a sports field context, traction is a shoe-playing surface interaction. In this context it is measured as the amount of force required to tear the turf, by linear, or more commonly, rotational force. A number of devices to measure traction exist, but usually involve turning a studded disk of a designated weight until the grass breaks (Canaway and Bell 1988). These traction devices have been designed to mimic the rotational force placed on a shoe in play. As these devices do differ, some caution should also be exercised when comparing traction values. Current standards are simply that traction ratings should be above 20 Nm.

Shoe-surface traction increases with increasing ground hardness (Orchard 2001) and high traction is commonly associated with knee and ankle injuries (Neylan 1999). There is a general consensus that improper levels of traction (especially high traction) between the shoe and the playing surface may result in injury. (Nigg and Yeadon 1987) discussed how the fixation of the foot on the ground is a critical component in the mechanism of injuries. Shoe-surface reactions that limit frictional rotation and increase impact resistance have been correlated to higher frequency of lower extremities injuries such as shin splint, tibial periostitis, achilles tendonitis and synovitis (Andreasson 1985). AFL ACL injuries are more likely to correlate with traction and ground cover, as a function of rainfall and grass characteristics, than with hardness alone (Orchard 2001).

Conflict exists with respect to how traction is affected by shoe design, specifically cleat style and configuration. (Milburn 2000) states the number, length or type of cleat does not directly relate to the amount of shoe-surface traction, and that traction properties are more closely related to the grass than the pattern of the sole. Most other authors, however, agree that various shoe styles, including cleat length, layout and design, do affect shoe-surface traction, potentially affecting the amount of force required to produce movement at the shoe-surface interface and impact the incidence of injury. (Warren and Mallette 2002) evaluated various cleat styles and found differences in the force needed to move different sole types and cleat configurations. In particular, longer cleats are associated with increased shoe-surface traction and increased ACL injuries in AFL (Lambson, Barnhill *et al.* 1996).

Reducing shoe-surface traction, however, by enforcing players to wear shoes that provide lower shoe-surface traction is not feasible. The most effective means of reducing traction, and hopefully injury, is to alter the playing surface (Orchard 2002). Traction is highly (positively) correlated with a number of surface characteristics such as ground hardness, grass type and density and root density, and negatively with soil moisture content (Holmes and Bell 1986; McNitt, Middour *et al.* 1997; Orchard 2002). As previously discussed, surface hardness is mainly controlled by moisture content (Baker 1991) and softening the surface by altering irrigation management practices may reduce hardness, traction and ACL injury incidence (Orchard 2002; Orchard, Seward *et al.* 1999).

Grass type, density and root density (Baker 1991) are not so easily influenced from game to game. Warm season, stoloniferous grasses such as couch grass (*Cynodon dactylon*) have been the traditionally used grasses on northern Australian sports turf fields. They provide higher surface traction than tufted grasses like cool-season, perennial ryegrass (*Lolium perenne*) (Orchard, Seward *et al.* 1999). Using perennial ryegrass may play a considerable role in reducing ACL injuries in AFL (Orchard 1999). It is already sown over couch grass on all premier and financially able non-premier AFL sportsgrounds.

Reducing the height of mowing cut (Mooney and Baker 2000) and removing verdure (Rogers and Waddington 1989) can significantly reduce traction and may be a means of altering traction properties from week to week.

The importance of traction to the ongoing playability of non-elite fields is of high priority because high-traction, warm season grasses are used on non-elite AFL fields, and because these grounds are frequently relatively hard which also increases their inherent traction. In Australian conditions, on natural/landfill construction fields, it would be rare to encounter too little traction and therefore the priority is to establish upper field traction limits and ensure values are within them.

Moisture

Moisture is the amount of water held in the soil profile at a give time. Soil moisture can be measured volumetricly or gravimetricly, or with soil moisture sensors such as tensiometers, gypsum blocks or various capacitance or TDR electronic moisture meters. No standards for moisture content of sports fields currently exist.

Moisture plays a considerable role in the performance and quality of any sports turf surface. Adequate soil moisture is necessary for root and shoot growth and recovery from wear, and for uptake of essential nutrients from the soil.

High soil moisture decreases the air filled spaces between the soil particles and therefore the oxygen available to the root system. Long periods of very high soil moisture, promoting anaerobic conditions, inhibit root growth and function. Many soil borne pathogens are favoured by high soil moisture and cause problems after heavy rainfall or irrigation.

Soil moisture is directly related to hardness, wear tolerance and recovery from wear. As soil moisture increases hardness decreases, but so too does the ability of the grass to withstand wear. Grass cover can quickly deteriorate after play on a wet surface, decreasing traction and surface stability. Using the field when soil moisture is near or at field capacity increases the risk of increasing compaction and therefore the inherent hardness of the field.

Moisture can be manipulated by irrigation scheduling practices, installing or optimising drainage systems and adding amendments that increase or decrease the water holding capacity of the soil.

Moisture is one of the critical parameters to record on any playing surface, but perhaps particularly on non-elite fields as, because moisture directly affects hardness, it is probably the most easily available and economical means for non-elite clubs to manage hardness. Monitoring soil moisture will also provide a field manager with information regarding the output of the irrigation system and of the relative drainage across different areas of the field.

Surface evenness

Surface evenness is a measure of how level a playing surface is. Evenness can be measured using a straight edge or any of the numerous profile meters that exist. The deviations from the edge or meter are documented on a micro (mm) or macro (cm) scale. Standards for surface evenness in elite sports are from 4-10 mm deviations from level.

Surface evenness at a micro level is extremely important in sports where ball roll is important such as soccer, hockey and bowls. In sports such as AFL, where the ball is kicked or bounced, macro, or general surface evenness, is more important. Macro surface evenness is of particular importance and maybe areas of slumpage occurring on a landfill site, slumpage or lack of maintenance initiating potholes in the surface, or general surface unevenness due to numerous grass species, weeds or worn areas. Such unevenness is prevalent on non-elite fields and can pose serious danger for a running athlete.

Surface evenness is maintained by annual topdressing, constant remediation of small depressions and maintaining a weed free, and consistent turf sward.

Measurement of this parameter is not a priority, however, as for AFL, macro-unevenness is of greatest importance. Macro unevenness, particularly holes and depressions, can be gauged by eye and their presence should necessitate immediate action. Micro measurement is therefore not necessary.

Ground cover and type

Ground cover and type is the amount of vegetative matter growing on the playing surface and of which species it is composed. Ground cover and type are usually measured using a quadrat and the percentage cover and percentage grass types within the quadrat are calculated. Usually only green cover is measured, not remnant or dead material.

Reflectance ratio has also been used to determine ground cover. There are no standards for grass cover and type.

Ground cover and type significantly affect the quality and safety of the playing surface and also affects the aesthetic appeal of a ground. (Bell and Holmes 1988) note that playing quality is highest where grass cover is good and the surface is firm. They also found the amount of grass cover is the primary factor determining player opinion of the pitch quality. Minimum standards for grass cover are impractical (Bell and Holmes 1988), but without grass cover, roots (cool season grasses), or roots and stolons (warm season grasses), would quickly disintegrate and the overall quality of the surface deteriorate. Therefore grass cover should be maintained at all times (Bell and Holmes 1988).

Ground cover and type is usually positively correlated with traction and negatively correlated with ball bounce (Holmes and Bell 1986) and wear. (Aldous and Chivers 2003) suggest grass type and thatch depth may be the important factors in AFL ACL injuries. Stoloniferous grasses have a higher traction rating than tufted grasses (e.g. couch versus perennial rye grass). A surface comprised of many weeds (grasses or broadleaf) promotes variable surface traction and surface unevenness, and possibly increased risk of injury.

Ground cover is promoted by irrigating and fertilising adequately, limiting compaction and limiting broadleaf and tufted weed species on the playing surface. Ground cover is also promoted by rotating training sessions around the field, and specifically away from partially worn or general wear areas.

Grass cover and type is an important parameter as it is influenced by, and influences, hardness, compaction, moisture and wear. It also reflects the nutritional status of the profile and the ability of the turf to recover. It may be more important on non-elite fields (e.g. AFL) where these hardness, compaction and nutrition are not currently managed.

Sward height

Sward height is the length of the turf on the playing field. Sward height is measured using a rising disc apparatus (Peel 1987). The rising disc is a lightweight disc, with a hole in the centre. It is placed on the turf surface, a graduated rod is placed through the hole onto the surface and the height is measured from the rod. Sward height is measured in mm and the current standards are between 20 and 75 mm.

Sward height primarily affects ball roll and deceleration and therefore sports such as soccer, hockey, golf and bowls. As sward height is increased, distance rolled decreases (Richards and Baker 1992). Low sward height is therefore not so important AFL and the mowing height can be somewhat relaxed. Player discomfort, however, increases, and agility and ease of movement decreases, as mowing height is extended (particularly where the turf is both thick and long) and lower sward heights and verdure have been associated with lower traction (Mooney and Baker 2000; Rogers and Waddington 1989).

Sward height is obviously managed by mowing practices, but the height at which the turf is cut within the benchmarking standards should be determined with respect to the impacts grass height has on sward health, root growth and water use. These are discussed in section 6.

Sward height is an important parameter to monitor as it provides an indicator to measure the success of the mowing maintenance regime in place for the field. It may also be a key measure of the condition of the surface with respect to player comfort and movement and overall surface play.

Ball-surface interactions (bounce, rolling resistance, friction and spin)

Ball roll

Ball roll is measured as the distance rolled after being released down a slope of a set length from a set height. It is of most importance in sports like soccer, hockey, golf and bowls where ball roll is an integral part of the game. This parameter is not relevant to AFL.

Ball bounce resilience

This is a measure of the bounce and is the ratio of the height the ball bounces to from which it was dropped. The height from which a ball is dropped is not important, but frequently 3m is used, and is used for soccer.

Ball bounce is usually highly correlated to hardness. (Holmes and Bell 1986) found on a range of construction types, ball bounce was negatively correlated to moisture content. Soil moisture and hardness are also positively correlated, and may be the primary correlation. Consistency of bounce is an important requirement in AFL.

Rolling resistance

This is significant in sports where ball roll and the speed of the surface are important. It is measured by calculating ball deceleration or the distance rolled by the ball. This parameter is not relevant to AFL.

Friction and spin

Friction between the ball and the surface is responsible for variations in speed, direction and rate of rotation after contacting a surface. This is usually analysed by video documentation when measured (Neylan 1999). It is not frequently included in the majority of benchmarking analyses. While there may be some relevance to AFL, it is not a priority and should be omitted in favour of other parameters.

Other parameters affecting surface conditions

Infiltration

Infiltration is usually expressed as a rate (e.g. mm/hr) and describes the rate at which water will enter the soil profile from the soil or playing surface. No specific standards are in place with respect to playing quality, but they do exist for newly constructed (sand based) fields. These are not relevant to non-elite fields. The infiltration rate should be as high as possible at construction as it will always decrease over time.

Infiltration can be measured using a double ring infiltrometer or a disc permeameter. A double ring infiltrometer measures saturated hydraulic conductivity and consists of two concentric, metal rings. Both rings are partially driven into the profile (to equal depths), with the small ring positioned in the centre of the large ring. Both rings are partially filled with water (to equal depths) and the mm water dropped down the side of the inner ring in a set time period is measured. Alternatively, mariott bottles can be placed above both rings and the mm water lost from mariott bottles, maintaining constant water levels in the rings, can be measured.

To ensure saturated conductivity is measured accurately, it is recommended to conduct the test within a few days of irrigation, or to wait at least 20 minutes before commencing measurements. A delay may not be appropriate on sand or sand based profile and judgements with respect to the delay will need to be made on a site/soil profile basis.

A number of disc permeameters are available including a ponded permeameter and a tension disc permeameter. They determine hydraulic conductivity over a range of negative potentials. While they are easier to use than double ring infiltrometers, they do measure lateral as well as downward infiltration.

In areas of high rainfall, especially high intensity rainfall, high infiltration rates allow increased capture of precipitation for the root zone and works in conjunction with surface drainage to prevent ponding. In wet environments it therefore has a significant affect on the number of hours of play achieved on the field. Where rainfall is less frequent, or is very low intensity, exceedingly high infiltration rates are not necessary. High rates are, however, often touted as a necessary component of every pitch.

A sealed surface layer, and/or finely textured soil layers at the immediate soil surface, reduces infiltration. Infiltration is influenced though by compaction and soil layering within the profile. Low infiltration rates can promote surface ponding and, in conjunction with poor percolation and drainage, unnecessarily wet profiles, anaerobic soil conditions and root diseases. All significantly lower the ability of the grass to grow, tolerate wear, recover from wear and to contribute to a uniform, safe playing surface. Unnecessarily wet profiles are also more susceptible to compaction, and should be avoided through managing infiltration where possible.

Turf managers need to incorporate the infiltration rate of their field into irrigation management decisions, as only short, frequent irrigation events should be conducted on a field with low infiltration rates to prevent the ponding and surface degradation described above.

Infiltration can be managed by surface cultivation treatments that disrupt the playing surface and the soil profile immediately below the surface. Thatch build-up also decreases infiltration and must be managed to maintain maximum infiltration rates.

Infiltration is a key parameter providing an indication of soil compaction and drainage. As infiltration may change slowly, or in response to management practices or field renovation, frequent measurement is not necessary.

Wear

Wear is described as physical deterioration of the playing surface due to traffic on the field and can be divided into abrasion and divots (Bugbee and Johnson 2002). Wear can be measured as the area affected, the percentage degradation of the surface, or a factor of both. Like ground cover, no standards are in place, but the less wear present the better for surface and playing quality.

Wear is usually concentrated in specific, high traffic areas (Neylan 1999) and is one of the most important abiotic turf stresses (Trenholm, Duncan *et al.* 2001). It is significantly increased if the soil is saturated or soil moisture is high. Considerable reduction in turf density can be seen and roots, shoots and stolons may die (Trenholm, Duncan *et al.* 2001). Wear is linked to loss of photosynthetic and growth capability and increased susceptibility to disease, insect and weed pressures (Trenholm, Duncan *et al.* 2001). These all promote the degradation of a quality playing surface into something less desirable or safe. Possibly the greatest injury risk from wear comes from increasing ground hardness, in some cases decreasing traction, and particularly increasing surface unevenness.

Promoting the percentage of wear tolerant *Cynodon* couch grasses (Carrow and Petrovic 1992) on a non-elite AFL field may help decrease wear. Increasing shoot density may also help to increase wear tolerance and recovery. In some situations increased potassium applications increases wear tolerance, while there is a trade off between increasing shoot density and tissue softness with increased nitrogen applications (Batten, Beard *et al.* 1981; Trenholm, Duncan *et al.* 2001). Therefore, ensuring a moderate fertiliser regime is in place may significantly decrease wear and increase turf recovery. Ensuring adequate soil moisture will also promote turf growth and wear recovery.

While wear is important, it is not a priority parameter as measurement of grass cover and density encompasses the measurement of turf cover degradation and recovery induced by wear.

Compaction

Soil compaction is a decrease in the size and shape of soil pore space after the compression of soil particles, resulting in a more dense soil mass (Carrow and Petrovic 1992).

Compaction is measured by quantifying one or more of the parameters that are affected such as bulk density, porosity, soil strength or others listed below.

Increasing soil compaction increases soil bulk density, soil strength, water filled pore spaces and carbon dioxide levels. Penetration resistance, air filled space, macro pore space, oxygen levels and exchange, moisture extraction and infiltration rates, however, are decreased (Agnew and Carrow 1985; Waddington 1992). Soil surface compaction has been shown to be the most common limiting factor in turf maintenance (Carrow 1990; Carrow and Petrovic 1992). (Waddington 1992) adds the two most important effects of compaction are decreasing soil oxygen levels and increased mechanical impedance created by the increased bulk density and soil strength. Many authors have found that compaction decreases both shoot and root growth (Carrow, Shearman *et al.* 1990).

Weight contributes significantly to compaction, with heavier objects creating greater compaction than lighter objects. A field will then sustain greater compaction under constant play by adult athletes in comparison to junior athletes.

Walking foot traffic usually compacts a profile in the upper 2-10 cm of a profile (Beard 1973). A running athlete (e.g. a football player), places a significantly greater compacting force on the profile than a walking athlete (Waddington 1992). Compaction may still remain in the upper 2-10 cm of the profile, but may eventuate more quickly under running than walking traffic.

Compaction and wear are commonly associated with each other, with compaction arising from high wear and wear tolerance and recovery decreasing on a compacted profile. Large differences in compaction are found between low and high wear areas. Compacted, high wear areas suffer from inadequate infiltration and drainage and compaction is significantly increased if the field is used at or near field capacity (Turgeon 2002; Waddington 1992).

Maintaining good ground cover helps to prevent compaction as (Rogers and Waddington 1989) found that bare surfaces were more susceptible to compaction. Compaction can be minimised by rotating training practices, preventing play on saturated fields and using de-compaction machinery within the field maintenance programme.

Compaction is a common problem on non-elite fields, AFL and other, and is a primary parameter to be measured. While the impacts of compaction are primarily noted by an athlete as hardness, the detrimental effects of compaction on drainage, soil oxygen/aeration levels and plant and root growth should also make it a priority with non-elite field managers.

Elite and Proposed Benchmarking Standards

To date, benchmarks and guidelines have been produced for elite or near-elite sporting levels/fields. Current standards developed for such fields are presented in Table 1.

Table 1. International Elite and Near-Elite Playing Field Standards.

Proposed standards	Rugby (McClements and Baker 1994)	Soccer (Bell and Holmes 1988; Holmes and Bell 1986; Richards and Baker 1992)	Hockey (McClements and Baker 1994)
<u>Hardness</u>			
Preferred	50-100 G_{max}	20-80 G_{max}	90-140 G_{max}
Acceptable	30-180 G_{max}	10-100 G_{max}	65-200 G_{max}
<u>Traction</u>			
Preferred	≥ 35 Nm	≥ 30 Nm	≥ 35 Nm
Acceptable	≥ 25 Nm	≥ 20 Nm	≥ 25 Nm
<u>Surface evenness</u>			
Preferred	≤ 8 mm	≤ 8 mm	≤ 4 mm
Acceptable	≤ 10 mm	≤ 10 mm	≤ 5 mm (≤ 6 mm in goal)
<u>Grass length</u>			
Preferred	25-50 mm	25mm	10-18 mm
Acceptable	20-75 mm	50mm	8-25 mm
<u>Rebound resilience</u>			
Preferred	20-50 %	20-50 %	
Acceptable	15-55 %	15-55 %	

Of the sports that have international standards for field parameters in place, rugby is the most similar to AFL with respect to ball shape and game style. The standards for rugby may then be a logical starting point for developing standards for AFL.

The rugby standards have been developed in a climate of considerable difference to a northern Australian climate and at standards of play above that usually seen on the non-elite field. Some of the value ranges are not relevant and need to be adjusted.

Hardness

Minimum values of hardness of less than 50 G_{max} will almost certainly never be seen on non-elite Australian fields and do not need to be included in hardness standards. Maximum values are however frequently over 100 G_{max} and the preferred range should possibly be extended to 140/150 G_{max} for non-elite fields. The acceptable range should still be limited at 180 G_{max} to limit hardness related injuries.

Traction

While the rugby standards focus on the minimum traction figures, these are not likely to be of concern on Australia non-elite fields where even if ground cover is minimal, moisture levels will probably be low enough to provide adequate traction. Research on non-elite fields in northern Australia to-date has indicated that traction values of over 60 Nm are common. Focus should be placed on developing information regarding the uppermost preferred and acceptable traction values with respect to injuries.

Surface evenness

To ensure player safety, the surface evenness values should be adopted as they are, or at most, the preferred value extended to 10 mm. If this change was made, the acceptable value should not be extended further, but be made redundant.

Grass height

The international standards for rugby could be adopted as they are. Only research to show AFL players prefer a significantly different height range, or that grass height significantly influences other parameters not documented by other authors, would provide reason to alter this standard.

Ball bounce resilience

The ball bounce resilience standard could be adjusted for the preferred to 30-45% and the acceptable to 25 – 55% to cater for the increased importance of consistent bounce in AFL.

Profile construction methods and their effects on surface quality and performance

Soil profile construction and maintenance are the major factors affecting playing quality (Baker 1990; Hacker 1987), and proper construction and maintenance, coupled with managed use contributes to the development of a good playing surface (Rogers, Waddington *et al.* 1988). (Hacker 1987) suggests the over-riding influence on surface quality is the effect of the construction on the water infiltration and drainage rates. Soil profile construction and maintenance therefore influences the incidence of surface related sports injury.

The most common types of construction methods are described below. Pipe, slit, sand carpet and suspended water table constructions are only discussed briefly as they are rarely used for non-elite fields.

Natural soil

A natural soil profile consists of only the soil native to the area in which the field is constructed. It is generally unamended and there is no artificial drainage in place, bar that which is provided by the profile itself or a sloping surface.

Most non-elite fields are constructed on a natural soil or landfill profile. While these fields are generally unamended, if re-shaping or levelling has been necessary, they may have a considerably mixed profile. Earthmoving/field construction units do not seem to guarantee to return the profile to the site in the same order or condition. This can have significant affects on hardness, rock inclusions, drainage, moisture retention, the pH of the profile and grass growth.

Natural soils, subjected to heavy wear, have poor infiltration and drainage properties (Baker 1988). (Baker 1988) found that the infiltration capacity of profiles of less than 90% sand decreased by 90% within two seasons of play.

Landfill construction fields

A landfill profile is constructed over a historical landfill site. Strict regulations govern new landfill sites, but in the past any existing regulations were widely interpreted and the profile of such sportsgrounds can be completely unknown.

Landfill sites were capped with an ash product, followed by clay and some degree of topsoil (Power 2004). The ash, clay and topsoil layers vary considerably in depth, and the topsoil in quality. Variation in the profiles of most landfill fields has increased since their construction by the addition of other soil to the surface to alleviate differential settling in the landfill layer.

The topsoil, now the root zone, was sourced by price and to complete the land filling process. It was not sourced to promote maximum turf growth, and rock and other inclusions are common. Even though landfill fields in the Brisbane metropolitan area are between 30 and 45 years old (Power 2004), it is not uncommon to find materials from the landfill still moving through the profile to the surface. The objects are glass, plastic and or metal and are assorted and varied. As nearly 70% of city council sports grounds in Brisbane are on landfill sites, concern for safety of a large number of AFL and other athletes using these fields is legitimate. Subsidence of 25 mm/year is average for Brisbane landfill sites (Power and Whinnet 2003). Large subsidence events can still occur though, and may leave from small pot-holes to large depressions. This is also a concern for player-safety.

Like natural-soil fields, drainage is limited to what is afforded by the material of the profile. In addition, if the clay layer was applied even reasonably thickly, the capping layer should be impermeable to water. Infiltration and drainage may be restricted if lateral drainage does not occur through the soil and across the capping layer. Excessive moisture in the profile limits soil air content, root and shoot growth and promotes soil-borne diseases and the rapid loss of ground cover under wear. Such an event, due to climatic conditions in a northern Australian AFL playing season (winter) or irrigation, may be rare, but must be considered where the constructed profile is especially shallow.

(Power and Whinnet 2003) found roots would not penetrate an ash layer of greater than 25 mm thickness. Therefore landfill root zones maybe considerably limited by this layer if it is present close to the surface of the playing field.

Crowned and sloped fields

While crowns and slopes are not strictly a construction type, they are established at construction. Both provide fields, soil, landfill or other, another means to increase drainage.

A crowned field has its highest point in the centre with the field sloping downwards in all directions from the crown. The angle of the slope should promote runoff and movement of water away from the surface without impeding player surface.

The sloped field is usually sloped along either of the axes, or across the diagonal. While being relatively functional, the excess water from the top the slope must move a long way before it is removed from the surface.

Both systems require perimeter drainage to ensure the excess water continues to move away from the field.

Amended in-situ soil profiles

Amendments may be either physical or chemical in nature and typically aim to improve infiltration and drainage rates, reduce compaction, and improve nutrient holding capacity, turf establishment and resilience.

Natural materials

Inorganic amendments

The most common inorganic physical amendment is sand. Others include calcined clays, light expanded clay amendment (LECA) and calcined diatomaceous earth. They usually act by increasing the average particle and pore size within the profile.

The addition of sand increases air filled porosity and water movement and decreases water retention in the profile. The sand used should be chemically inert and resistant to weathering. Sands containing flat or easily weathered particles, or weakly cemented particles, should be avoided (Waddington 1992).

Calcined clays are clays heated to 700°C or more. They can be graded into sizes and their incorporation usually increases air porosity and permeability. While they are porous and hold water within the calcined clay particle, most of this moisture is not available to the plant (Waddington 1992). Light expanded clay amendment (LECA) has been used on clay loam profiles and found to be similar to the addition of non-porous river sand or gravel because the internal water is not readily available for plant use (Spomer 1998).

Diatomite, or diatomaceous earth, is a calcined hydrated silica (from diatoms) that forms stable lightweight granules (Waddington 1992). Their incorporation increases air porosity and permeability and again, while the granules hold water, much of it is unavailable to the plant.

The addition of calcined clays or diatomaceous earth increases the drying power of a surface (Fresenburg 1999).

Other inorganic amendments include vermiculite, perlite, expanded shale, pumice, slag, sintered fly ash and clinoptilolite zeolite. The aim of all is to increase air porosity, infiltration and drainage (Waddington 1992).

Organic amendments

Much literature exists extolling the benefits of organic material in soil. Peat is the most popular organic amendment in sports turf (Waddington 1992). While 3-5% organic matter is usually recommended as the organic matter component of a profile, peat is incorporated as an amendment from 5-20% (by volume). The benefits of amending with peat are increased water holding capacity, infiltration, root penetration and aeration, and decreased bulk density (Waddington 1992). Other benefits attributed to the addition of organic matter in general are improved soil aggregation, increased soil air pore space, drainage, thatch break down and nutrient cycling and micro-organisms and micro-organism habitats.

Most sports turf research concerning organic amendments has been concerned with sand profiles. Incorporation of organic material into a sand profile can help turf establishment and avoid dry patch, and can promote good turf uniformity and density in the longer term (Gibbs, Liu *et al.* 2000). Adding 5% peat (vol/vol) to sand profiles increases the water storage capacity by up to 15% (Münster 1998), but may have no effect on ground cover, traction or visible turf quality. Large additions of peat (20%), however, can reduce hardness and ball bounce in the short-term, but also reduce infiltration by up to 38% (Baker and Hacker 1988). Most non-elite fields are sandy loam or finer textured, and hence have sufficient inherent water holding capacity. Organic materials would be applied principally to promote soil structural improvement and enhance biological activity.

Ensuring non-elite fields contain at least 3-5% organic material would be expected to promote good soil structure and biological activity, and thus improve plant health and quality.

Biological amendments

Numerous biological amendments, purporting to contain microbes, microbial enzymes or unknown substances, are available. The advantages of their use are increasing plant and soil health, breaking down thatch, limiting disease occurrence and reduced chemical inputs. While the theories behind the products are reasonable, most have not been scientifically tested and their true effects cannot be validated. One biological amendment, designed to increase thatch breakdown, was investigated in the United States (Carrow and Johnson 1992). Over a two-year period, in a bermudagrass trial, no effects on the thatch breakdown were found. The authors also found similar results in trials on 'Meyer' zoysiagrass. (Waddington 1992) also notes positive effects of many biological and biochemical treatments are rare.

Lack of scientific trialling does not imply these products cannot be of use to managers of non-elite fields producing a consistent and safe playing surface (AFL or other), but that turf managers should be vigilant in trialling the products on their fields.

Chemical amendments

Chemical amendments act to encourage particle aggregation and/or reduce aggregate dispersion. Common chemical amendments include gypsum and polyacrylamides.

Gypsum is reported to increase aggregation and infiltration, but many authors suggest gypsum will not alleviate poor permeability caused by other soil problems (Waddington 1992). Chemicals such as polyacrylamides, bituminous emulsions and polyvinyl alcohol are reported to stabilise aggregation, change soil CEC and soil wetting properties. (Waddington 1992) noted these had no positive effects on compacted sand soils.

(Carrow and Petrovic 1992) list a selection of chemical soil conditioners, encompassing the products above and various wetting agents, algal, fungal or bacterial polysaccharides and vinyl acetate-maleic acid copolymer, but added there is little research to evaluate their effectiveness where wear may be imposed. They propose wear destroys any aggregation or structure formation very quickly.

Manufactured amendments

Crumbed rubber

Crumbed rubber is granulated rubber from old tires. Crumbed rubber additions to the soil profile enhance the physical properties of soils susceptible to compaction and add resilience to sports turf (Groenevelt and Grunthal 1998). USGA test results showed admixtures of 20% or less of crumb rubber maintained total porosity values while 10-20% added crumb rubber significantly reduced surface hardness. The addition also reduced soil shear strength and moisture levels in non-compacted field tests. Turf grown under simulated traffic showed greater wear tolerance when crumbed rubber was added at 34.1 t/ha or greater (Rogers, Vanini *et al.* 1998). As a top dressing, (Baker, Hannaford *et al.* 2001) found crumb rubber to increase porosity, and decrease bulk density, capillary porosity, hardness and shear strength. They did, however, question its effect on water retention and surface stability if it was used as a dressing in large quantities.

Mesh elements/Reinforcement material

Mesh elements are used to alleviate instability problems that occur on profiles that have very high sand contents (Richards 1994). The aims to provide a series of randomly interlocking mesh pieces throughout the profile. Mesh elements can be included at different rates (i.e. kg elements/m³ sand) and may be different sizes (Canaway 1994). Other products are available and include fibre reinforcements and various mat products such as Tecnotile, Tensar mat, VHAF (Baker, Cole *et al.* 1988), DuPont Shredded Carpet, SportGrass and TurfGrids (McNitt and Landschoot 2000).

Generally, reinforcement materials can help with ground cover, infiltration, ball bounce and roll. The effect on traction seems to vary with the product and the depth at which it is placed, sometimes unacceptably increasing traction. Soil profiles benefit most from the inclusions, with little extra being achieved from their addition to a sand profile (Baker, Cole *et al.* 1988). These results may be highly dependent on climate and rainfall, and most appropriate to climates with frequent rainfall like Britain where the studies were conducted. The benefits in soil profiles may not be so readily seen in northern Australia where lack of, not excess, moisture is a limiting factor.

Mesh elements have been documented to improve soil physical conditions and improve infiltration, aeration and root growth in warm season grasses (Canaway 1994) infiltration, traction, hardness (Canaway 1994), available pore space, air-filled pore space, bulk density and volumetric moisture content (decreased) (Richards 1994). Other authors, however, have found little evidence to support the inclusion of such amendments (McNitt and Landschoot 2003).

While mesh inclusions have provided good results in soil systems, the conflicting results suggest limited, non-elite budgets should not be stretched to include mesh elements over other management practices.

Artificially drained profiles

Pipe drain

Pipe drains are placed across the field at spacings of 5-10 metres. Over the pipes the drains are filled with hard stone to about 15 cm of the surface. A blinding layer of medium-coarse sand is placed over the stone and sand topsoil placed over the blinding layer up to the surface. This type of drainage system may be useful for controlling a ground water problem. Drainage from the surface will only effectively remove surface, ponded water. Once water is not ponded on the surface, drainage will be reduced to the natural, often very slow, rate of the profile (Gibbs 1988).

Slit drain

Slits are placed in the profile across the pipe drain system already in place below. The slit spacing is in the range of 60 – 100 cm. The slits are filled with the stone/aggregate product to about 15 cm of the surface (i.e. to match the pipe drain layer). The remainder of the slit is filled with medium/coarse sand and the field is top dressed with sand. Ongoing topdressing must be with sand to prevent the surface of the slits from closing over with field soil.

A slit drain system can improve the drainage potential of a pipe-drained system by a factor of 11 (Gibbs 1988). In both slit and pipe drained pitches, infiltration and drainage from the surface is considerably higher near the drains (Gibbs 1988).

Sand carpet

A sand carpet construction is one where the site is graded, a basic pipe and slit drain system is installed with the topsoil in place, and a 10 cm layer of sand is spread over the entire surface of the site. Grass is then established on this 'sand carpet'.

If constructed properly, infiltration will occur uniformly across the surface of the field allowing uniform drainage (Gibbs 1988) and can improve the drainage potential of a pipe-drained system by a factor of 50 (Gibbs 1988).

Suspended water table

The suspended water table system comprises a pipe drain system underneath a 10 –15 cm layer of hard stone. Over the stone is a 5 cm blinding layer of coarse sand or grit. A further 25 – 30 cm of a chosen root zone is placed over the blinding layer (Baker and Isaac 1987).

Recommendations and Guidelines for Construction of Non-Elite Fields

Ensure construction contractors do not compact root zone according to engineering specifications.

Use laboratory testing to identify a good quality top soil/root zone mixture - good particle structure, low soil strength, 3-5% organic matter, no rock or other inclusions.

Ensure samples used for laboratory testing are representative of root zone to be used, and ensure the root zone tested is the material applied to the field.

Construct a potential root zone to at least 400 mm depth.

Any layering of soils within the root zone should have the finest textures at the base, and coarser (sandier) textures increasing toward the surface. There may be some benefits from having a sandy layer (no more than 50 mm thick) at the immediate surface to reduce hardness and excessive traction, and increase resistance to compactive forces, wear and surface unevenness.

Apply the root zone evenly across the field, with the exception of any sloping/crowing specifications.

Crown or slope the surface of the field- infiltration of any profile decreases over time and crowing or sloping increases the surface drainage of the field.

Ensure contractors leave the surface of the field even to promote the effectiveness of the crowing or sloping.

Install irrigation deep enough to allow cultivation and aeration practices to occur.

Maintenance and amendments and their effect on surface quality and performance

A number of the key maintenance procedures are discussed below. Most non-elite fields receive less maintenance including less fertiliser, weed management and aeration practices (Rogers, Waddington *et al.* 1988). In fact they may receive no maintenance beyond mowing or mowing and irrigation (Jeffrey 2003).

Aeration and cultivation

Aeration of the soil profile can be conducted by a number of implement types and include solid tines, hollow coring, slit tine aeration, verti-draining and spiking. There are many proposed benefits of aeration including increased air-filled space, decreased compaction, increased infiltration and drainage, increased root growth, disrupting soil layers improving the application of fertiliser, generally stimulating turf density and aiding soil modification and is generally considered essential (Binns 2001; Cockerham, Givault *et al.* 1993).

Aeration is recommended in at least early spring, summer and autumn to promote root and plant growth (Cockerham, Givault *et al.* 1993). More frequent aeration is recommended where it can be conducted and especially where the field may be suffering from compaction. Care needs to be taken if aerating during winter when turf recovery is slow, especially on a field where a winter sport is played.

Solid tines punch holes in the profile that can be up to 16 inches deep (Turgeon 2002). No soil is removed from the holes. The literature documents contrasting views regarding the benefits of solid tine coring. Frequently it is denoted to reduce compaction and increase water infiltration. Other authors (Turgeon 2002) express doubt and suggest it may contribute to increased compaction. Water infiltration into the holes from the surface would certainly be increased, but it does not follow that infiltration rates through the bottom and sides of the potentially compacted holes would also be increased.

Hollow coring removes a core of soil from the surface and creates large spaces for air and water movement within the profile. It is usually used for removing thatch, relieving severe compaction or soil from an undesirable profile (Binns 2001). Coring depth should be alternated to prevent formation of a compaction zone below the coring (Cockerham, Giveault *et al.* 1993). Cores may be removed or reincorporated when dry. Fertilisation after coring helps to place the fertiliser below the surface. Top dressing after coring is a usual practice that prevents excessive movement of profile material into the core space and amends the soil profile.

Root growth is generally noted down into the holes created by coring regardless of the profile type or its problems (Zontek 2002) and coring promotes deep rooting of warm season grasses in particular.

A verti-drainer is comprised of a long set of tines that, depending on the implement, reach down to 200-400 mm. It can be used with or without a heaving action that further loosens the soil. It should be used when the soil is moist and is aimed at alleviating severe compaction (Binns 2001). It can also be used in conjunction with other coring mechanisms to aid prevention of a coring compaction layer (Cockerham, Giveault *et al.* 1993).

Spiking uses an implement with nail-like steel tines (Cockerham, Giveault *et al.* 1993). It punches small holes in the profile like a solid tine corer and can be used to increase the permeability of the turf surface. Spiking probably will not help infiltration if compaction, not a sealed surface layer, is causing the problems in the profile (Canaway, Isaac *et al.* 1986).

Research results are, however, conflicting regarding the positive outcomes of aeration. Even positive effects of aeration activities are also often relatively short lived (Aldous, James *et al.* 2001), especially if conducted during a playing season when wear is continuously imposed on the playing surface (Canaway, Isaac *et al.* 1986).

(Rogers and Waddington 1990a) note coring has little immediate effect on hardness and inconsistent effect on shear resistance and (Carrow and Johnson 1992) found core aeration, with the cores removed, decreased shoot density.

(Gibbs, Liu *et al.* 2000) (New Zealand) found the use of a Verti-drain or a Hydro-ject on constructed golf green surfaces gave the softest surfaces, irrespective of root zone composition. (A Hydro-ject injects water into the soil profile.) The Hydro-ject also was particularly good at reducing dry patch on the sand base root zone when used with a wetting agent. (Binns 2001) also commended the Hydro-ject for the alleviation of dry patch, but doubts the use of the Hydro-ject as a method of aeration.

In Australia, aeration using Verti-drain reduced surface hardness and soil strength and improved infiltration rate and volumetric soil moisture in clay loam profile. However, the effectiveness was short term, and much reduced with active play (Aldous, James *et al.* 2001). (Siviour 2001) states verti-drain is effective for aeration purposes, but is not as effective in increasing water movement into slits and drains as vibra-moling or shatter-mastering.

Overseas research showed neither a Verti-drain nor a deep aerating rotovator produced a long-term loosening effect or any change in puddle formation or playability on sporting fields in the Netherlands (Zwiers 1987).

Similarly, a range of cultivation treatments failed to improve oxygen diffusion into soil profiles assessed on golf courses in the USA (Carrow 1990) and failed to have any long term effects on the density or colour of the turf in the UK as measured by reflectance ratio (Baker, Cook *et al.* 1999).

Frequent slit tine aeration in wet conditions and in the presence of wear has been found to decrease the ground cover on a field and to decrease infiltration (Baker 1994). Slit tine aeration should not be conducted under wet conditions as smearing of the soil can occur and has been linked to decreased infiltration (Baker 1994). While northern Australian winters are not typically cold and wet, most warm season grasses are dormant at this time. Frequent slit tine aeration during this time could also promote loss of ground cover due to low winter growth and recovery. This would apply to all aeration and cultivation techniques.

In other trials, slit tine aeration had no effect on water infiltration rate and no measurable effect on hardness (Baker, Cook *et al.* 1999) and was shown to not provide adequate aeration and drainage between the slits on sporting fields in the UK (Gibbs and Baker 1989). However, the performance of the slits depends very much on the method of profile construction and tine spacing.

Other authors have found cultivation generally increased root growth and that deep cultivation increased deep rooting.

Recommendations

Research results show the success of aeration or cultivation seems to be dependent on the implement type, the individual ground, its composition, condition and level of compaction and the reason for which the implement is used. Short-term effects indicate the frequency of aeration and de-compaction treatments needs to be as high as the turf quality and the budget will allow.

Aeration and cultivation should not be conducted in mid winter during grass dormancy or slow growth to prevent unnecessary damage to the playing surface.

Aeration should be timed with topdressing to allow remediation of soil profile. Fertilisation can also be conducted at this time to target fertiliser to the root zone.

While Aldous (Aldous 2002) suggested the need for further assessment of the effects of Verti-drain timing, frequency, depth and spacing on the longevity and effectiveness of tine hole under Australian environmental and cultural conditions, it is recommended other aeration and cultivation methodologies are also assessed with respect to surface quality and playability in Australian conditions.

Top dressing

Top dressing is the practice of adding a thin layer of soil or amendment to an established or establishing turf stand (Turgeon 2002). It helps to control thatch, create an even surface, promote grass recovery and can be used to change the soil profile (Turgeon 2002). It can also help maintain surface evenness (Fresenburg 1999; Siviour 2001) and help with drainage and infiltration (Siviour 2001).

If too little top dressing is added, the profile may end up with a thatch, soil, thatch layering system. Topdressing should always be conducted with a material as similar as possible to the soil of the profile or the last topdressing material. Topdressing with inappropriate topdressing materials can also create a layering effect in the profile and reduce infiltration, internal drainage, aeration and root penetration (Turgeon 2002; Waddington 1992). Even small differences in the layers can cause adverse affects in the profile (Turgeon 2002).

A usual practice is to top-dress with medium or medium-coarse sand (Cockerham, Givault *et al.* 1993; Fresenburg 1999). The particle shape of the dressing should be considered as it contributes significantly to the stability and the packing qualities of the profile (Fresenburg 1999). Top dressing (with sand), in conjunction with core aeration, increases soil air space, reduces compaction and thatch build-up, increases infiltration, changes the bulk density of the profile and promotes deeper root development (Carrow and Johnson 1992; Fresenburg 1999).

Recommendations

Don't top dress with a material of finer composition than the last top dressing or the soil profile and make an effort to match the top dressing material with that of the last dressing or the soil profile.

Conduct frequent and thick topdressings to prevent a thatch/soil layering effect in the profile.

Fertilisation

Fertilisation plays a considerable role in maintaining the quality of the surface. It is intended to supplement the nutrients that are naturally present in the soil and directly affects the growth, health and recovery of the ground cover, can affect the types of ground cover that are present on the field and affects the soil microflora.

Fertiliser programmes are created after considering the soil type, the turf species, the sporting application, the amount of maintenance that can be conducted on the field and the budget available for the fertiliser and the maintenance. While many managers fertilise by guess and by 'the look' of the turf, the most accurate methods to determine the nutritional needs of the turf are regular soil and/or tissue analyses. Creating a fertiliser regime by matching turf nutritional needs to the results of an annual soil analysis is probably adequate for a low budget, non-elite field, and far more than is currently practiced.

Nitrogen is the most required nutrient for turf growth and is the nutrient most often deficient (Cockerham, Givault *et al.* 1993; Lawson 2001; Rogers, Waddington *et al.* 1988). For example, some practice fields in the United States receive a 10 fold reduction in nitrogen application (compared to the game fields) even though they sustained the most wear and traffic (Cockerham, Givault *et al.* 1993). In south-east Queensland, non-elite fields also receive little to no fertiliser per annum.

Appropriate rates of nitrogen increase wear tolerance (Turner and Hummel 1992). Turf grown under high nitrogen is less tolerant of wear, while turf grown under low nitrogen is incapable of sustaining growth to recover from wear and traffic (Canaway 1984). Raising the annual nitrogen inputs, however, is not sufficient to overcome wear injury. (Carrow and Johnson 1992) found small amounts of supplemental nitrogen, coupled with irrigation, were necessary to promote rapid recovery from wear.

Different genera, species, and even cultivar, will respond to varying rates of fertiliser throughout the year. For example, nitrogen application rates influence the colour and quality of zoysiagrasses, particularly in autumn (McCrimmon and Williams 1997). Nitrogen rates have also been shown to influence shoot density, with density increasing as nitrogen rate increases. There is an upper limit for increasing shoot density with nitrogen applications (Carrow and Johnson 1992) and excessive nitrogen favours shoot growth at the expense of root growth (Turner and Hummel 1992). (Carrow and Johnson 1992) recommend that if shoot density is of primary importance, a cultivar with an inherently higher shoot density should be chosen rather than increase the risk of wear with high nitrogen applications.

The type of fertiliser, controlled or conventional release, coupled with the soil type of the field will influence application rates and frequencies. As the sand content of a soil profile increases, the fewer nutrients are retained in the profile at any time. Conventional release fertilisers are released quickly and can be easily leached through and lost from a sand profile. The use of controlled release fertilisers prolongs the period between applications on any type of field profile.

Using controlled release fertilisers (CRF's), or very small, frequent fertiliser applications, promotes consistent turf growth and wear and disease resistance. These practices also promote healthy growth of the natural soil microflora. Microflora populations fluctuate with the addition of inorganic fertiliser and the greater the fertiliser addition, the greater the fluctuation of the population. A stable, healthy microflora population in the soil in turn promotes good soil structure, increased pore space, drainage and natural breakdown of thatch.

Use of controlled release fertilisers, or small frequent applications of conventional release fertilisers, not only contributes to good soil and turf health and wear tolerance, but contributes significantly to negating any unnecessary loss of nutrients from the soil profile into ground water or urban drainage systems. Irrigation practices also play a considerable role in achieving minimal nutrient leaching from the sports turf profile.

On the negative side, fertilisation at recommended nitrogen rates has been found to decrease infiltration rates due to an increased root mass blocking soil pores (Canaway and Bennett 1986). While thatch production does not seem to be a problem on non-elite fields in northern Australia, thatch production would increase if the fields were fertilised, particularly if heavily fertilised, and infiltration may be impeded. This would imply management of thatch might be necessary when fertilising to encourage a healthy, growing turf sward.

Other nutrients are important in sand based systems, but are rarely deficient in soil-based constructions and will not be discussed here.

Recommendations

Small, frequent applications of fertiliser are recommended for all non-elite sports fields. Using controlled release fertilisers are a good means of ensuring a constant, steady supply of nutrients and provide the part-time or volunteer field manager with a means of doing this.

In geographical locations where the turf does not enter dormancy over winter, restricted fertiliser budgets should be allocated to fertiliser applications during the playing season, when the field is in constant use, to promote recovery from wear and the continued growth and health of the turf sward. This will also help prevent worn patches and patches becoming colonised by weed species.

Where turf does enter winter dormancy, fertiliser budgets should be targeted to pre and post dormancy allocations, providing optimum turf cover going into dormancy and promoting recovery from wear as the turf moves out of dormancy.

Fertilisation should not be scheduled in conjunction with extreme rainfall or irrigation events, as while the loss of the nutrients from the profile into drainage systems is not environmentally responsible, it is likely that the manager of a non-elite sports field cannot afford to replace nutrients lost from the profile.

Fertilisation can be conducted in conjunction with coring and topdressing if the field manager prefers to target the fertiliser straight into the root zone.

Irrigation

The primary reason to irrigate turf is to supply an adequate amount of water to the plant for its growth. Water is stored in the soil profile and the water available depends on the soil type and the depth of the root zone. Watering to depths below the root zone is wasted water and money and increases nutrient losses from the profile. Nutrient extraction occurs in the active root zone, which is the area where most of the root mass exists (Barton and Colmer 2001). The depth of this will vary with the root zone composition and the compaction of the root zone. It can be from 100 – 700 mm down from the playing surface. Leaching of nutrients to below the active root zone will occur if inappropriate types or amounts of fertiliser are used, particularly in conjunction with high irrigation or rainfall.

Irrigation frequency is determined by how much water is lost from the profile (evaporation, plant use) and how deep the root zone is. A deep-rooted turfgrass accesses more water than a shallow-rooted grass and needs longer, but less frequent irrigations. Most of the literature states less frequent irrigation promotes more developed root systems and healthy turf growth. Australian authors (Menzel and Broomhall 2003) found droughting warm-season turfgrasses encouraged deep root growth and deep soil water extraction.

While some overseas authors found increasing the length of the intervals between irrigation events decreased quality and turf density, Broomhall and Menzel's research showed irrigation of warm-season grasses can be extended to weekly or even fortnightly with little impact on turf growth or quality (Broomhall and Menzel 2002).

(Beard 1973) specifically states as frequency of irrigation increases above the optimum positive plant water balance, shoot growth, root growth, chlorophyll content and succulence decrease, while shoot density increases. Authors whom disagree, and promote frequent watering, are usually referring to a greens situation and/or grass under acute heat stress.

Warm-season grasses are used on northern Australian AFL fields. They are reasonably drought tolerant, although differences are evident between species and varieties (Menzel, Smart *et al.* 2003). Couch, and particularly common blue couch (*Digitaria didactyla*), two of the dominant warm-season grasses on these AFL fields, have good water use efficiency and tolerate less frequent watering quite well. Warm-season grasses, including the couch genera, also recover quickly and entirely from drought stress induced wilting (Menzel, Smart *et al.* 2003), implying turf can recover if irrigation schedules are unintentionally reduced beyond turf water use requirements.

Irrigation is also a primary tool for managing field hardness. Increasing moisture levels decreases hardness and could be used to soften hard grounds for safe play. This may be particularly relevant to AFL non-elite fields where maintenance to relieve hardness may not be accessible or affordable in a non-elite budget.

Recommendations

Use evapotranspiration and root zone data to develop water-wise irrigation practices. Extend irrigation frequencies to promote deep root growth and drought tolerance - irrigate less frequently, but apply more water at each irrigation event.

When rescheduling irrigation frequencies, account for the capability of the irrigation system to deliver large amounts of water infrequently and the infiltration rate of the field. Do not allow ponding on the surface of the field.

If the irrigation system and field infiltration rates allow large, infrequent irrigation events to be conducted, do not do so within 24 hours of play to help prevent compaction and excessive degradation of the turf surface.

While warm-season grasses recover from wilting and drought stress, irrigation schedules should limit the frequency of wilting during the playing season. This means irrigation frequencies should not be extended to wilting point. Drought stressed grass that is subjected to wear will not recover like non-worn turf in the experiments of (Broomhall and Menzel 2002).

If the opportunity of re-turfing a field should arise, or turfing a constructed non-elite field, species with low evapotranspiration (ET) should be chosen. Species with low ET's, which use less water (mm) per day are usually more hardy and drought tolerant and can help increase water use efficiency and water saving and therefore budget dollars.

Weed management

Weed management is conducted on sports fields to maintain a uniform playing surface and the aesthetic appeal of the field. At elite sports levels, a surface comprised of only one grass species is usually desired, and all other grass and plant species are considered weeds. On non-elite fields, however, only a durable, but even, ground cover is required. Therefore more than one grass species is acceptable and tufted grasses and broad leaf dicotyledons are the species considered weeds.

Weeds in a turf sward may decrease the ability of a surface to 'play true' (Beehag 2000) and cause surface unevenness. Tufted grass species contribute to 'untrue' ball bounce and surface unevenness as the tuft of the crown and foliage sits above the crowns and stolons of the desired grasses. Soft, broad-leaf weeds have low wear tolerances and recovery abilities. Under conditions of wear, they quickly degrade and leave areas of patchy and uneven playing surface. Some of the tufted species, e.g. *Eragrostis* spp., grow well under compacted conditions and successfully out compete the more sensitive stoloniferous species.

Selective herbicides are considerably fewer in Australia than overseas and many desired species are sensitive to the available products (Beehag 2000). Where a number of acceptable grasses make up a sports turf surface, the range of selective herbicides is further reduced. Chemical control of tufted grasses may be most effectively achieved with selective application methods (e.g. wick wiping) rather than selective chemicals.

Weed control should ideally be conducted when the desirable species are growing actively to promote replacing the weeds with turf, rather than replacing the weeds with other weeds. Any practice that stresses the desirable species and opens the sward promotes weed colonisation (Beehag 2000). Care should be taken to match the herbicide against the species present on the field to limit turf damage and further limit weed colonisation.

Recommendations

Conduct extensive weed elimination programmes outside the playing season to allow recovery of the playing surface and to promote surface evenness and quality during the season.

Decrease compaction to discourage tufted weed species and to encourage the persistence of desirable turf species.

Use wick wiping or wandling to remove tufted species or individual broadleaf or other species.

Mowing

Mowing can be conducted using a flail, rotary or reel mower, although the type of mower impacts turf quality. The differences between reel and rotary are far less significant than between reel/rotary and flail mowers. For turf applications (rather than roadsides, large parks etc), flail mowers decrease sward and reduce shoot density and quality (Carrow and Johnson 1992).

Mowing with dull blades increases disease susceptibility, turf quality, leaf/shoot density and water use. While the decreased water use would immediately seem like a positive benefit, it is due to a loss of turf quality and shoot density (Steinegger, Shearman *et al.* 1983) rather than real water savings.

Frequency

Mowing frequency can be determined simply as a calendar cut, or by the time taken for the turf to reach a maximum acceptable height. A calendar cut is the most simple to implement, but does not account for seasonal growth variation. The latter is dependent on accurate measurement, quantitatively or by eye, of the turf length, but does provide a more consistent sward (Shildrick 1986).

Height

Height is primarily dependent on the application, and secondarily on the turf species and variety. Height standards have developed for some sports such as hockey, soccer and rugby (Section 2.4).

Mowing height significantly influences root development and water use. Consistent low mowing of turf grasses decreases root development and overall root biomass and weakens the turf (Mooney and Baker 2000; Parr, Cox *et al.* 1984). For example, cutting *Lolium perenne* at 20 mm decreased the root growth at all depths of the profile and resulted in a 35% drop in overall root biomass (Parr, Cox *et al.* 1984). Water consumption of cool season grasses increases with height of cut (Kneebone, Kopec *et al.* 1992). The effects of increasing mowing height of warm season grasses is not well documented, but is known to at least temporarily increase water use. Water consumption of low mown grasses is decreased, but is due to a smaller shoot biomass and is at the expense of a healthy, developed root system.

(Colbaugh, Beard *et al.* 1980) found mowing height of a *Cynodon* species significantly influenced the incidence of dollar spot. At lower mowing heights dollar spot was prevalent and was not found at heights over 1.5/2.0 inches. A height x nitrogen application rate was evident in this trial also.

Height is often relaxed in the off-season to help turf recover and to endure environmental conditions outside its preferred climate range. This has implications for mowing maintenance of warm-season grasses used for winter sports in northern Australia. While these grasses may not enter true dormancy and continue to grow through winter, growth and recovery is slowed during this time. Warm-season grasses on non-elite fields used for AFL in northern Australia are not mowed especially low, but managers of these fields may promote the wear tolerance, disease tolerance and a quality playing surface by ensuring height is not decreased over the coldest months of winter.

Clippings

(Beard 1973) calculated returned clippings may contribute up to 2 lbs of nitrogen/1000ft² per year and can be used as an important, organic fertiliser source. Trials with couchgrass have shown that returning the clippings increased shoot density and colour. While it is commonly perceived that returning clippings promotes a thatch problem, (Carrow and Johnson 1992) found that when using a reel mower, returning the clippings actually reduced thatch by 11%. (Beard 1973) concurred with these results. The clippings returned in these trials were of a short and fine nature and the results may not be replicable where the clippings were long, large or coarse. This implies to successfully return clippings to a field; cuts should be frequent and determined by maintaining a specified height of cut as discussed in above.

Recommendations

Mowing should be conducted frequently so clippings are fine and can be returned without detriment to the sward and so that the proportion of the shoot removed at each mowing is small (up to 30%).

Ensure all implements have sharp blades to reduce mowing damage to the sward.

If possible, mow turf at the higher end of the permissible range of heights to promote root development. Frequent mowing is then necessitated to keep turf within the recommended range.

During periods of stress or slow growth, e.g. winter for warm-season grasses, relax mowing heights if possible. This will also help reduce dollar spot incidence in areas where dollar spot is troublesome.

Over Seeding

Over seeding is used to establish groundcover after wear (Canaway, Isaac *et al.* 1986) or to provide ground cover more suited to seasonal conditions. (Cockerham, Givault *et al.* 1993) notes *Lolium perenne* to be the most durable species for over seeding *Cynodon* varieties. Over seeding *Cynodon* species with *L. perenne* is practised in Australia on elite and financially able, non-elite fields, particularly in southern areas where *Cynodon* species enter true dormancy. Fields are also over sown with *L. perenne* because it has lower traction properties as discussed in previous sections.

The success of over seeding is dependent on the capability of the species to establish in the window between seasons, and to resist wear in the following season (Canaway, Isaac *et al.* 1986).

Recommendations

Managers of northern, non-elite fields (where couch grasses continue slow growth during winter) may find their budget better allocated to irrigation, fertiliser and de-compaction than seasonal over seeding.

If over seeding is conducted, managers must ensure it is established as warm-season grasses move into dormancy.

Miscellaneous issues potentially more relevant to elite fields

Shade

Shading on fields enclosed by stadia provides numerous problems with respect to maintaining a quality, playing surface. These include lack of light for grass growth, excessive moisture and high relative humidity in the grass canopy, increased incidence and severity of disease, etiolation and reduced root growth.

Varieties

On premier sports grounds, where the surface will be a turf monoculture, the choice of turf species plays an important role in the ongoing playing quality of the surface. This is particularly true if the surface is to sustain high wear and if stadia shade the playing surface. In such conditions, a fast-growing, shade-tolerant species will promote consistent playing quality (Bugbee and Johnson 2002).

Disease

Disease tends to be more problematic on fields where the turf is stressed. For example in shaded stadia, on closely mown turf and in cool, wet climates. These conditions are not relevant to most non-elite AFL fields and disease not usually a problem.

Recommendations

Condition and performance monitoring for non-elite fields

1. The primary parameters to measure frequently are hardness, traction, moisture and ground cover. Compaction and infiltration are also extremely important parameters but can be measured less frequently.
2. Monitoring the important parameters should be incorporated into the field managers' maintenance programme to consistently monitor the quality and safety of their field, and to provide constant information to guide management processes.

Construction of Non-Elite Fields

1. Ensure construction contractors do not compact root zone according to engineering specifications.
2. Use laboratory testing to identify a good quality top soil/root zone mixture - good particle structure, size and distribution, low soil strength, 3-5% organic matter, no rock or other inclusions.
3. Ensure samples used for laboratory testing are representative of root zone to be used, and ensure the root zone tested is the material applied to the field.
4. Don't separate topsoil material into types – this promotes the formation of layering within the profile and will create substantial growing problems.
5. Apply the root zone evenly across the field, with the exception of any sloping/crowning specifications.
6. Apply root zone to at least 400 mm.
7. Crown or slope the surface of the field- infiltration of any profile decreases over time and crowning or sloping increases the surface drainage of the field.
8. Ensure contractors leave the surface of the field even to promote the effectiveness of the crowning or sloping.
9. Install irrigation deep enough to allow cultivation and aeration practices to occur.

Management and Maintenance of non-elite fields

1. Prioritise removal of tufted weed species to promote surface evenness.
2. Top dress annually for levelling, protection from moving objects in a landfill site and greater grass growth and persistence.
3. Conduct irrigation 24 –48 hrs prior to a game to decrease hardness.
4. Do not irrigate less than 24 hours to prevent increased compaction from traffic on wet soil.
5. Reduce mowing heights to help lower traction values on fields with dense couch or other stoloniferous species.
6. Ensure mowing heights are not reduced excessively (1) during the coldest winter months to help the warm season grasses on the field endure winter weather and (2) to help prevent the incidence of dollar spot, a common turfgrass disease.
7. Keep the percent ground cover as high as possible to help prevent wear, compaction, moisture loss, hardness.
8. Ensure training is spread over the field to limit concentrated areas of wear (non-elite clubs cannot afford remediation and need to employ as much prevention as possible).
9. Aerate and de-compact as frequently as possible to help prevent further compaction problems.
10. Initial aeration and de-compaction activities may need to be particularly intense to combat years of compaction and no maintenance.
11. Allocate money from even a small maintenance budget for fertiliser applications throughout the playing season if the club cannot afford a yearlong regime. This significantly promotes turf recovery from wear.
12. Make all fertiliser applications small and frequent, rather than periodic and relatively large, to promote even growth, a more consistent turf sward and healthy plant, increase disease resistance and promote healthy soil microbe populations.

13. Check the organic matter content of the field when conducting nutritional analyses. If it already approximately 5%, continue to monitor, but don't spend scarce budgetary dollars on further additions of organic matter. If less than 3-5%, investigate the addition of organic matter.
14. In northern Australian winter conditions, where many warm season grasses do not enter true dormancy, use budget to irrigate, fertilise, and de-compact rather than over seed.

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AFLQ ground soil profile characterisation

Summarised from (Raine and Eberhard 2004).

To enable the identification of appropriate soil and irrigation management treatments to improve the performance of AFLQ field surfaces, an initial field sampling program was undertaken in December 2003, to characterise the soil profile material present on four of the AFLQ Premier League sporting fields.

Field sites

The four QAFL fields involved in the characterisation study were selected on the basis that they represented the full range of existing quality of playing surfaces within the QAFL Premier League competition (Table 2). Soil profile core samples and surface measurements were obtained at four locations in each field representing various levels of training and playing intensity. The sites sampled and measured on each field were typically representative of the: outside flank area (low traffic/wear) training areas (intermediate-high traffic area, usually on flank near the club house); centre square area (intermediate-high traffic/wear), and goal mouth (high traffic/wear).

Table 2. Perceived playing surface quality of the selected QAFL fields.

Field	Perceived quality of playing surface ¹
Morningside	Good
Sherwood	Acceptable
Everton Park	Acceptable
Zillmere	Below average

¹as assessed by QAFL ground staff

Soil profile cores

Soil profiles were sampled to a depth of 500 mm using a 3 tonne hydraulic Mole Rig fitted with a 100 mm diameter push tube. Four cores were sampled at each one of four locations with the field. The cores were extracted from the push tube, photographed and placed in a protective PVC pipe for transport. Individual soil horizons in each core were identified on the basis of soil colour, texture and density differences. A sample of each horizon was then passed through a 2 mm sieve to separate and quantify the fraction of coarse fragments and soil material. The colour, texture and pH of the soil material in each horizon was then described using the methods outlined in (McDonald, Isbell *et al.* 1990).

Surface measurements

Measurements of the soil surface roughness, bulk density, moisture content and penetration resistance were taken at each of the four sampling locations on each field. Photographs of the representative grass cover were also taken at each location. Surface roughness was measured using a Rimik Profilemeter with a 1 m frame width which contains 32 steel rods (5 mm diam) at 30 mm spacings. The rods were lowered onto the soil surface and individual rod height relative to the frame recorded by datalogger. Ten surface roughness profiles were sampled at each location in the field. While it is possible to present the surface roughness using a variety of indices, the average difference between the adjacent rods was chosen as it most appropriately represents the physical roughness over the scale which would influence both ball bounce and foot stability. Surface hardness was measured using a Geotester pocket penetrometer fitted with a 60 degree cone tip (2.5, 3.5 or 4.5 mm diam). The cone was inserted by hand into the soil surface to a depth of 40-50 mm and the maximum penetration resistance measured. Twenty penetrometer measurements were taken at each of the four sampling locations in each field.

Up to four core samples (48 mm diam) of the surface 0-50 mm layer were extracted using a sampling tube with cutting edge. These surface samples were subsequently used to obtain bulk density measurements and the soil moisture content at sampling.

Hydraulic modelling of soil-water movement

Simulation modelling was used to conduct a preliminary evaluation of potential differences in soil-water movement associated with differences in the soil profiles found both across and between the fields. The model Hydrus-2D (Simunek, Sejna *et al.* 1999) was parameterised using the measured textural properties of the soil cores and used to simulate the water movement within each soil profile when either 25 mm of water is applied (eg typical of an irrigation event) or 60 mm of water is applied (eg. similar to a reasonable rainfall event). In both cases, the soil profile was assumed to be uniformly dry prior to the application of the water and there was no allowance for lateral soil-water movement. A range of additional soil physical measurements are currently being undertaken on the soil profile cores. This work will provide improved characterisation of the saturated hydraulic conductivity, air filled porosity and soil-water characteristic curve for the surface and other major horizons. This data will be used to improve the parameterisation of the soil-water model in an effort to more accurately predict the influence of both irrigation management alternatives and soil amendment options.

Significant differences in both grass cover and soil profile were found both between each of the fields and within each of the fields. Soil information sheets were produced for each of the four sampling sites on each of the four fields. These sheets (example Plate 1) include a photograph of the surface grass cover taken at the time of sampling, the full soil profile description aligned with a photograph of the soil profile core, and the results of the simulation modelling for the two alternative wetting events.

Results and discussion

Everton

The Everton field shows a clear difference in soil geomorphology across the field. The south-western side of the field near the club house has been produced by cutting down into the bedrock with mixing with either local or imported clay fill material. However, the north-eastern side of the field has been produced by levelling the lighter textured alluvial soil material associated with the local creek. The cricket pitch on this field has been constructed out of approximately 200 mm heavy clay overlying approximately 300 mm of 10-20 mm coarse gravel.

Morningside

There is a high degree of horizontal layering present in each of the soil cores taken across this field. In general, the surface 200-300 mm material is composed of up to 4 different layers of sandy loam to sandy clay loam material. At each site across the field, there is a significant subsoil layer of light to heavy clay which could be expected to impede both soil-water movement and root growth. However, the depth and thickness of this layer was variable with the layer extending below 200 mm in the southern goal mouth and south-western flank area but not found until approximately 360 mm in the north-eastern flank area. The north-eastern flank area also has a layer of coarse fragments intermixed with the soil material extending between approximately 100 and 300 mm depth which could be expected to improve the drainage in this area of the field. The centre square core sampling was taken beside the cricket pitch at this field and the cores recorded show the edge of the clay pitch extending through at a depth of 200-300 mm. On the day of sampling, a free standing water table was found at a depth of approximately 400 mm on the north-eastern flank possibly reflecting the lateral movement of water in the 100-400 mm horizons.

Zillmere

The surface soil material across this field ranged from a sandy loam to a sandy clay loam. The depth of the surface material ranged from 140-230 mm and was typically laid over a 50 mm medium to heavy clay layer. The variability of the depth to the clay and coarse fill layer is likely to influence the effective rooting depth of the grass and influence its ability to access both nutrients and water. Mottling was found within the 300-500 mm subsoil clay layers suggesting that internal drainage of soils at this field may be problematic. A thick layer of coarse fill material (ash) was found at 290-500 mm on the south-western flank area. However, this fill material horizon was only approximately 50–80 mm thick in the other areas of the field and was found at a depth of approximately 300 mm in the centre square area, 200 mm in the north-east flank area, and approximately 150 mm in the southern goal square area. Some coarse brick material was found intermixed in the 160-310 mm depth at the southern goal square area. The centre square samples were not taken on the cricket pitch at this site.

Sherwood

The differences in the soil profiles across this field reflect the differences in elevation and the ability of the operators to accurately apply the requisite thickness of each layer during construction. There is a layer of coarse fill material in the subsoil of this field but the depth and thickness of this layer varies with location. The south-western flank of this field has a shallow layer (approximately 100 mm) of sand and sandy loam material overlying a thin horizon of light clay (100-130 mm) with the remainder of the profile consisting of the fill material. The surface (0-170 mm) layer of the southern goal mouth area is dominated by a light clay soil with the coarse fill material extending below a depth of approximately 300 mm. The north-eastern flank has approximately 60 mm of sandy loam overlying clay material which extends to a depth of approximately 250 mm where there is a layer of the coarse fill material approximately 50-150 mm thick. The centre of the field is underlain by a heavy clay cricket pitch at a depth of approximately 200-450 mm. This surface above the clay layer is composed of loamy sand to sandy clay loam horizons which show no evidence of water logging. This suggests that water does not pond above the clay layer but instead drains laterally off the clay layer upper boundary.

Comparison of simulated soil-water movement studies

The simulated soil-water movement for both the 25 mm and 60 mm water application are shown on the information sheets for each soil profile at each field (example Plate 1; full report in (Raine and Eberhard 2004)). The results highlight the significant variations that could be expected in irrigation performance and utilisation of rainfall as a consequence of soil-water holding capacity, effective rooting depths and internal drainage rates. In general, the application of 25 mm of water (eg typical irrigation) would result in the wetting of between 130 and 200 mm of soil. Only the eastern flank area of Sherwood exhibited any signs of transient waterlogging with the root zone due to the application of this volume of water. However, where larger volumes of water (eg 60 mm) are applied by either irrigation or rainfall, then the depth of wetting was found to range from 350 to 500+ mm with significant transient waterlogging in some areas of both Sherwood and Everton fields. Transient waterlogging would be expected to affect root growth, grass disease susceptibility and nutrient availability.

average turf cover



Morningside

North-east flank
Low Wear

wetting characteristics (estimated)
Initial conditions: very dry (-100m)

Soil profile description

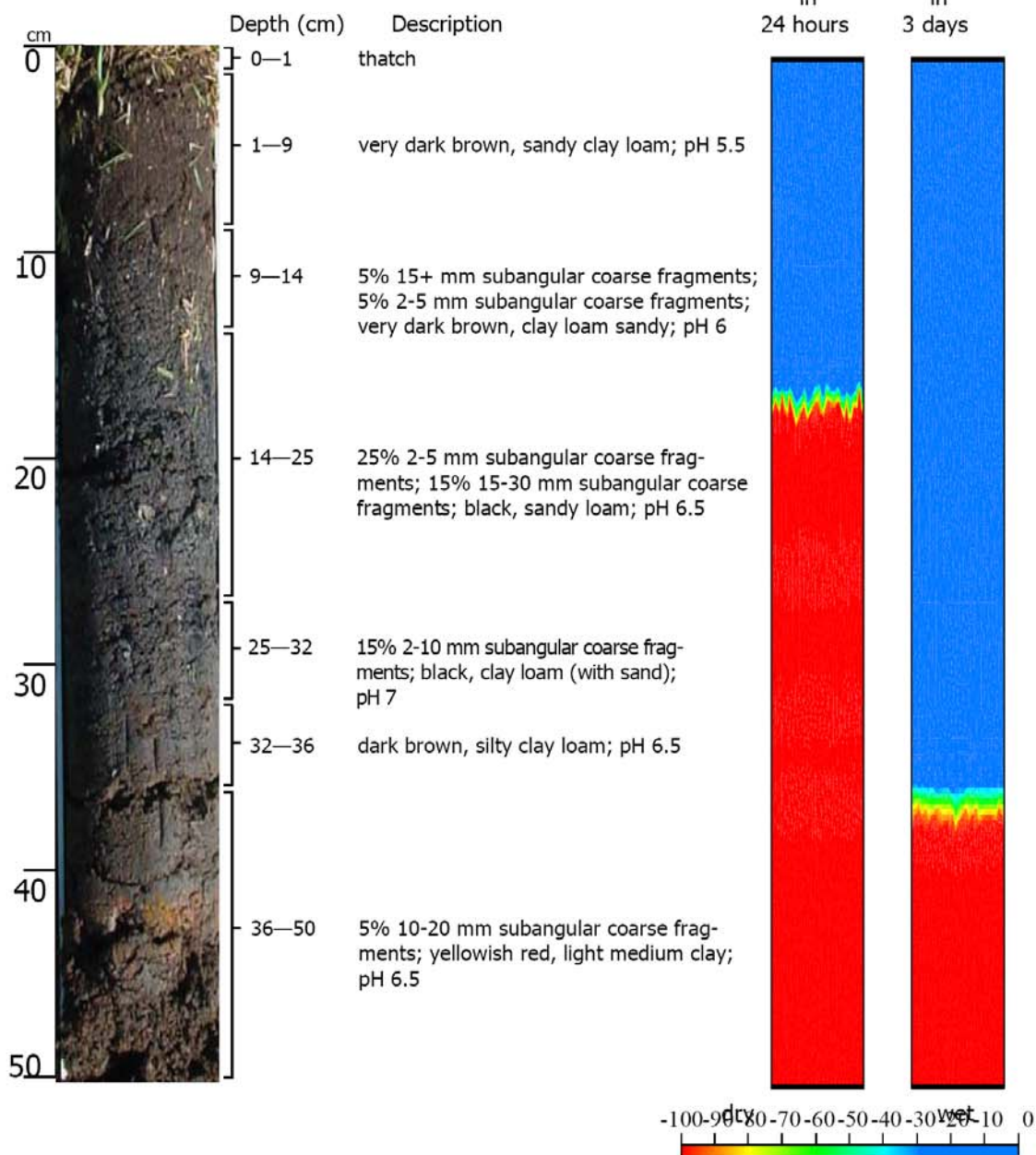


Plate 1. Example of soil profile characterisation sheet.

Comparison of field surface measurements

The physical properties of the surface 0-50 mm soil layer varied significantly both between the four fields and across the individual fields. The clay content of the surface soil on the sampled fields varied from 5 to 70%. Similarly, the bulk density of the surface soil ranged from 1.1 to 1.7 g cm⁻³ (Figure 1) and the penetrometer resistance ranged from 2.7 to 7.1 MPa (Figure 2). A significant ($P < 0.1$) positive relationship was identified between penetrometer resistance and bulk density (Figure 3). Sherwood was found to have the highest bulk densities and penetrometer resistances of the fields measured. There was no significant difference between the average penetrometer resistances measured on the other fields. However, within individual fields, there was a wide range of both penetrometer resistance and bulk density. The penetrometer resistance was found to be consistently lower in the low traffic/wear areas associated with the outer flanks at each field site. There was typically no significant ($P < 0.05$) difference in penetrometer and bulk density measurements taken in the intermediate-high wear areas on each field.

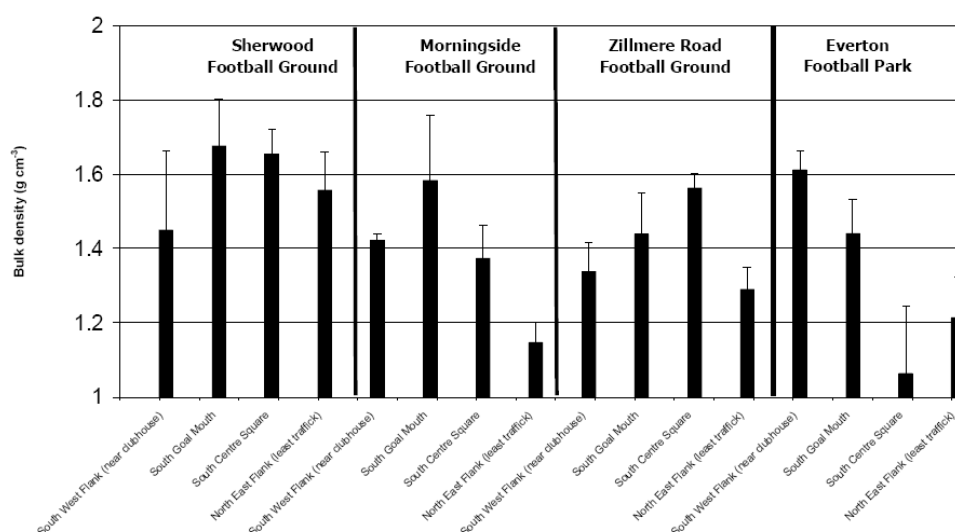


Figure 1. Bulk density of surface 0-50 mm on four sporting fields.

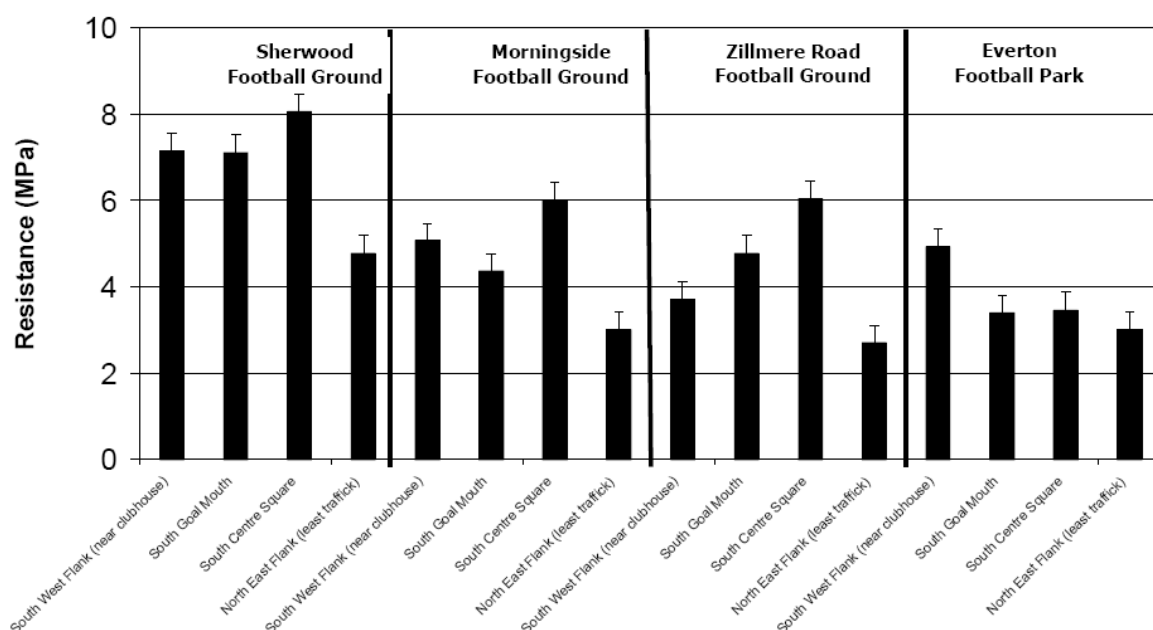


Figure 2. Maximum penetrometer resistance of surface 0-50 mm on four sporting fields.

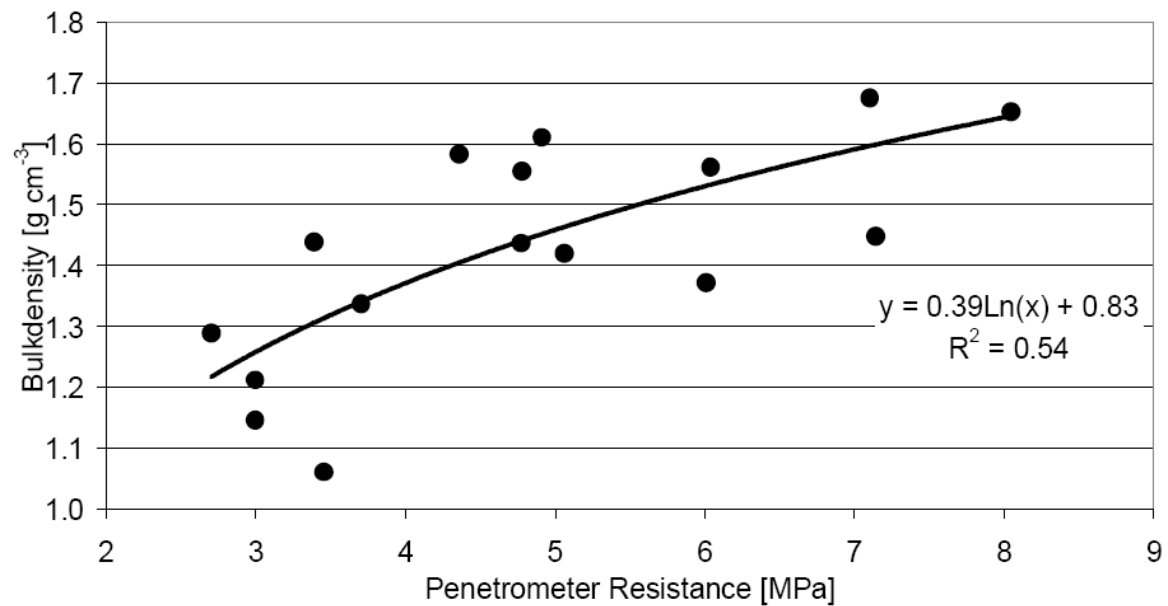


Figure 3. Relationship between bulk density and penetrometer resistance.

Despite widespread and relatively consistent rain across each of the fields approximately five days before sampling, the volumetric moisture content of the surface soil on the day of sampling ranged from 18 to 48% (Figure 4). Differences in moisture content across the fields would be expected to reflect the variation in soil texture, depth to various restricting layers and compaction of the surface layers. For example, the high moisture content measured in the Everton centre square area is due to the high clay content of this material while the high moisture content measured in the north-east flank area of Morningside is likely to be related to the shallow watertable observed at this site during sampling. A significant ($P < 0.1$) inverse relationship was found also between water content and bulk density. However, it is not clear from the current data whether this relationship was found because of differences in texture (i.e. lighter textured soil will have low water holding capacity but pack to high densities) across the sites or differences in compaction (i.e. compacting soil will reduce the volume of pore space and water holding capacity). Hence, further work is required to identify the exact nature of relationship in this case.

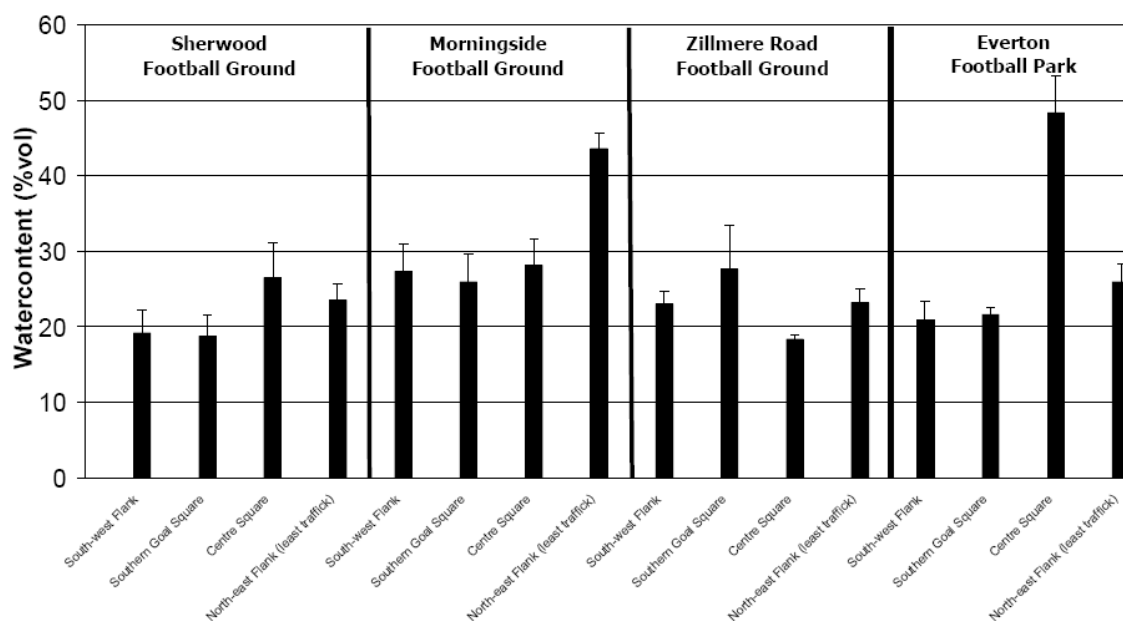


Figure 4. Volumetric water content of surface 0-50 mm at time of sampling.

The roughness of the field surface was found to vary both between the fields and within the fields (Figure 5). Sherwood was found to have the highest average roughness of 5.2 mm (per 30 mm spacing) compared with 4.4 mm for Zillmere and 3.7 mm for Morningside. No data was obtained for the Everton field due to a malfunction of the equipment. Measurements of surface roughness on elite fields have been found to typically range between 2 and 4 mm. For Sherwood and Morningside, surface roughness was found to be higher in the low traffic/wear flank areas than in the higher wear areas. This may be due to a combination of both increased grass cover and grass height in these areas. For example, high traffic/wear areas which have low grass cover and smooth worn surfaces would be expected to have low surface roughness. Similarly, an area with a high grass coverage and a low grass height would be also be expected to have a low surface roughness. However, in areas with high grass cover where the grass is cut higher, there would be an expectation that the roughness would increase. Hence, the surface roughness as measured using the Profilemeter appears to be a function of grass type, percentage of grass cover, grass cutting height and intensity of traffic/wear. The implications for ball bounce and foot stability playability arising from this data are not clear and further work is required to confirm the nature of these relationships.

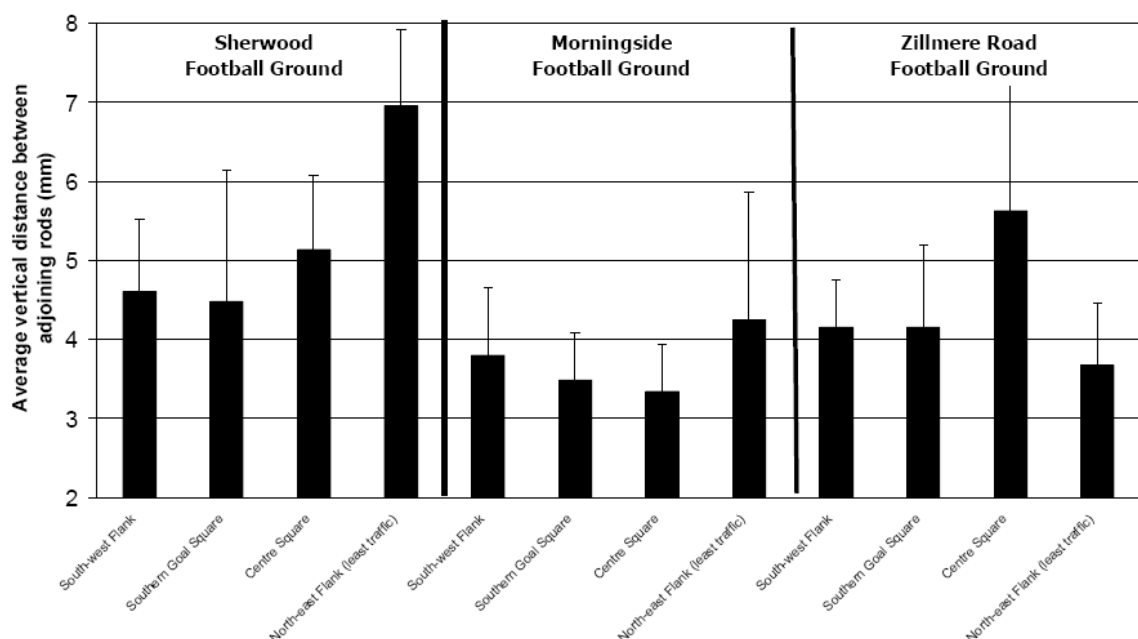


Figure 5. Surface roughness on three sporting fields measured using a profilemeter with 30 mm rod spacings.

Conclusions

The objective measurements undertaken in this characterisation study have confirmed that the soil profiles on the QAFL Premier League sporting fields are highly variable. This suggests that care should be taken in extrapolating data from soil amendment and irrigation trials conducted at any one field to other sporting fields unless there is some understanding of the soil materials present at each site. The nature of the materials at each field site will need to be characterised and the development of amendment and management strategies should be targeted to address key constraints on each field. The range of different soil profiles encountered in different areas within the same field also suggests that the development of soil profile amendment and irrigation management strategies to improve the playability of these surfaces will also need to consider both the spatial and temporal variations in the soil material.

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Simunek J, Sejna M, Genuchten V (1999) The HYDRUS-2D software package for simulating two-dimensional movement of water, heat, and multiple solutes in variably saturated media. In. (International Groundwater Modelling Center, Colorado School of Mines: Golden, Colorado, USA)

AFLQ ground surface benchmarking, renovation and maintenance

Surface quality assessment benchmarking

Introduction

As outlined in the project introduction and literature review, an important component of this project was benchmarking the current and ongoing status of surfaces on our community-standard fields. We looked at several methods of objectively measuring sports surfaces and factors that impact most on player-surface interactions. These covered the range of general influences previously discussed, including friction and traction, hardness and resilience and ball-surface interactions (Neylan 1999; Rogers and Waddington 1990). Other parameters included moisture, surface evenness, ground cover, compaction, ball bounce, sward height, and wear.

Materials and methods

At each of our project fields, we undertook a benchmarking assessment on 9 occasions during the life of the project; July 2003, November 2003, February 2004, April 2004, July 2004, October 2004, February 2005, July 2005, and finally in October 2005. These sampling periods covered pre-season, mid-season and post-season conditions for 3 years. They helped us assess the initial conditions and ongoing trends in the conditions of the playing surfaces, for each of the fields, as the project progressed.

The fields sampled were sports fields for the AFLQ clubs of Broadbeach, Mayne (Everton ground), Labrador, Morningside, Mt Gravatt, Redlands, Western Magpies (Sherwood ground), Southport, and Zillmere. We also assessed the AFLQ / Brisbane Lions facility at Coorparoo, St Margaret's Girls College ground at Windsor, and the Brisbane Cricket Ground (Gabba).

At each benchmarking, we conducted assessments on 6 sections of the ground: the 2 goal mouths, just inside the AFL centre square north-west and south-east corners; and on the north-east and south-west flanks of the grounds, 20 m from the respective centre square corners. This sampling plan is shown in Plate 2.

At each sampling site, we marked out a 5 m by 5 m grid, divided into 9 sections (Plate 2), and conducted the measurements described below in each section, i.e. 9 sub-samples per grid.

As described in the following pages, we measured the following surface attributes.

Surface hardness - (Plate 3). Four drops of a 2.25 kg Clegg Hammer (Clegg 2006) from a height of 45 cm, with the reading recorded on the final drop. Initial readings were reported as Clegg units (direct from the readout), or alternatively multiplied by a factor of 10 to give a G_{\max} value. For example a Clegg Hammer reading of 14 equals 140 G_{\max} .

Surface torsional resistance – (Plate 4). A circular 30 cm diameter disc with 6 football studs and an imposed weight of 40 kg, dropped from a height of 6 cm to embed in the turf surface after (Canaway and Bell 1988). The rotational force required to break the grip from the turf surface was recorded. For all assessments up until February 2005, a simple torsion wrench was used to ascertain whether the force required was greater than 60 Nm, (recorded as Yes or No). For all measurements post-February 2005, an actual force reading was recorded. To maintain consistency, all data was analysed as the percentage of the 9 readings per sample site >60 Nm.

Surface shear resistance – (Plate 5). A Clegg Shear Tester was used to ascertain the force required to displace turf using a 5 cm wide blade inserted 2 cm into the turf surface.

Turf height - (Plate 6). A simple 25 cm diameter Styrofoam disc is floated on the turf surface and a central rod measures the height of turf above the firm playing surface.

Surface soil strength – (Plate 7). An impact penetrometer with a 1 cm² flat tip is forced into the soil surface by the force of dropping a 1 kg weight from a height of 1 m, and the penetration depth measured (Orchard 1999). In our assessments, we recorded the depth of penetration of the first and third drops, to obtain near surface and deeper penetration values.

Turf coverage and composition – (Plate 8). We used a 50 cm*50 cm square quadrat, segregated into four, to estimate the percentage of overall ground cover, and the proportion of each turf and weed species within the quadrat area. These percentages were recorded.

Surface soil moisture - (Plate 9). We measured the volumetric moisture content in the top 6 cm of the turf/soil surface, by inserting a Theta probe (Anonymous 2007) and recording the water content output (Universal calibration).

Although we initially also measured ball bounce, this was discontinued after the first few measurements, as it was too difficult and time consuming to develop an objective methodology.

The more destructive torsion and shear tests were not conducted on the elite Gabba ground.

For each ground at each benchmarking assessment, there were a total of 54 individual measurements for each playing surface characteristic. The results were analysed using standard analysis of variance procedures, to account for effects of time, location, and position on ground.

We also conducted additional analyses, to determine useful relationships between playing surface characteristics, to better understand and predict the impacts of management and environmental factors on the playing surface.

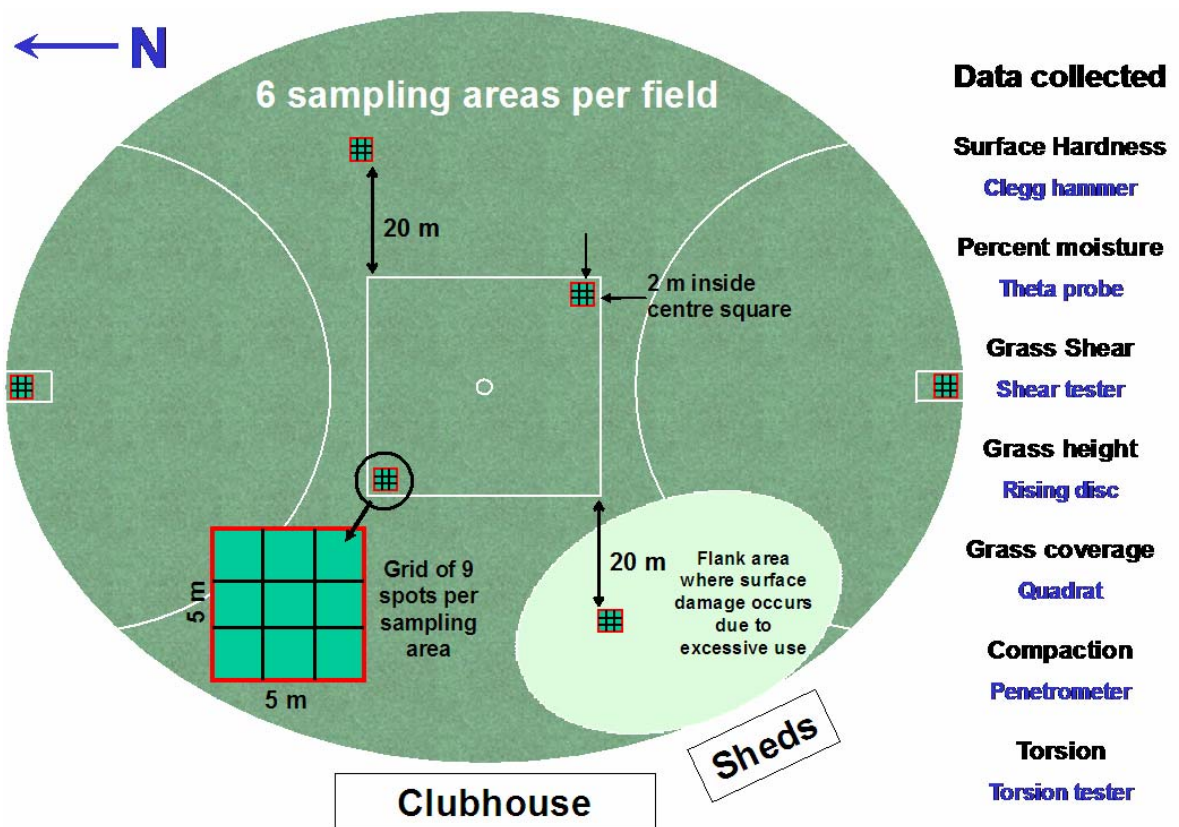


Plate 2. Representation of benchmarking sampling pattern.

Clegg Hammer


<p>What it reads:</p> <p>Clegg impact</p> <p>CIV/M (1 CIV = 10 gravities or G_{\max})</p>	
<p>What it measures:</p> <p>Hardness of the surface including the grass, thatch roots and very top of the root zone by measuring the shock absorption rates of surfaces.</p>	
<p>How it measures:</p> <p>It gauges the deceleration of a mass dropped from a height coming in contact with a surface. (A hard surface will stop (or decelerate) a weight more quickly than a soft surface and the G_{\max} figure will be greater.)</p>	
<p>What it means:</p> <p>Shock absorption is important for reducing risk of short and long-term impact injuries. International standards say G_{\max} readings of 70-130 are desirable. Up to 150 G_{\max} is acceptable. 200 G_{\max} is considered to run the risk of serious concussion. Hardness is decreased by increasing soil moisture levels or decreasing soil profile compaction. Also affects the ball bounce and running conditions on surfaces. The Clegg can be used to monitor the affects of concentrated usage (i.e. training) on fields/parts of fields.</p>	 <p>A photograph showing a person in a light-colored uniform using a Clegg Hammer on a grass field. The hammer is a yellow and red device with a long handle. The person is holding the handle and the device is positioned vertically on the grass. The background shows a grassy field with some shadows.</p>

Plate 3. Measuring surface hardness.

Torsion tester


<p>What it reads:</p> <p>Torsion strength</p> <p>Force in Newton meters (Nm) (or ft lbs)</p>	 A photograph showing a person from the waist down, standing on a grass field. They are holding a torsion tester, which consists of a vertical metal rod with a circular base and a handle. The person is using a tension wrench to apply force to the handle. The device is being used to measure the torsional resistance of the grass surface.
<p>What it measures:</p> <p>Measures the traction needed to break the surface (usually turf).</p>	
<p>How it measures:</p> <p>The readings tell how much force is needed to release 6 football tags on a circular disc from the turf, with a 40 kg mass pushing down on it. Readings are taken with a tension wrench</p>	
<p>What it means:</p> <p>Poor or excess traction can contribute to injury and also affects the way a surface will allow good play. 30-50 Nm is considered desirable for soccer.</p> <p>Traction is dependent on the amount and density of grass cover and the soil moisture content. (Good grass cover and soil moisture increases traction.) Traction is presumed greater for couch type grasses (i.e. forms a mat with stolons etc) in comparison to rye type grasses (i.e. individual plants, no stolons/runners).</p>	

Plate 4. Measuring surface torsional resistance.

Shear tester


<p>What it reads:</p> <p>Shear strength</p> <p>Force in Newton meters (Nm) (or ft lbs)</p>	 A photograph showing a person wearing a blue shirt, dark shorts, and brown shoes, using a silver shear tester on a grassy field. The person is holding the handle of the device, which is a vertical frame with a horizontal blade at the bottom. The blade is being pushed into the grass. The person is also holding a small electronic device, likely a gauge, which is attached to the frame. The background is a green grassy field under bright sunlight.
<p>What it measures:</p> <p>The force needed to break a 25x20 mm blade out the surface</p>	
<p>How it measures:</p> <p>The blade is pushed down into the surface and forced out horizontally with a lever and the gauge measures the force</p>	
<p>What it means:</p> <p>It indicates the surface's resistance to divoting. Player surveys revealed that the threat of losing footing through divoting was high on their concerns. Measurements also indicate the strength of the roots and stolons in the grass. Results vary considerable with tufted weed species.</p>	

Plate 5. Measuring surface shear resistance.

Rising disc


<p>What it reads:</p> <p>Grass height</p> <p>Millimetres of grass height</p>	 A photograph showing a person's hand holding a vertical metal rod that passes through the center of a white, circular disc placed on a green lawn. The disc is slightly raised from the grass, and the person is kneeling on the grass to the right of the disc. The background is a well-maintained green lawn.
<p>What it measures:</p> <p>Measures the height of grass.</p>	
<p>How it measures:</p> <p>A lightweight disc is placed on the top of the grass and height measure is pushed through a hole in the centre of the disc.</p>	
<p>What it means:</p> <p>This can be used against player survey data to determine which grass heights are better for good play. It can also be used as a guide for bounce readings (e.g. does high grass cause reduced bounce) Helps to quantitatively monitor upward growth rates of turf with respect to current or new management regimes and to monitor mowing height with respect to contract/maintenance specifications.</p>	

Plate 6. Measuring turf height.

Penetrometer

What it reads:

Compaction

Centimetres penetration into the soil.

What it measures:

Soil compaction due to lack of pore space within the soil profile. The penetrometer is designed to mimic a plant root.

How it measures:

A 1 kg mass is dropped from a 1 metre height to cause a 1 cm square flat steel tip to penetrate the soil.

What it means:

Compaction decreases the capacity of roots and water to penetrate the soil, limits soil aeration and microbe growth and causes more runoff of irrigation due to limited drainage.

It generally increases the hardness of the surface underfoot contributing to 'impact' injury rates. Particularly long-term contribution to injury.



Plate 7. Measuring surface soil strength.

Quadrat


<p>What it reads:</p> <p>Grass coverage</p> <p>Percentage coverage</p>	
<p>What it measures:</p> <p>The coverage of the surface with grass/weed and make up of the grass/weed cover.</p>	
<p>How it measures:</p> <p>Operator gives a visual assessment of coverage and composition of grass/weed type.</p>	
<p>What it means:</p> <p>Measure of weed, tufted and running species and the overall coverage of the ground. This can be used to determined weed control remediation or establish requirements for resurfacing with other more suitable species of turf.</p>	

Plate 8. Measuring turf coverage and composition.

Moisture meter


<p>What it reads:</p> <p>Moisture content</p> <p>Percentage moisture by volume</p>	 A photograph showing a person in a light-colored uniform kneeling on a grassy field. They are holding a moisture meter probe in their right hand, which is inserted into the grass. In their left hand, they hold a small electronic device connected to the probe by a cable. The device has a small screen and buttons. The background is a lush green lawn.
<p>What it measures:</p> <p>The moisture in the soil at a depth of 6 cm</p>	
<p>How it measures:</p> <p>Reads the dielectric constant of the soil and materials in the soil including liquids and converts to 'Volumetric Soil Water Content'</p>	
<p>What it means:</p> <p>Besides showing how wet or dry the soils are, the moisture readings will also be used as co-variate for analysis of other readings (hardness, compaction, bounce). The readings can also be compared to player surveys to determine suitable moisture levels for play.</p> <p>The moisture meter can therefore be used as a management tool for manipulating hardness, traction, grass growth, bounce and to monitor how different parts of the field hold moisture after rain or irrigation events.</p>	

Plate 9. Measuring surface soil moisture.

Results and discussion

An in depth, confidential report was completed for each of the club grounds studied in the project.

Critical benchmarking parameters

After analysing the benchmarking results during the project, the most important factors affecting playing surface condition of these community standard sports fields were surface hardness, soil strength and compaction (penetrometer measures), grass coverage/weediness and surface moisture content. The less critical measures of torsional and shear resistance, and turf height are discussed later.

At the end of the project, we categorised the fields into five groups, on the basis of their surface soil profile, ground management intensity and amelioration effort.

Group 1 - High quality, intensively managed, sand surface (Gabba, Coorparoo, Southport)

These fields have surfaces with very high sand contents, either through construction or long-term sand topdressing. They each have several paid curator staff, are relatively highly resourced, and have relatively intense amelioration and irrigation efforts. An example of the benchmarking results for Coorparoo (Figure 5) show consistently high soil moisture contents. Surface hardness readings were 60-70 G_{max} in the flanks and centre squares, and steady or slightly decreasing. Goal square hardness was 10-20 G_{max} higher at Coorparoo, but no harder at the Gabba or Southport. Hardness readings on all three Group 1 fields were never greater than 100 G_{max} .

First drop penetrometer readings were steady at 3-3.5 cm at all 3 fields, except for early in the project in the Coorparoo goal squares (Figure 5), and around the ground at Southport, where they were 2-2.5 cm, but improved over time. These compare well with a suggested AFLQ benchmark level of 2.5 cm or greater, and indicate good, low, soils strengths at the immediate profile surface. Third drop penetrometer levels of 8-9 cm at Coorparoo (Figure 5), 7-8 cm at Southport, Coorparoo goal squares, and the Gabba, are excellent compared to an AFLQ benchmark of 4.5 cm, and indicate uncompacted conditions in the primary turf root zone. The benchmark indicators also show steady or improving compaction conditions at the 3 fields.

General grass coverage levels of 80-95% at Coorparoo (Figure 5) and Southport, and 90-100% at the Gabba (all desirable species), indicate very good playing surfaces. Whilst the Gabba retained 80% coverage in the goal squares, there was noticeably less coverage at Southport (60-70%), and a notable seasonal coverage decline at Coorparoo; down to 40-60% in late winter (Figure 5).

In general, given the levels of preventive and ameliorative management, the only issues with these high standard grounds was maintenance of grass coverage in the goal squares during the latter part of the football season.

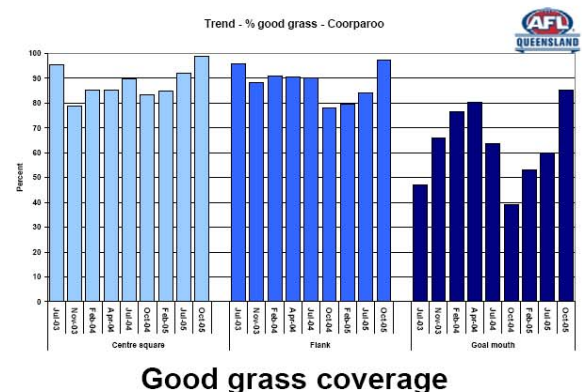
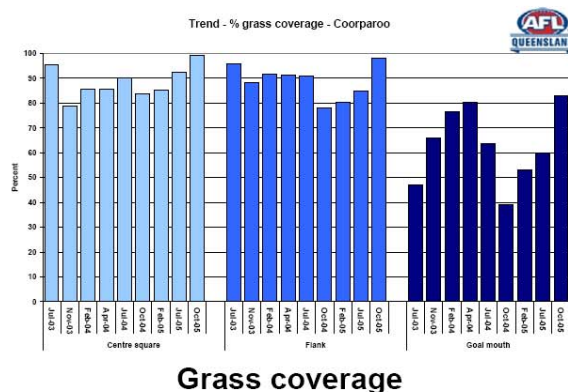
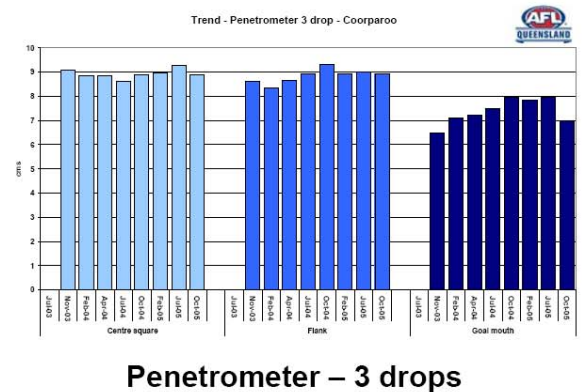
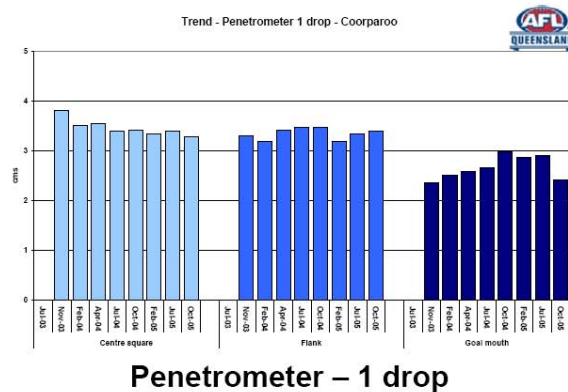
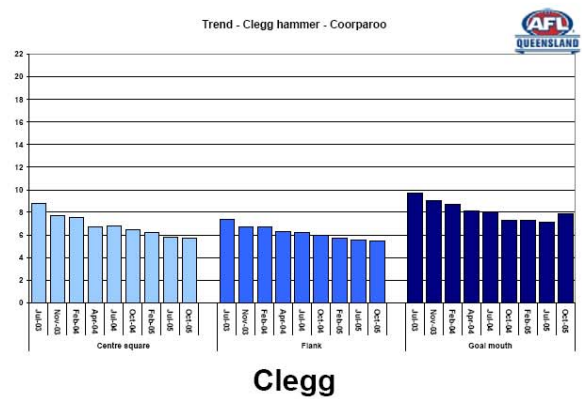
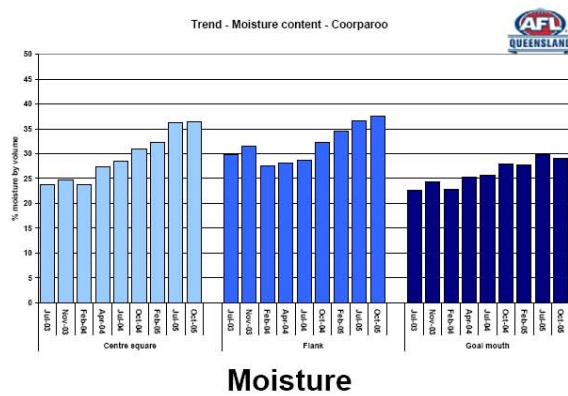


Figure 5. Trends in key benchmarking parameters at Coorparoo sports field. To convert Clegg values to G_{max} , multiply by a factor of 10.

Group 2 – Standard AFLQ ground, with reasonable initial condition (Morningside, Mt Gravatt)

These fields have variable loam to clay loam surfaces, with a mix of turf types, drainage, and levels of wear across the grounds. They were in reasonable condition at the start of the project, with close oversighting by AFLQ curating staff. An example of the benchmarking results for Morningside (Figure 6) show consistently high soil moisture contents, albeit lower in the Morningside goal mouths. At both fields, initial surface hardness readings of 100-110 G_{max} in the flanks and centre squares, have been gradually reduced to by the end of the project; to around 80 G_{max} at Morningside, and 70 G_{max} at Mt Gravatt. There has been a marked reduction in goal square hardness at Morningside from a concerning 150 G_{max} in the summer of 2003/4, down to 90-100 G_{max} (Figure 6). At Mt Gravatt, the reduction was from 110 G_{max} to 80 G_{max} during the same period.

At Morningside, first drop penetrometer readings improved from 1-1.5 cm early in the project, to 2.5-3 cm (only 2 cm in goal squares) by the end of benchmarking (Figure 6). In contrast, first drop values at Mt Gravatt were steady at 3-4 cm; only 2-2.5 cm in the goal squares. These results suggest that the general field sections have improved to basically reach the suggested AFLQ benchmark level of 2.5 cm or greater, although some ongoing work is needed to further improve the goal squares. Third drop penetrometer levels of 2.5-3 cm at Morningside have improved to around 7 cm in the centre and flanks, and 5-6 cm in the goal squares (Figure 6), again exceeding the AFLQ benchmark of 4.5 cm. There were slight improvements during the project from 5.5 cm to 6.5 cm in the Mt Gravatt goal squares, whilst the rest of that field was steady at around 8 cm penetration; in excellent condition.

General grass coverage levels of 90% at Morningside (Figure 6) and Mt Gravatt in the centre square and flanks were consistent. There were some problems with weediness, particularly on the more compacted south-west flanks closer to the club houses. At both fields, there is some reduction in weediness (indicated by slight improvements in the percentages of good grasses), but still a way to go, with 30% coverage by weedy species.

Despite current efforts, there is still a significant seasonal decline in grass coverage in the goal squares during the football season, with 40% loss at Morningside (Figure 6), and 50% at Mt Gravatt. Often the retained cover is dominated by the weed species such as Elastic Grass and Crowsfoot Grass, rather than desirable couch or kikuyu.

The implementation and continuation of ameliorative practices such as aeration and scarification have improved hardness characteristics and surface profile compaction levels on both fields during the project. General field physical characteristics are now similar to the more 'elite' Group 1 fields. The two main problem areas that need more work are improving soil profiles in the goal squares; retaining their turf cover during the latter part of the football season, and reducing the levels of weediness, particularly in the highly worn sections of the centre square, south-west flanks, and goal squares.

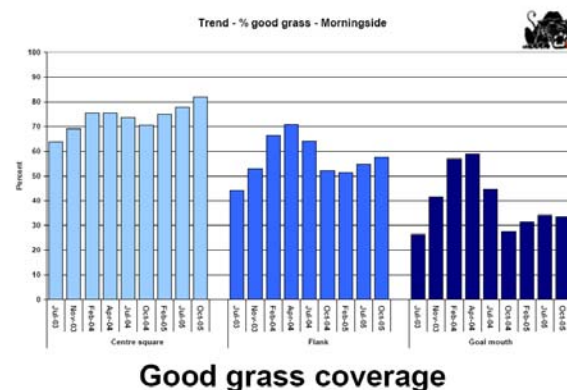
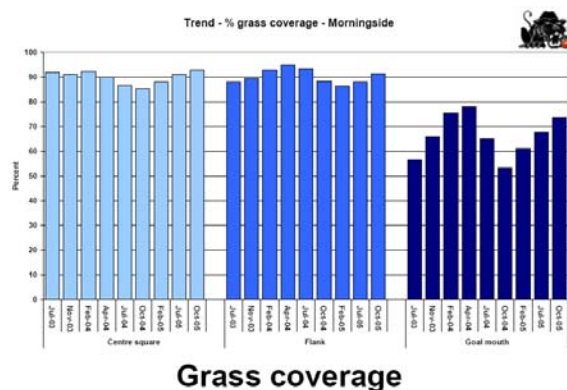
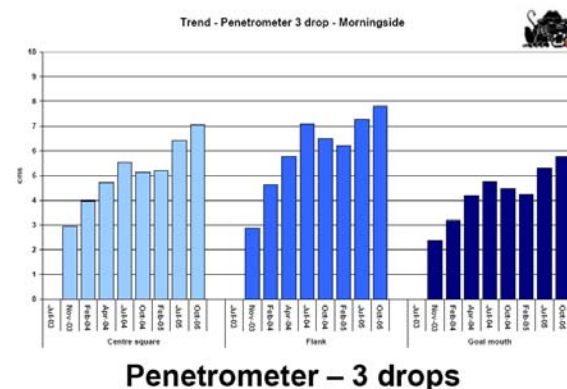
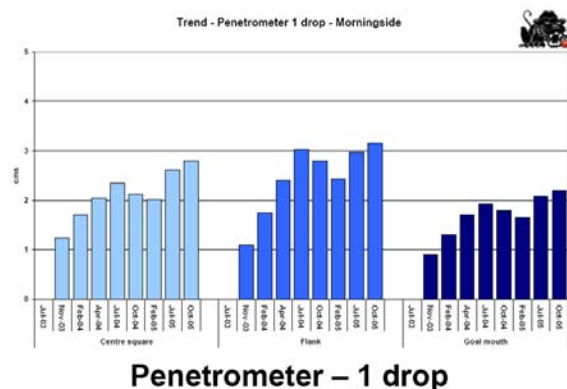
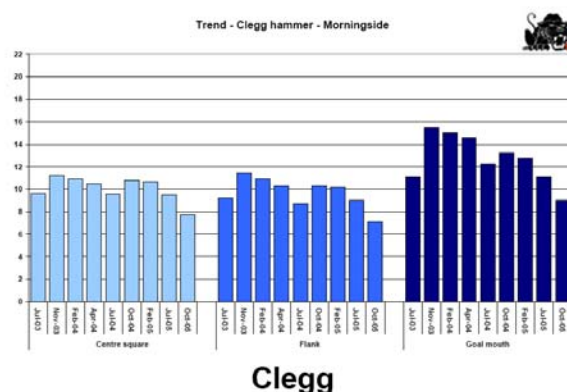
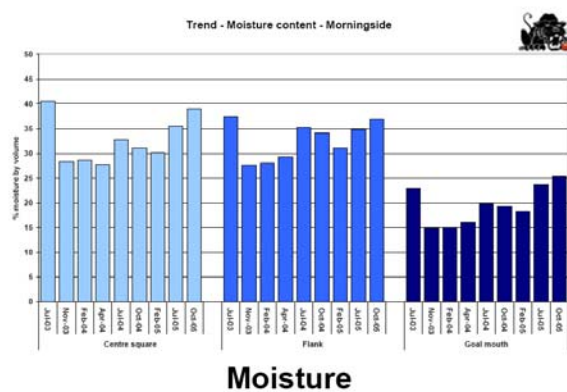


Figure 6. Trends in key benchmarking parameters at Morningside sports field. To convert Clegg values to G_{max} , multiply by a factor of 10.

Group 3 – Standard AFLQ ground, with poor initial condition (Sherwood, Zillmere)

These fields have variable sandy loam to clay loam surfaces, with a mix of turf types drainage conditions, and levels of wear across the grounds. They were not in great condition at the start of the project. Sherwood was very uneven and weedy, highly compacted and hard; whilst Zillmere was hard and had no functioning irrigation.

Following poor benchmarking results in the first half of 2004, greater attention was directed to managing irrigation and aeration at Sherwood. The improvements in soil moisture conditions (Figure 7) during the latter half of the project reflect this increased attention. General field hardness was reduced from a peak of 140 G_{max} to around 80 G_{max} by the end of the project, whilst very worrying hardness levels of 200 G_{max} in the goal squares were reduced to around 110 G_{max} .

The installation of a reticulated irrigation system at Zillmere in early 2005 enable much better management of surface soil moisture conditions (Figure 8). With improved soil moisture, and ongoing aeration, surface hardness improved from 110-120 G_{max} (160 G_{max} in the goal squares), down to 80 G_{max} across the field by the end of benchmarking.

At both fields, first drop penetrometer readings improved from 1-1.5 cm early in the project, to 2.5-3 cm (only 2 cm in the Sherwood goal squares) by the end of benchmarking (Figure 7, Figure 8). Thus, the general field sections have improved to reach the suggested AFLQ benchmark level of 2.5 cm or greater, although some ongoing work is needed to further improve the Sherwood goal squares. Third drop penetrometer levels have improved in the centres (6 cm) and flanks (7 cm) of both fields (Figure 7, Figure 8), again exceeding the AFLQ benchmark of 4.5 cm. Although the Zillmere goal squares have improved markedly (Figure 8), the Sherwood goal squares just make the AFLQ benchmark.

General grass coverage levels of 90% at Sherwood (Figure 7) in the centre square and flanks were steady. There were significant problems with weediness, particularly on the more compacted south-west flanks closer to the club house. This has not improved during the project. Although the overall goal square coverage grass did improve, they were still particularly weedy at the end of benchmarking. They have since been renovated as part of a later experiment.

As the drought in south-east Queensland bit hard, the grass coverage of the non-irrigated Zillmere field gradually deteriorated (Figure 8). With the advent of irrigation, the improvement in total coverage and proportion of desirable grasses was obvious.

These fields have been markedly improved in surface condition and root zone condition during the benchmarking phase of this project. As with the Group 2 fields, the two main problem areas that need more work are improving soil profiles in the goal squares; retaining their turf cover during the latter part of the football season, and reducing the levels of weediness, particularly in the highly worn sections of the centre square, south-west flanks, and goal squares.

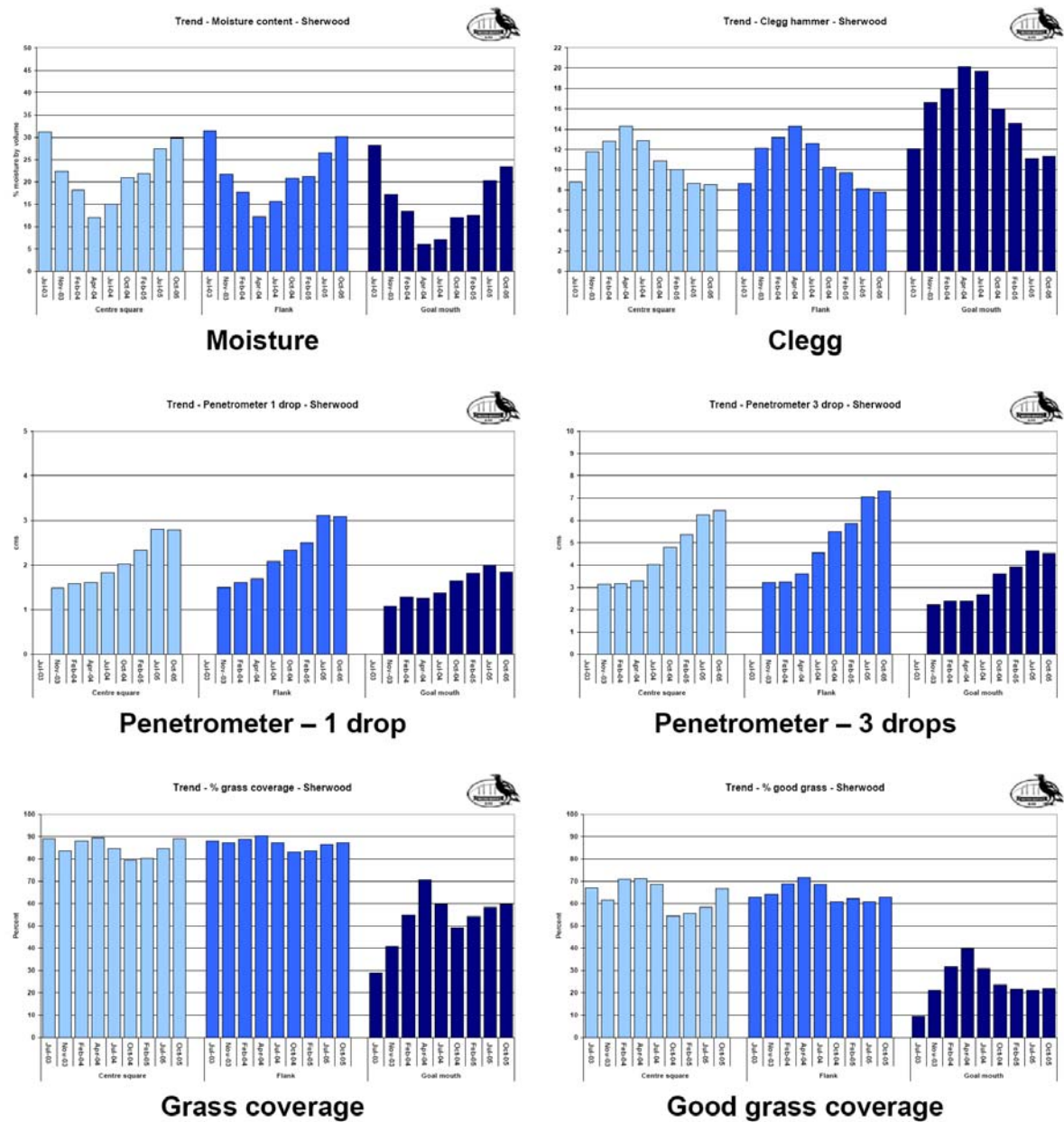


Figure 7. Trends in key benchmarking parameters at Sherwood sports field. To convert Clegg values to G_{max} , multiply by a factor of 10.

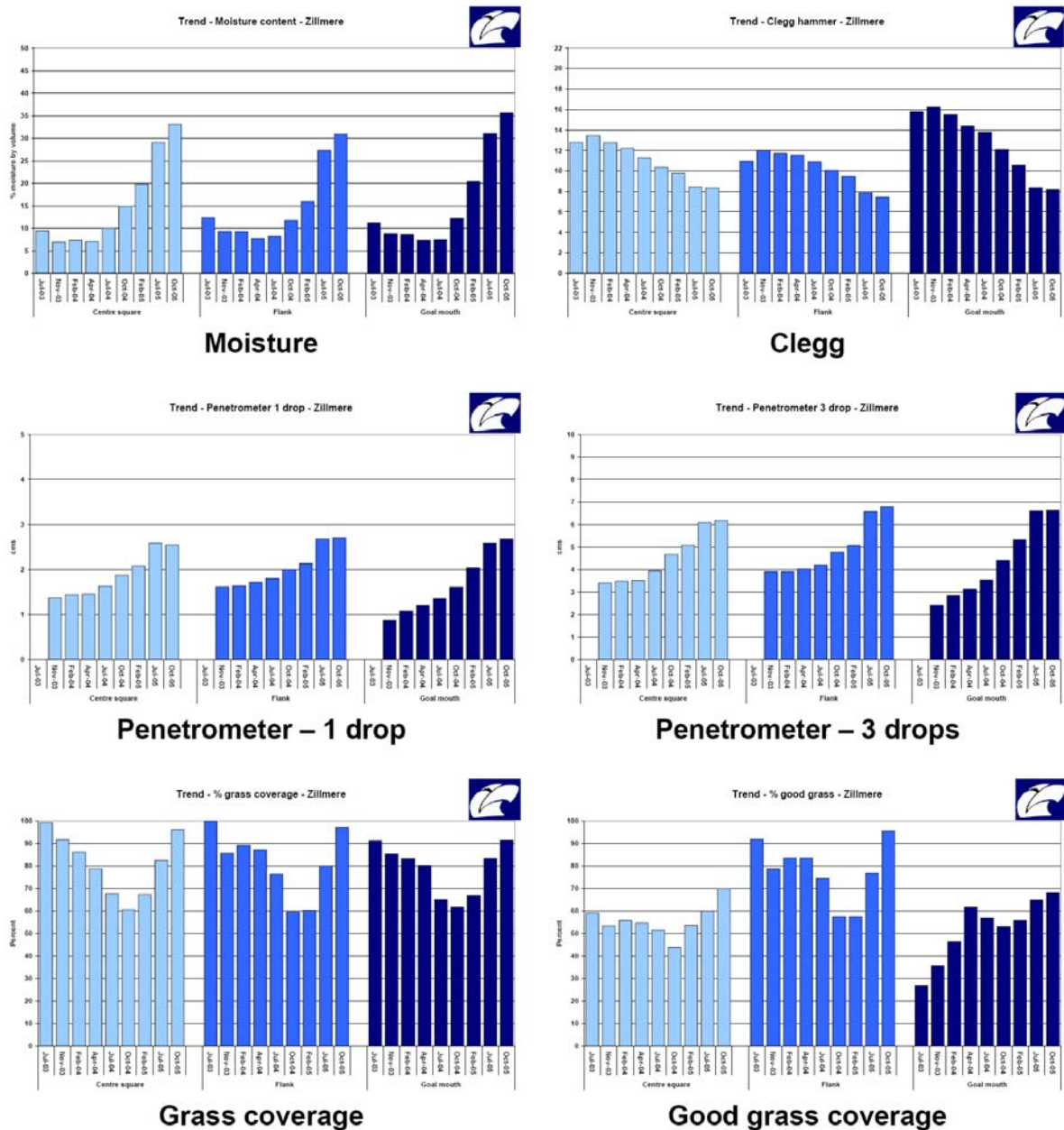


Figure 8. Trends in key benchmarking parameters at Zillmere sports field. To convert Clegg values to G_{max} , multiply by a factor of 10.

Group 4 – Standard grounds, with moderate condition change (Everton, Redlands, St Margaret's)

These fields have variable sandy loam to clay loam surfaces, with a mix of turf types, drainage, and levels of wear across the grounds. St Margaret's field was in good condition at the start of the project; whilst Everton was patchy with significant weed cover and no irrigation. Redlands had several areas of low ground cover and issues with their irrigation system.

Because of uncertainty surrounding future use of the sports field, little ameliorative effort was directed toward the Everton field. As a consequence, hardness trended closely with moisture content – during dry periods hardness rose significantly (resulting in ground closure in July 2004). Interestingly, Everton was the only ground in the project where the centre square was consistently harder than the goal squares, generating hardness levels of 120-150 G_{max} until July 2005. Goal squares and flanks were generally 20 G_{max} lower. Intensive amelioration in early-mid 2005, as well as favourable moisture conditions, meant hardness at Everton declined to 80-90 G_{max} by July-October 2005. Hardness at Redlands followed a similar pattern; with obvious dependence on soil moisture condition at the time of assessment (Fig. 9). Goal squares fluctuated between 120-150 G_{max} , with other areas 20-30 G_{max} lower. Again, favourable soil moisture, increased amelioration, and repairs to the irrigation system, improved hardness levels during mid-late 2005 (Fig. 9). St Margaret's ground was aerated in the summer of 2003/4, which reduced hardness to around 100-110 G_{max} for most of the monitoring period. Readings of 90 G_{max} during winter of 2005 were probably most representative of final ground condition (the last assessment was soon after heavy rainfall, with very soft ground conditions).

At Everton, first drop penetrometer readings were 1.5-2 cm during drier periods, and around 2.5 cm when surface moisture was greater. There was little general improvement trend over time, until the final assessment in 2005. The third drop readings on this field were 4-5 cm when dry, and around 6 cm when moist (compacted centre squares 1 cm less on both occasions). Penetrometer readings at Redlands up to February 2005 were very consistent; 2 cm on the first drop, extending to 4.5-5 cm on the third drop (Fig 9). Goal square values were about 0.5 cm less. There was some indication of reduced compaction at the final 2 assessments, although this is compounded by increased soil moisture levels (and consequent lower soil strength). At the first assessment at St Margaret's, the soil was very compacted, recording first drop levels of 1.5-2 cm, and third drop of 3.5 cm. There was a marked improvement in penetration for the remainder of the project, with first drop readings of 2.5-3 cm and third drop readings of 5-6.5 cm. The exceptions were the dry Spring/Summer of 2004/5, where levels reverted to the initial values. The values at these 3 fields suggest compaction is still a significant problem, which still needs ongoing effort to reach the superior levels of aeration achieved on other grounds.

The centre squares at Everton are relatively worn (50-65% turf coverage), with limited improvement during the project. Whilst the flanks were better (70-80%), the goal squares deteriorated during the benchmarking period (final value around 60% coverage). Much of this can be attributed to a lack of irrigation at the ground. There has been some improvement in the level of weediness during the last few months of the benchmarking period. The turf coverage at Redlands was fairly consistent in the general ground areas (80-90%), although there was some deterioration during the Spring/Summer of 2004/5 (Fig. 9). There was a slight improvement in the coverage of the goal squares. However, the ground tended to become slightly weedier during the benchmarking period, shown by the reducing proportions of good grasses. Turf coverage at St Margaret's declined from 80-90% to 60-70% during 2004/5, with increased weediness as well. There was some recovery during the last two benchmarking periods in late 2005.

These fields have not shown the quantum improvements identified in the other standard AFLQ grounds in the study. During the last two benchmarking periods in 2005, there was some improvement in measured conditions. These were also associated with better moisture conditions, either resulting from the improvement of irrigation, or rain (at the last assessment). Neither Everton nor Redlands had the same levels of renovation activities

initially as the other fields – it was not thought to be a worthwhile investment of time and resources where the irrigation capacity to back up the effort was not possible. These fields have since had an increased renovation effort from AFLQ. St Margaret's were provided with the benchmarking report, and advised what remediation was required, but implementation was not a component of this project.

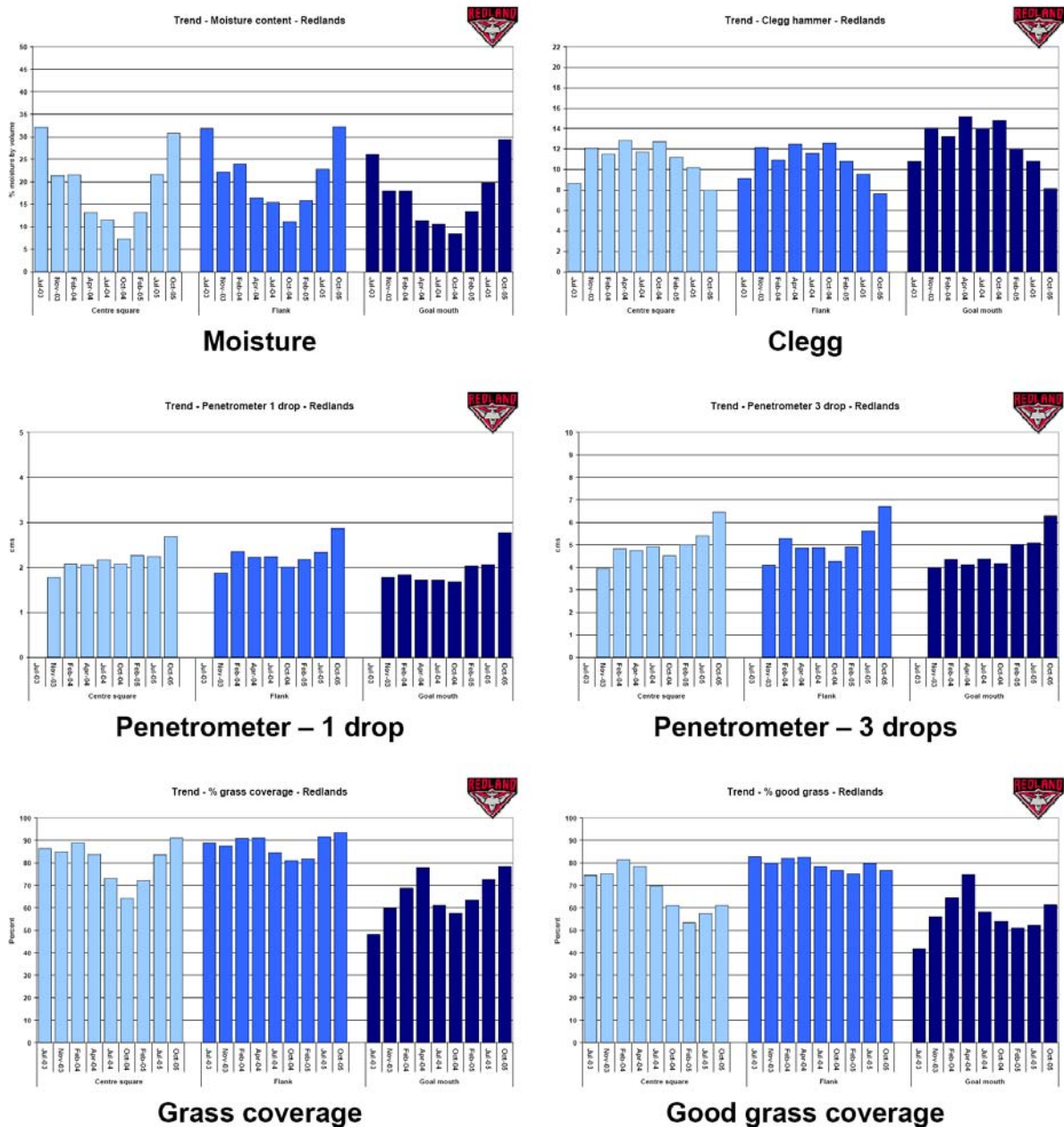


Figure 9. Trends in key benchmarking parameters at Redlands sports field. To convert Clegg values to G_{max} , multiply by a factor of 10.

Group 5 – Gold Coast managed fields (Broadbeach, Labrador)

These fields are an interesting control group; not being managed under the auspices of the project or AFLQ. They have not been subject to the same amelioration effort as the Brisbane-based fields.

Surface hardness levels were steady during the benchmarking period, possibly slightly trending higher, although it is hard to discern, due to confounding moisture effects. Both Broadbeach (example Figure 10) and Labrador fluctuated between 100-120 G_{max} for most of the benchmarking period, with goal squares 10-20 G_{max} higher. Both fields were harder (around 140 G_{max}) during summer 2005.

Both Broadbeach and Labrador had compacted surfaces, with most first drop penetrometer readings constant around 2 cm for most of the benchmarking period, with Broadbeach goal squares only allowing 1.5 cm penetration (Figure 10). Third drop penetrometer readings for both fields declined or were steady during the benchmarking period, reaching 4-5 cm in the general field, and 3.5-4 cm in the goal squares. Similar to Group 4, these results suggest more attention is required to ongoing aeration and compaction management if the turf root zone conditions are to be optimised.

Grass coverage at Broadbeach was relatively good, with little weediness compared to most of the Brisbane fields. Goal square coverage improved during the first half of the project, with that condition then maintained for the rest of the benchmarking period (Figure 10). In contrast, the Labrador field lost turf coverage during the 2004/5 summer, down to 60%, with an increase in the proportion of weedy species. Although total coverage increased slightly during the last two assessments, desirable species' coverage remained static, at only 40% in the goal squares, to 50-60% in the general field.

Although currently in reasonable condition, the compaction levels indicate a watch on turf performance and surface hardness is warranted. It is possible that the condition of these fields will start to decline unless some ameliorative activity is undertaken.

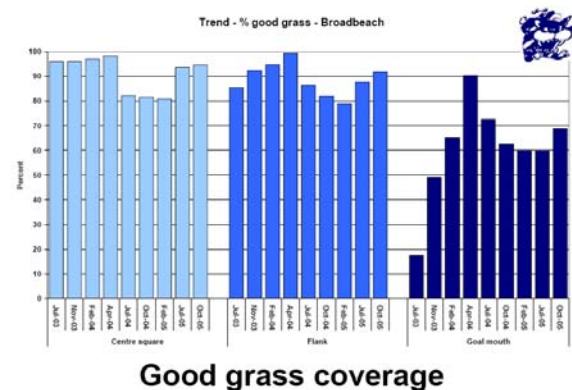
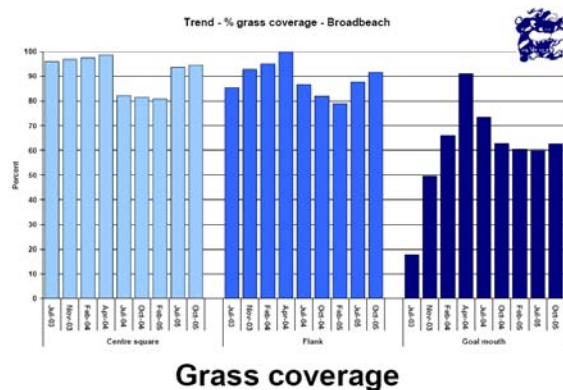
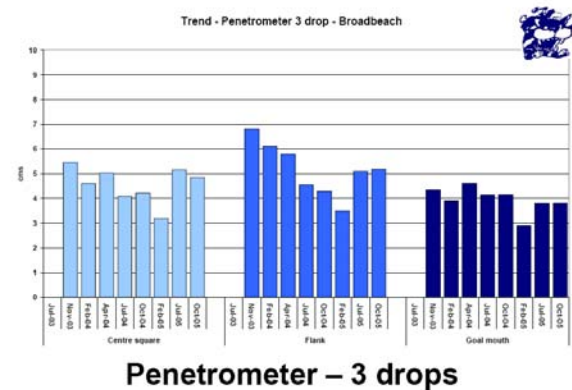
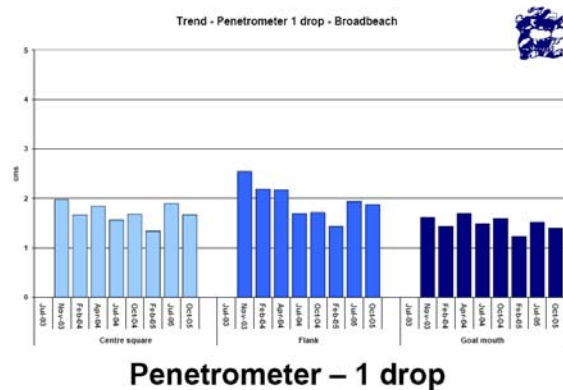
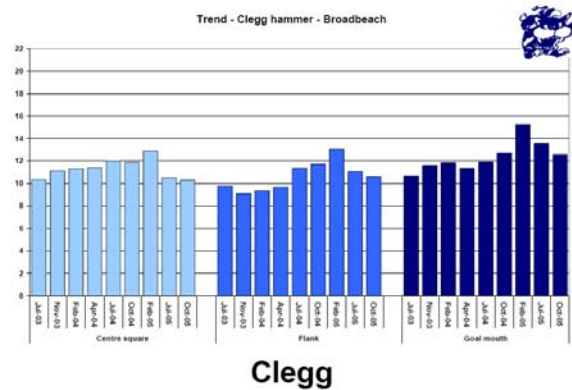
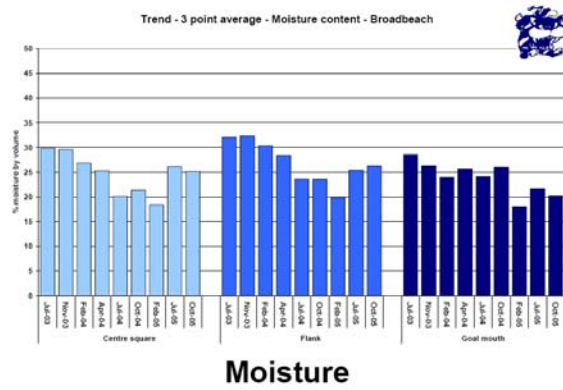


Figure 10. Trends in key benchmarking parameters at Broadbeach sports field. To convert Clegg values to G_{max} , multiply by a factor of 10.

Other benchmarking assessments

Torsion

Our testing procedure was primarily looking for evidence of excessive grip in the playing field surfaces. Using a benchmark of 60 Nm, we rarely found any evidence of excessive torsional resistance. The average (across all fields, for the whole project) was only 1.5% of readings above 60 Nm. The maximum proportion of excessive readings for any individual field on any occasion was only 11%. On these variable community fields, we could not relate torsion readings to any factors such as soil moisture, surface hardness, grass cover, or type.

Shear

During the 3 seasons of measurement, average shear resistance across all fields was 25 Nm, ranging from 9-57 Nm. Predominantly couch fields tended to have slightly higher average shear values (28-31 Nm), compared to couch/kikuyu fields, or fields with less grass coverage (20-25 Nm).

Shear resistance readings above 35 Nm were generally associated with either drier than normal soil conditions (roots more firmly held in the soil surface), or the presence of tufted weed species such as Elastic Grass (*Eragrostis* spp.) or Crowsfoot Grass (*Elusine indica*).

Shear resistance readings less than 20 Nm were measured in areas with little or no grass cover, or where grasses were in poor condition and weakly rooted. In some of the higher clay fields, such as Mt Gravatt, shear resistance readings were also lowered by excessive soil moisture.

In general, for these community standard fields, shear resistance as of itself was not considered an important measure of ground condition. As indicated above, variable readings outside the normal range (which may impact on the consistency of footing perceived by players) were mainly associated with either bare or poorly grassed areas, weedy, or excessively wet areas. Most of these factors are readily observed, without requiring the refinement associated with a specific shear test measurement.

Turf height

As intuitively expected, turf height was mainly impacted by the intensity of management (mowing), the timing of the field assessment in relation to the previous mowing, the time of year (growth and sport being played), and the presence of tufted weedy species (taller), or bare areas (shorter).

With the exception of the Gabba, all the fields had average turf heights in the range 25-35 mm during the project. During the football season, turf heights in most fields were 27-31 mm, with the weedier fields (Zillmere, Everton, Sherwood) at 33-35 mm.

The bigger variance in height was during the off-season, primarily depending on the level of ongoing management, and whether or not club or higher standard cricket was being played.

In less intensively managed, non-cricket fields (Everton, Labrador) heights were 35-40 mm, whilst on non-cricket fields with greater management (Coorparoo, Morningside, Mt Gravatt, Sherwood, Southport, Zillmere) turf was only a few mm higher than during the football season.

Fields where cricket was played over summer (Broadbeach, Redlands, St Margaret's) were 20-25 mm during summer, with the Gabba turf height reduced to 10 mm.

In the early part of the project (2003-2004), mowing heights were raised to 50 mm on the AFLQ Brisbane grounds, in order to promote better turf growth. There was some adverse comment from the footballers that this was too long for optimal play, so Nick Jeffrey reduced his football season mowing height to 38 mm.

Measured turf heights were a function of mowing height, weed presence, amount of bare soil, and leaf blade strength and can therefore be different to the mowing height. For example, due to bareness in the goal squares, turf heights averaged across the whole of the Morningside field tended to be 5-8 mm less than the mowing height during this project.

In summary, torsion and shear were rated by the project team as 'good' for all except 2 of the fields (Mt Gravatt, Sherwood), which rated as 'satisfactory' (Table 3). Mt Gravatt rating was affected principally by a soil type which readily loses strength at high moisture levels. Both Mt Gravatt and Sherwood suffer high levels of wear in the goal squares, and poor turf growth on the highly worn south-west flanks, with bare soil reducing surface strength characteristics.

Turf height on all except 2 fields was rated as 'good' (Table 3), with Labrador's lower rating because of reduced maintenance during the off season, and Sherwood through excessive weediness and bare goal squares.

Table 3. Summary of ratings for less critical field benchmarking parameters.

Field	Torsional resistance	Shear resistance	Turf height
Broadbeach	Good	Good	Good
Coorparoo	Good	Good	Good
Everton	Good	Good	Good
Gabba	Not rated	Not rated	Good
Labrador	Good	Good	Satisfactory
Mt Gravatt	Satisfactory	Satisfactory	Good
Redlands	Good	Good	Good
Sherwood	Satisfactory	Satisfactory	Satisfactory
Southport	Good	Good	Good
St Margaret's	Good	Good	Good
Zillmere	Good	Good	Good

Modelling hardness of AFL fields

In 2005, biometricians analysed a subset of the in-season data from 2003 and 2004, to determine the key factors associated with field hardness (Giles, Swain *et al.* 2005). The data set included 3 benchmarking dates, 11 fields, 4 sites within the field, and the 9 samples per sampling position. The 4 sites were:

- Heavy wear (goal squares)
- Moderate wear (centre squares)
- Medium use, heavy training areas (south-west flank)
- Light use, little training (north-east flank)

Residual maximum likelihood was used to model log-transformed hardness (measured by Clegg hammer) as a function of moisture, field, site, date, and all two and three factor interactions. The model was simplified by progressively dropping the least significant term ($P > 0.01$ for the Wald test) until all terms remaining were significant. Terms dropped from the model then re-tested for inclusion. Other terms (grass height, percentage ground cover and various measures of grass composition) were tested for inclusion in the model, but did not improve it ($P > 0.01$).

The final model demonstrated a very strong relationship between hardness and soil moisture content ($P=0.002$), with strong interactions between fields and benchmarking date ($P<0.001$). Fields varied in their relationship between hardness and moisture – those with higher clay contents (estimated), little or no aeration activity prior to benchmarking, and high ground use, generally had a steeper relationship of hardness to moisture content (Fig. 11).

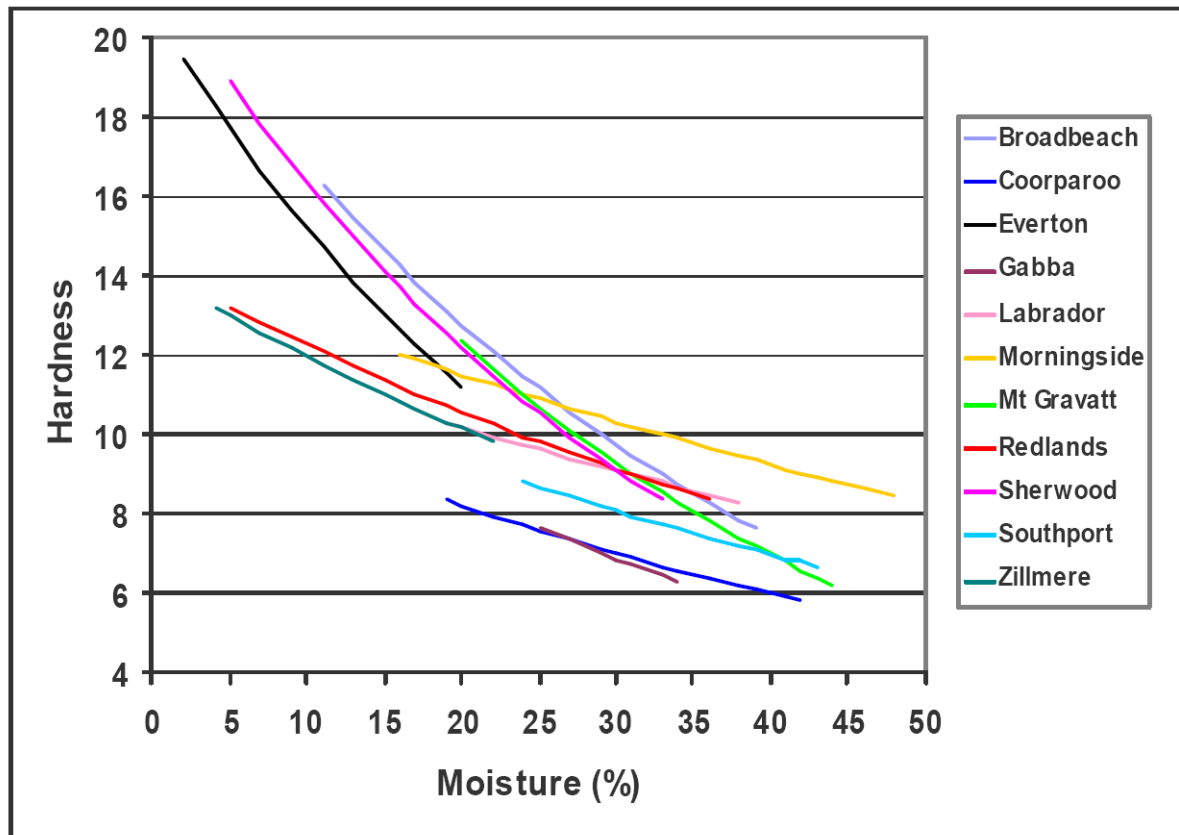


Figure 11. Relationship between hardness (Clegg hammer reading) and volumetric moisture content (%) for 11 fields. To convert Clegg values to G_{\max} , multiply by a factor of 10.

The analysis definitively described the presence of a training shed and cut/fill effect on ground hardness. Because of the orientation of the grounds, if cut and fill techniques were used, the western side, where the club house was most frequently constructed, was generally the cut area, where topsoil was removed (and often transported to fill the eastern side. Hence the western flanks are often less fertile, higher clay content, more compacted, and less well structured than the opposite flank.

In addition, the western flanks are often closest to the training rooms. They are also often the first areas provided with lighting for night training. The consequence is that the western flanks are more commonly used for warm-up, training drills, or casual training than the opposite flanks, due to convenience and general human nature.

In the analysed data subset, average goal mouth hardness ($103 G_{\max}$) and south-west flank hardness ($99 G_{\max}$) were significantly greater than the even the centre square ($93 G_{\max}$), and certainly the north-east flank was softest ($84 G_{\max}$).

Ground renovation and maintenance

Group 1 fields

The Brisbane Cricket Ground is managed as an intensively resourced, elite facility, with a team of ground staff and equipment. It has a very regular program of aeration, scarification, irrigation, fertiliser application, pest management program, and is very well drained. Its management practices have little application to community standard fields.

Southport has a team of dedicated ground staff employed by the club, which regularly undertakes the maintenance program described above. It is also primarily used for AFL, with little competitive use during the summer, and is over-sown with ryegrass for the winter football season (similar to the Gabba).

The Group 1 field most useful as a benchmark standard for community fields is at Coorparoo. A former landfill site, it was managed by Nick Jeffrey since 1997. By instigating a program of regular aeration and annual topdressing with sand, he has eventually built up a sand blanket over the 'native' soil profile. With a regular maintenance program including aeration, scarification, topdressing, fertiliser and wetting agent application, and very occasional pest management (see Table 4), this field now achieves surface performance levels the equivalent of the elite national AFL fields.

Table 4. Summary maintenance program for Coorparoo sports field.

Operation	Type/frequency
Aerate	Verti-draining to 25 cm monthly
Topdress	5-10 mm double-washed river sand September and December
Scarify	Every 3 months September through May
Fertilise	Topdressed every 2 months September through May, liquid fertiliser through boom during winter
Wetting agent	Every month through boom September through May
Herbicide	Selectives (e.g. diclofop, dicamba) applied twice September through November Contract wick wiping for Elastic grass control

Project renovated fields – (Morningside, Mt Gravatt, Sherwood, Zillmere, Everton, Redlands)

Ground amelioration was undertaken by Nick Jeffrey and staff; initially employed by Brisbane Lions, and then by AFL Queensland as their Queensland Facilities manager.

The sequence of activities undertaken to renovate the Brisbane AFL fields was:

- Aeration every 8-12 weeks to the maximum depth possible for the Vert-drain machine – dependent on ground compaction and moisture level at the time. Generally a depth of 25 cm was attempted, although on the harder grounds, it may initially have been only 5-8 cm
- Scarification to remove excessive clippings, thatch and other organic materials once every 4 months during the main growing season
- One - two topdressings with 10-15 mm of sand, to improve evenness, and restructure the texture of the surface profile over time.
- Installation or renovation of existing irrigation systems.

- Nutritional supplementation with granular fertiliser every 2-3 months Spring through Autumn; amounts depended on soil tests in some instances, or on the resources available for each ground.
- Annual herbicide application to try and reduce populations of key weeds, principally Crowsfoot Grass (*Eluisine indica*) and Elastic or wiregrass (*Eragrostis spp.*). This was generally done using a contractor using a wick wiper application system.

Initially the program targeted Morningside, Mt Gravatt and Sherwood fields. Due to the limited staff and equipment resources, and absence of effective irrigation on the other fields, this was thought to be the best investment. The sports field surface benchmarking results reflect this intensity of renovation efforts. Although there was significant initial effort at Zillmere, during the ongoing drought periods, this was reduced because the dry fields were too hard to aerate. There was generally little amelioration across all grounds during the winter of 2005, due to loss of staff and generally difficult drought conditions.

An interesting experience on these Brisbane fields was the effect of mowing height on surface performance and player experience. During the initial part of the project, the intent was to improve turf health, irrigation efficiency and field surface condition by increasing the mowing height to 50 mm. However, adverse comments by the players in the season of 2004 ('too difficult to run through'), resulted in Nick Jeffrey reducing the mowing height to 38 mm. Subsequent experience suggests this had no adverse impact on turf coverage or health, or the capacity to achieve very good irrigation efficiency (see later section).

By the end of 2005, AFLQ was so encouraged by the improvement in their ground conditions during the project, that they employed the project curator, Nick Jeffrey, as their state advisory curator, and employed another curator to assist with amelioration and maintenance activities. They also purchased a second set of amelioration equipment, and a large fairway mower, to allow more intense, timely and widespread application of the amelioration strategies.

By October 2006, capital improvements (mainly irrigation infrastructure) and remediation was completed on all targeted Brisbane AFL Queensland grounds. AFLQ developed an annual maintenance package of aeration, top-dressing, scarifying and fertiliser application, which it offers to implement for affiliated clubs at a subsidised fee. It also offers an advisory/renovation/maintenance package to other community standard sporting organisations responsible for sports field provision. Its current difficulty is meeting the demand, and deciding whether that demand warrants a further expansion in staff and equipment investment.

Overall, remediation and maintenance has resulted in ongoing good-excellent standards of playing surfaces at project fields, as measured by indicators of ground hardness, turf coverage, and player comment. Given the ongoing drought in SE QLD (and consequent water restrictions), this was a particularly notable achievement.

As would be expected, ground conditions are at their best immediately before the football season, following remediation activities and turf recovery, and then deteriorate with seasonal use. Remediation and management plans are targeted at maximising improvement during the off-season, and then minimising the rate of wear and re-compaction during the playing season.

Development of ground standard guidelines – an AFLQ example

Using the information and skills developed during the project, AFLQ put together a protocol for evaluating hardness of sports fields and making a decision on whether grounds could be used for competition (Senior or Junior) run under their auspices. In part, this was prompted by an incident at the Everton ground in June 2004, where a player and umpire suffered concussion on what was a hard field at the time; readings of 200-240 G_{\max} (Stockwell 2004). By pre-season 2006, AFLQ instigated a program for annual checks, or alternatively response to concerns about ground hardness at any time.

Following measurement of hardness using the standard Clegg Hammer procedure across 20 key field locations (goal mouths, centre corridors, flanks), readings above 160 G_{\max} result in official notification for the club to take ameliorative action. AFLQ directs closure of grounds with more than 2 readings greater than 190 G_{\max} . Grounds remain closed until remediation and successful re-testing. In June 2006, AFLQ closed 5 non-project fields in Brisbane, in response to high hardness readings. AFLQ followed up with advice and assistance, which enabled reopening of the grounds within a fortnight.

Discussion

Because hardness is the critical ground safety issue identified in this project, the team is committed to further scientific examination of the factors affecting hardness of sports fields. We have recently sampled all the AFL fields benchmarked in this study, collecting bulk density and soil moisture data, and samples for more precisely ascertaining field's texture (and therefore estimating clay content). Along with information on ground use and amelioration activities, we should be in a position to better model and predict those fields, sites and locations most likely to generate potentially hazardous hardness conditions.

In the meantime, the methods for minimising the risks include:

Regular amelioration activities using de-compaction methods (e.g. aeration),

Where possible, managing ground infrastructure, use and condition to minimise and spread compactive loads. Activities include movable goal posts (particularly for training), improved ground lighting to increase available training areas, rotating training areas, pro-active partial or full ground closures.

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AFLQ ground irrigation improvement

Introduction

Irrigation is a major infrastructure and operating cost for community standard sports fields. A major function of this project 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 cried out for 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 invest 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 with irrigation.

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. We estimated usage from field precipitation rates and likely irrigation regimes for the remaining fields.

Results and discussion

Our findings from auditing the nine fields were consistent with 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 Plate 10. 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 3 specific catch can precipitation analyses.

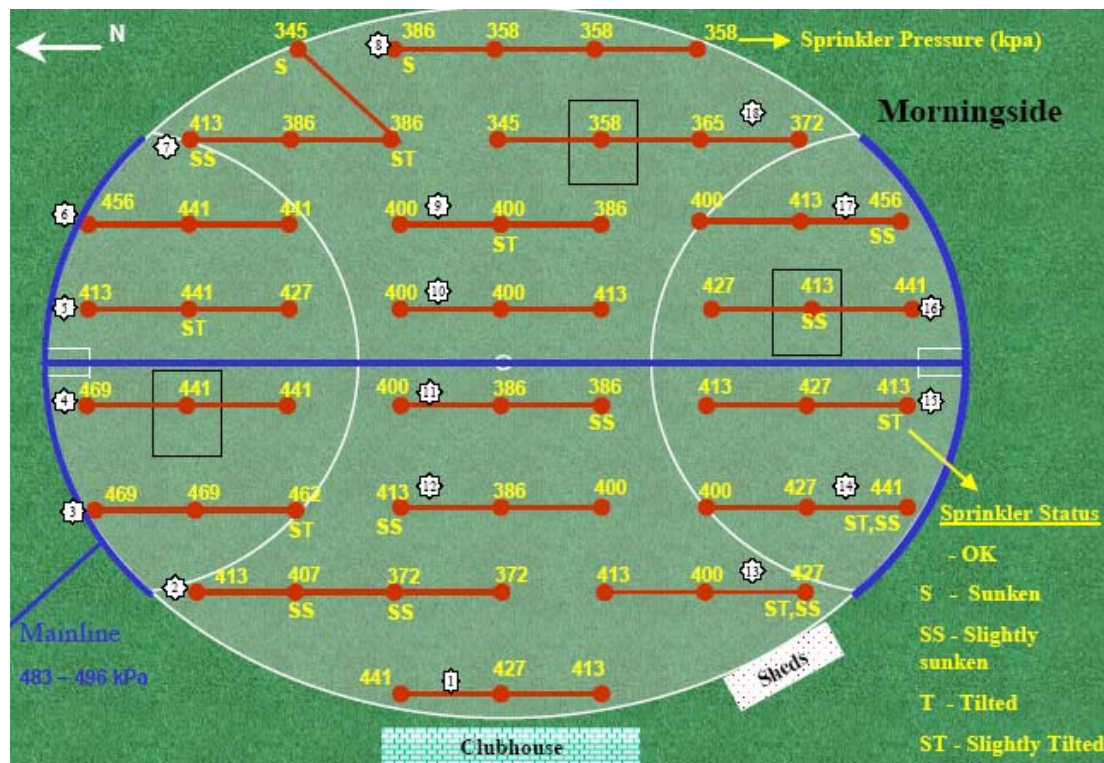


Plate 10. Sprinkler audit map for Morningside sports field.

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 (Fig. 12), with that value as low as 40% (of sprinklers functioning properly) on one field. Pressure at sprinkler heads varied considerably within and between fields (Fig. 13).

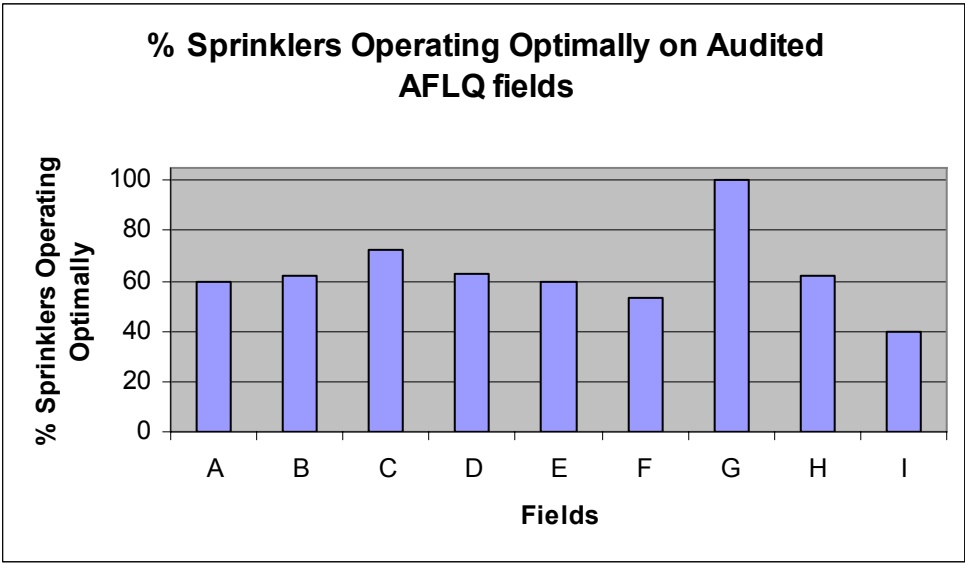


Figure 12. Only two of nine fields had more than 65% of sprinklers functioning optimally.

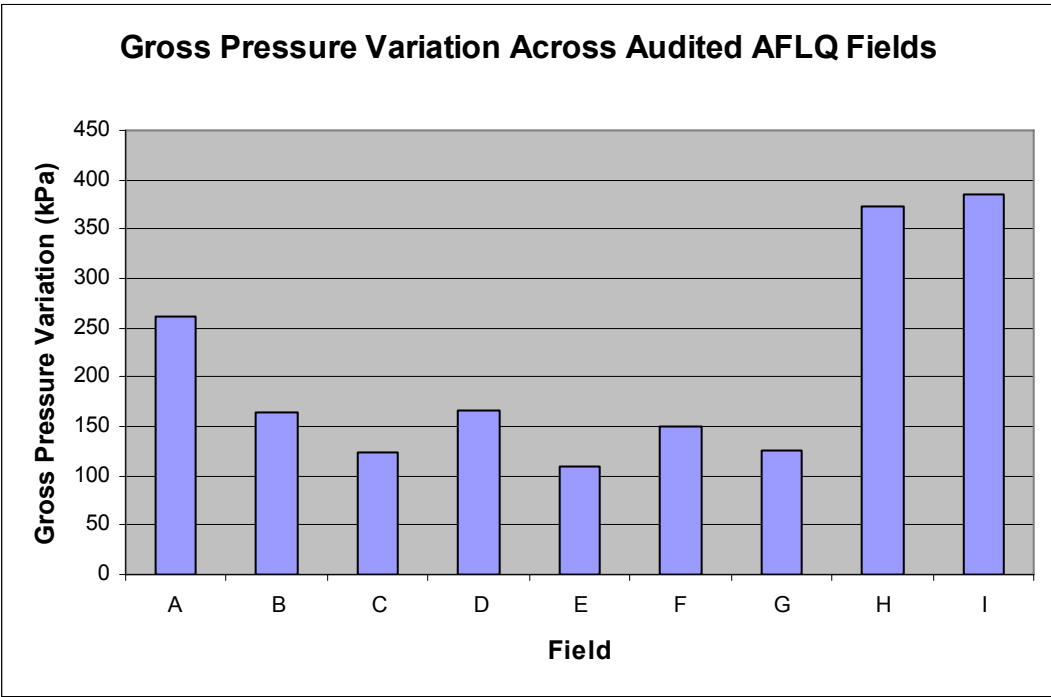


Figure 13. Sprinkler pressures across fields varied enormously.

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, number of sprinklers in a station) and the variation from system malfunctions, e.g. sprinklers sunken or broken, 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 (Fig. 14). This does not take away from the need to insist on within specification 'at-head' pressures when commissioning and reviewing an irrigation installation.

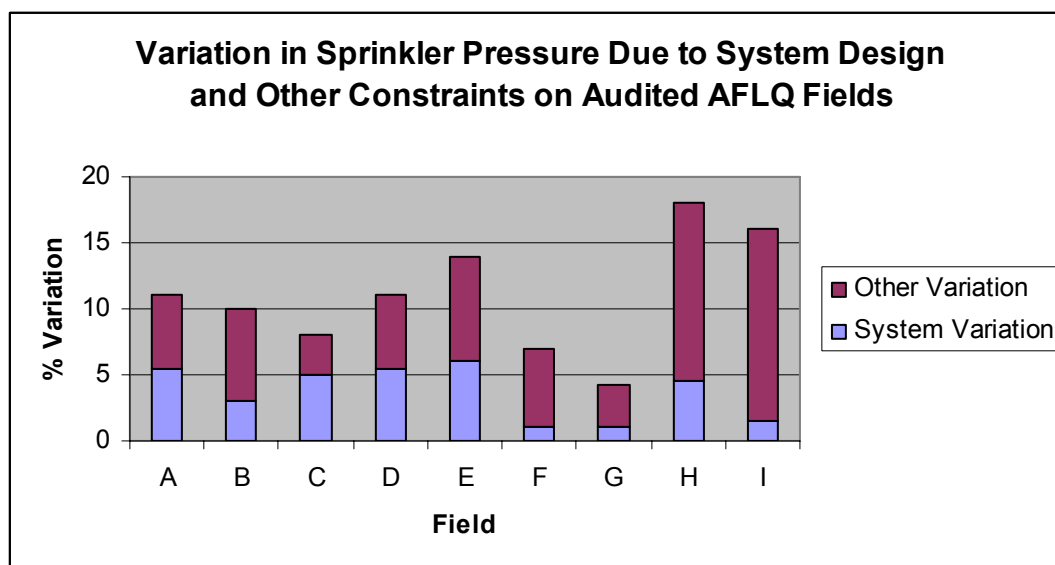


Figure 14. Sprinkler pressure variability due to both systemic pressure drops, and individual sprinkler malfunction.

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 sports field 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 their surface 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% (Fig. 15). The irrigation system of one of these fields was only months old (DU 55%), underscoring the need to check new systems.

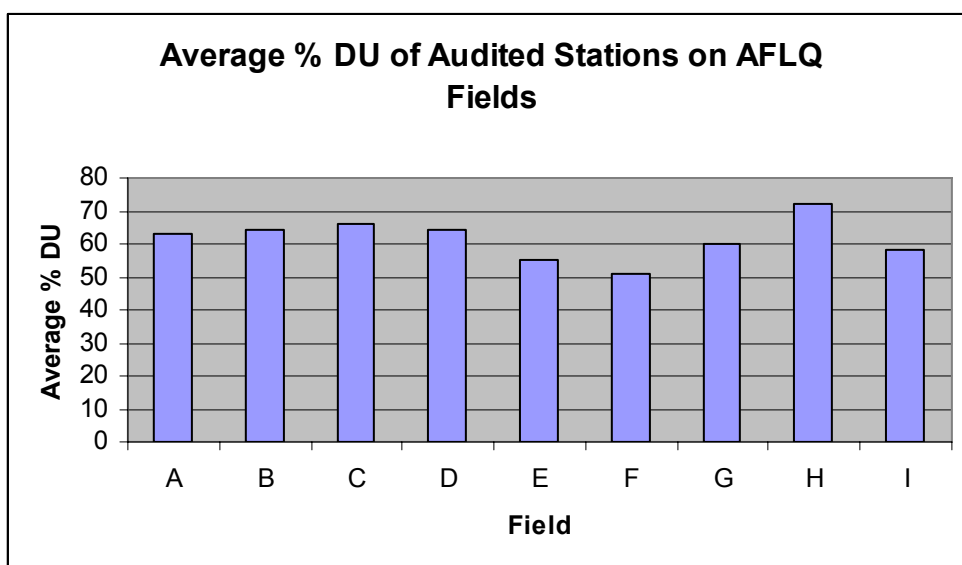


Figure 15. Average distribution uniformities across eight of nine fields were less than 65%.

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 Fig. 16. The plots illustrate classical dry areas around sprinklers and wet areas where all the contributing sprinklers overlap.

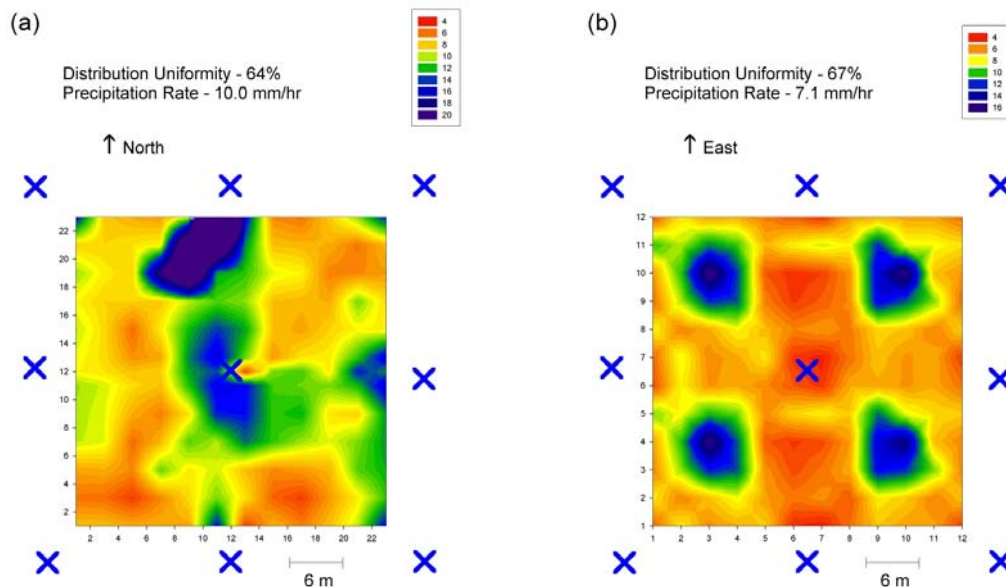


Figure 16. Precipitation patterns with (a) faulty sprinkler rotation or (b) systemic problems with sprinkler coverage. Each blue cross marks a sprinkler location.

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 7mm/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 invested. 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 the lack thereof can contribute significantly to a loss in system performance and DU.

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 (Fig. 17). 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 17.5 m radius and 60 L/hr at that operating pressure. However, 5 of the 9 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 improvement and the DU value of 76% reflects this. The effect of the south easterly wind can be seen in the drier SE corner (Fig. 17).

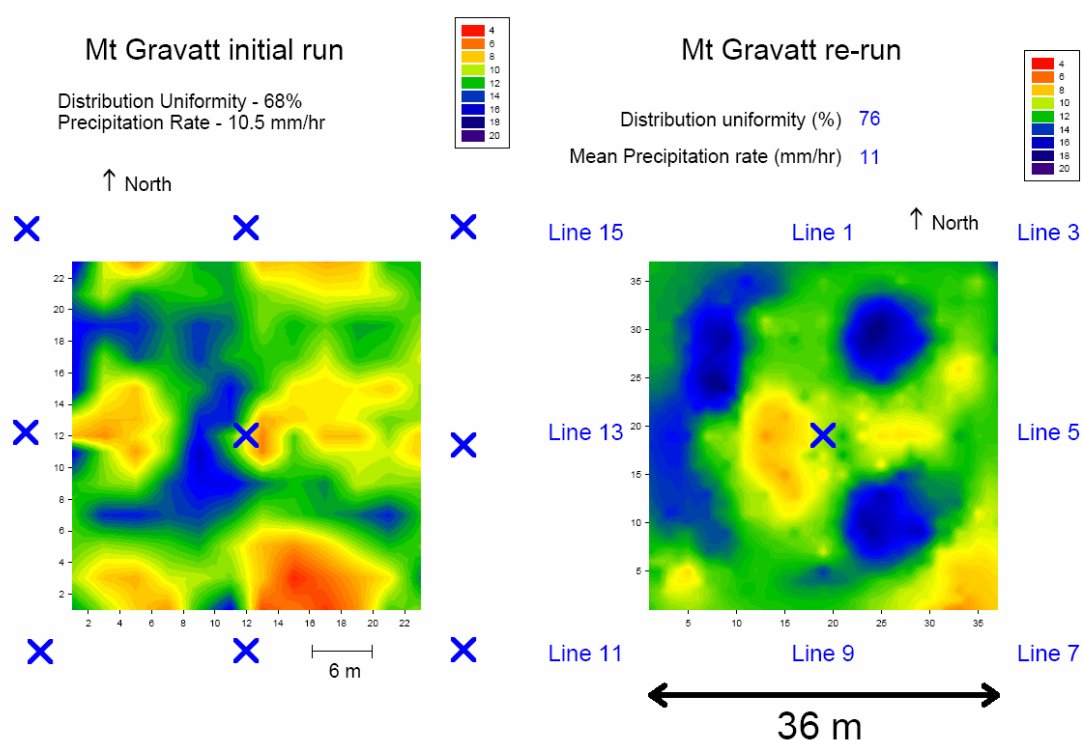


Figure 17. Precipitation patterns before (left) and after (right) maintenance of a typical sports field irrigation system. Each blue cross marks a sprinkler location.

After conversations with collaborative irrigation designers on commercial designs 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, i.e. 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%, and it replicated the pattern we observed in our best re-run at Mt Gravatt, i.e. wettest areas in the zones in between each of the sprinklers. That's with a model operating in best conditions, and with the ideal distribution profiles provided by research studies, conducted indoors with 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 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 3 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 (**Standard** irrigation). 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 under the Queensland Water Commission reticulated water supply restrictions enforced at the time. Mt Gravatt irrigation was not restricted, as they sourced their irrigation from a groundwater bore.

Site 2 was also calendar scheduled, but only once per week (**Weekly** irrigation), and 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 (**Strategic** irrigation); we tried to irrigate 15-20 mm per time to promote deep wetting and turf root growth. In this **Strategic** irrigation, we maximised the period between watering by monitoring turf and soil surface condition, and discussing what the curators were comfortable with. Between July 2005 and February 2006, Site 3 at Morningside and Mt Gravatt received 5 and 10 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 9 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 NRW SILO database.

Results and discussion

Rain, irrigation and turf condition

From June until mid-October 2005, only 50 mm of rain fell (Table 5), 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 (Plates 11, 12).



Plate 11. Irrigation strategy has little impact on turf condition at Morningside sports field, however turf water stress is apparent in October 2005.

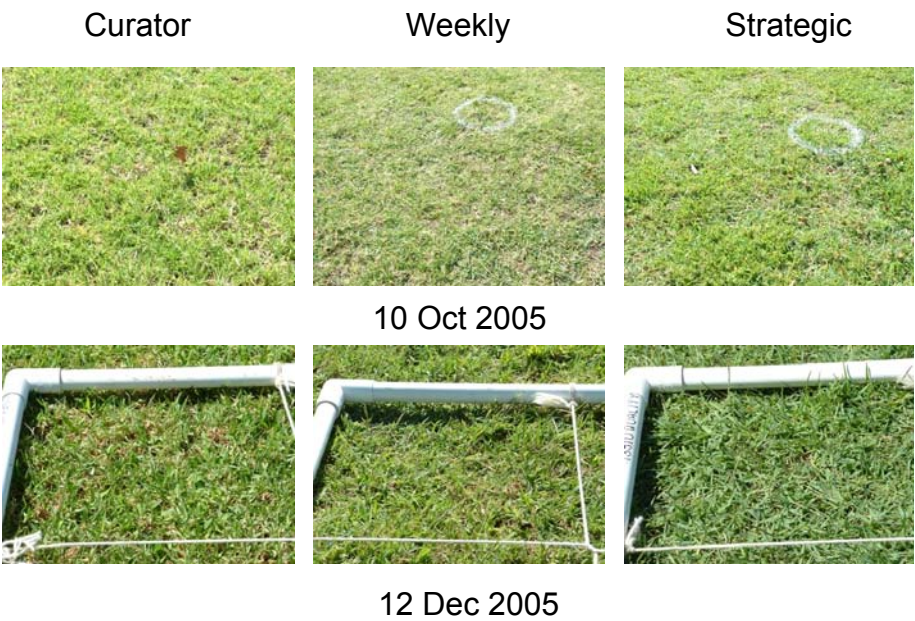


Plate 12. Irrigation strategy has little impact on turf condition at Mt Gravatt sports field, however turf water stress is apparent in October 2005.

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 (i.e. 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 5). 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, at 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.

Looking at turf pictures from late December, it is obvious that the grass was growing well in all treatments; benefiting from the summer rain. This good growth persisted into June 2006 (see example from Morningside in Plate 13). There was no difference in turf cover between the irrigation treatments for that whole period.

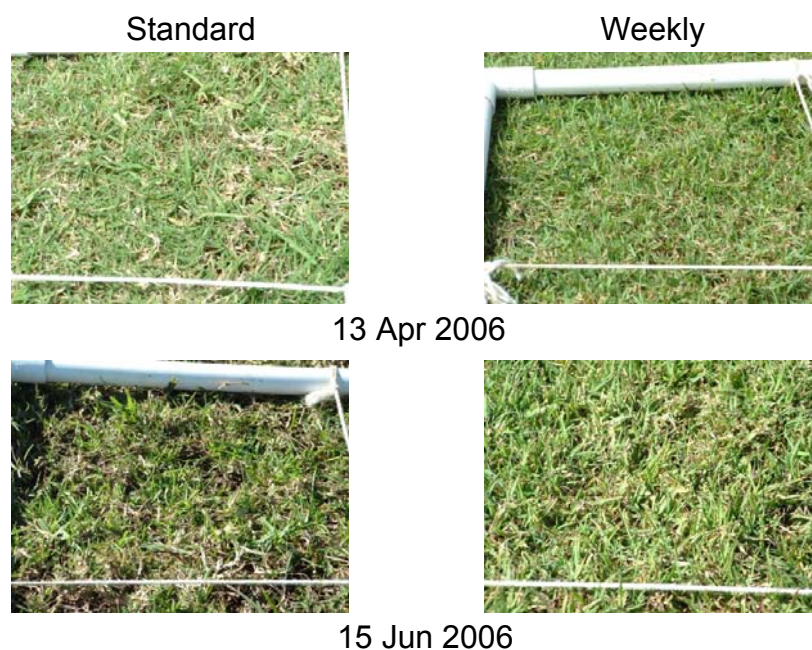


Plate 13. Irrigation strategy had little impact on turf condition at Morningside sports field in 2006.

Table 5. Evaporation, rainfall and irrigation values (mm) for Morningside and Mt Gravatt sports fields July 2005 through June 2006.

Period	Evap'n	Rainfall		Standard irrigation		Weekly irrigation		Strategic irrigation	
		M'side	Mt Gr't.	M'side	Mt Gr't.	M'side	Mt Gr't.	M'side	Mt Gr't.
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 (Fig. 18), we can see that hardness gradually increased from late June until the 10 mm rain event in early September, however they 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 2 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 (Fig. 18).

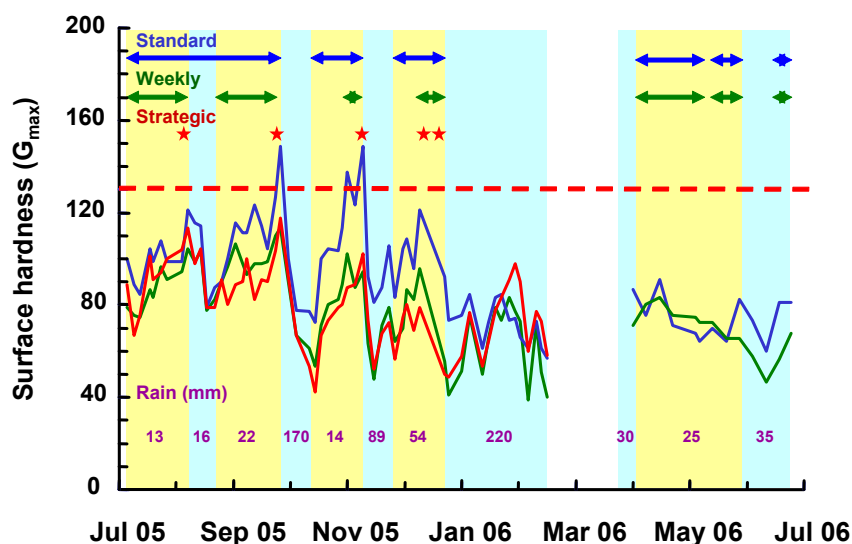


Figure 18. Impacts of irrigation treatments on surface hardness at Morningside sports field, between July 2005 and June 2006. Arrows for Standard and Weekly treatments show periods when irrigation was operational (otherwise turned off by rain sensor or manually). Stars for Strategic treatment show irrigation event. Dotted line shows current acceptable hardness level for community fields. Coloured regions show low rainfall periods.

At Mt Gravatt (Fig. 19), 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 100 G_{max} .

The interesting and informative site was where we were conducting the **Strategic** irrigation. 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 it 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 reached peak hardness levels of concern 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.

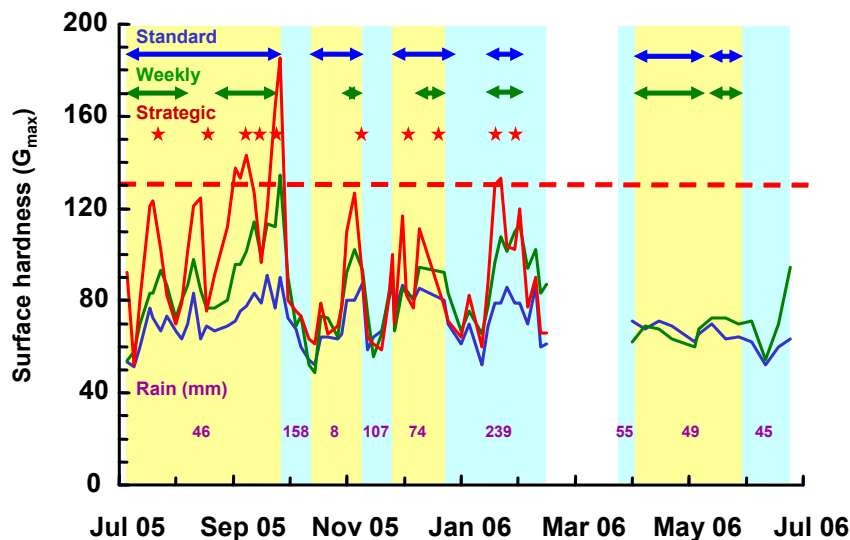


Figure 19. Impacts of irrigation treatments on surface hardness at Mt Gravatt sports field, between July 2005 and June 2006. Arrows for **Standard** and **Weekly** treatments show periods when irrigation was operational (otherwise turned off by rain sensor or manually). Stars for **Strategic** treatment show irrigation event. Dotted line shows current acceptable hardness level for community fields. Coloured regions show low rainfall periods.

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. Over the 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 appears 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 root-zone wetting rain fell, then we planned to initiate one major irrigation, to provide some rewetting of the root zone. This was not required during our demonstration period.

A combination of a sufficiently sensitive rain sensor on the irrigation system, and conjunctive curator 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 2005-7.

Why do we irrigate?

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

Reduce irrigation requirement by:

- Don't depend on irrigation to keep 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 irrigation)

Getting the irrigation equipment right

- Make sure the system design can deliver good sprinkler pressure, and at least go 'head to head'. Aim for distribution uniformity of 80% 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 system is working properly!!! Poor system maintenance is a major problem.
- At installation try and ensure stations run WITH usage pattern, not across. 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. Fig. 20 shows the Morningside design is more useful in this regard than the Coorparoo design.

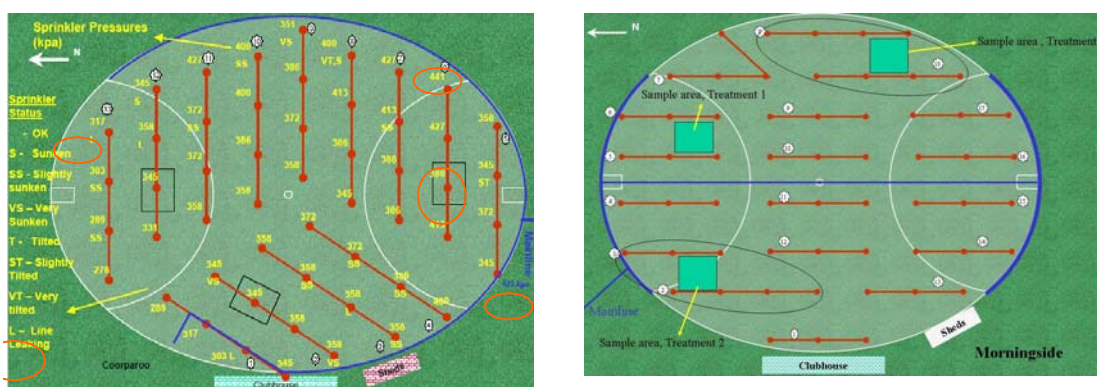


Figure 20. Comparison of irrigation designs non-compatible (left) and compatible (right) with differential irrigation of high wear areas.

Irrigation schedules

- Turf can go several weeks between irrigation without significant long term effects. However, wear recovery may be reduced, and surfaces can get hard
- Settled on weekly irrigations as best compromise
- Recommend AT LEAST 30 minutes per sprinkler (assuming 8-10 mm/hr)
 - Shorter runs are too inefficient
 - Prefer runs of 1 hr

The main messages

- Get the people things right – awareness, communication, training, agreed action plans
- Avoid the obvious stupid things! Examples are leaking or broken pipes/sprinklers, overgrown sprinkler outlets, malfunctioning controllers
- Manage soil structure! Hardness is the key turf/soil risk factor
- Make sure the responsible person understands 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 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 distance of just a few hundred metres, particularly storm events
- Maximise the benefits of any rain (good soil structure, good turf growth, good root systems)
- See how long YOU can comfortably hold off irrigation after rain
- If really stressed for water (through absolute volumes available, or imposed water, restrictions), prioritise to irrigate the most actively used areas

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Soil profile amelioration (laboratory studies)

Extracted from (Eberhard and Raine 2004)

Executive Summary

The Australian Football League Queensland has been investigating options to improve the performance of its Premier League sporting fields in Brisbane. The resilience and performance of grassed surfaces on sports fields is strongly influenced by the underlying soil physical, chemical and biological properties. Compaction of the soil surface and the presence of fine-textured soil profiles have been shown to be the most common limiting factors in turf maintenance. However, the Premier League fields have been constructed with a wide range of soil materials. As a first step towards identifying appropriate soil management treatments to improve the performance of these playing surfaces, a laboratory evaluation was undertaken to characterise the effect of water applications and soil amendments on the subsequent physical and hydraulic properties of various soil profile materials. The specific objectives of this investigation were to:

- Evaluate the factors influencing the potential for structural degradation of soil surfaces;
- Evaluate the potential to modify surface hardness properties by the application of water (e.g. irrigation/rainfall) prior to playing on these surfaces; and
- Evaluate the potential benefits of applying soil amendments on soil structural properties influencing agronomic responses, playability and injury risk.

Factors influencing the potential for structural degradation of soil surfaces

Soil texture has a dominant effect on the bulk density, hardness and shear strength of the soil surface. Sand was found to have a high bulk density which was relatively unaffected by either the level of compactive force applied or the soil moisture content at which the force was applied. In all cases, the penetration hardness was low due to the single grain structure of the sand soil. Increasing the compactive force applied was found to produce a slight increase in shear strength and made the surface slightly harder as measured by deformation.

The influence of both traffic (i.e. compactive force applied) and soil moisture management on compaction and shear strength is greater for fields with sandy clay loam and clay soils. The level of traffic appears to be the dominant factor influencing changes in hardness suggesting that it is more important to manage playing load and rotate practice areas on fields with these soils. As the amount of traffic increases, the relative influence of initial moisture content on bulk density and hardness decreases. On high traffic fields or areas, the level of surface compaction created will be high irrespective of whether there is a high soil moisture content. However, restricting play on wet fields with sandy clay loam or clay soils, particularly where these fields do not normally experience high traffic loads, should significantly reduce the incidence of surface compaction and reduce the frequency of routine aeration treatments.

Potential to modify surface hardness properties by the application of water

Application of water to sand based profiles only provides a benefit where the surface is particularly dry and exhibits a low shear strength resulting in inadequate foot stability and traction. Only a small amount of water (i.e. 5 mm) needs to be added to maximise the cohesive forces and shear strength. This water can be added immediately prior to playing without risk of inducing additional compaction. For normally compacted sandy clay loams, extremely dry conditions can result in excessive surface hardness. In these cases, an application of 5-10 mm of water should be sufficient to produce a surface moisture content of 7-17% and reduce the hardness to below critical levels. Applying larger amounts of water to sandy clay loam surfaces with little grass cover immediately prior to play may result in the surface exhibiting low shear strength and inadequate foot stability and traction.

Dry clay soils exhibit very high hardness values raising the risk of impact injuries. However, wet clay soil has a low shear strength which reduces foot stability and traction. Wet clay soils also have a high deformation potential which raises the risk of longer term structural degradation and agronomic impacts. Hence, clay soils should be managed to keep the moisture content within an optimal range. For the normally compacted clay soil the moisture should be in the range of 17 to 28 % volume. However, it should be noted that clay based soils should rarely dry out below 10% volumetric moisture content under field conditions and hence, the application of 5-10 mm of water should be sufficient to achieve the optimal surface soil moisture content. For clay soils, irrigation water should be applied at least 24 hours prior to play to reduce the risk of deformation and additional surface compaction.

Potential benefits of applying soil amendments on soil structural properties influencing agronomic responses, playability and injury risk

The incorporation of Hydrocell flakes into the soil profile did not produce any significant agronomic or playability improvements under the compacted conditions likely to be experienced on sporting fields. However, the incorporation of biosolids into the soil profile does appear to provide some agronomic and playability benefits. Agronomic benefits associated with improved soil-water capacity and internal drainage appear to be greatest on clay based profiles. The incorporation biosolids was also found to increase deformation and rebound suggesting that amended soils (particularly sand based profiles) would feel softer and more “springy” under foot potentially reducing the risk of injury. It is recommended that further research into the magnitude and longevity of benefits associated with the incorporation of biosolids be conducted under field conditions.

Topdressing with crumbed rubber was found to be an effective strategy to protect the underlying soil structure from compactive forces likely to be experienced in the field. Biosolid topdressing produced only marginal protective benefits on the underlying soil. Crumbed rubber deformation measurements suggest that it is will typically provide a softer surface with greater rebound potential than existing soil based surfaces. These characteristics would be expected to reduce player injury risk. Hence, it is recommended that the agronomic and playability benefits of topdressing with crumbed rubber be further evaluated under field conditions.

Introduction

Turf grasses on sports fields suffer a range of stresses caused by adverse soil physical, chemical and biological conditions (Carrow 2000). Previous studies (e.g. (Carrow 1990; Carrow 2000; Hacker 1987) suggest that the most important factor influencing grass establishment and tolerance to wear is soil profile construction, with the over-riding influence being the effect of soil structure on the water infiltration, aeration and drainage rates (Fig. 21). Similarly, declining turf quality under hot, humid summer conditions is exacerbated by poor soil aeration, excessive subsoil wetness, high temperatures and turfgrass diseases (Bigelow, Bowman *et al.* 2001).

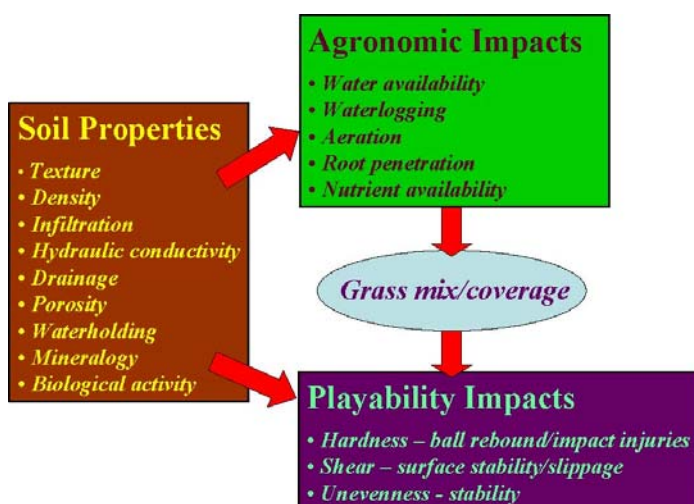


Figure 21 Conceptual model of soil properties influencing agronomic and playability factors as part of sports field management.

Compaction of the soil surface and the use of excessively fine-textured (i.e. clay and silt dominated) soil profiles have been shown to be the most common limiting factors in turf maintenance (Carrow 1990; Carrow 2000). Soil compaction reduces oxygen diffusion, total water use and moisture extraction in the soil profile (Agnew and Carrow 1985). The proportion of pore spaces >200 µm in diameter within the top 10-90 mm of the soil profile reduces over time due to compaction processes (Lodge and Baker 1993). Soil structural degradation occurs through both man-made (eg. intensive use) and natural causes (eg. sodic dispersion or an accumulation of organic matter) with large differences being found between high and low wear areas.

Cultivation is often regarded as the primary means of alleviating these problems. Rapid physical deterioration of sporting field soil profiles has been observed even with high levels of spiking and sand top dressing (Gibbs and Baker 1989). Hence, the benefits of cultivation are nearly always short lived.

Sand content and type has also been found to strongly influence both air-filled pore space and moisture content. Soil profiles containing more than 94% sand have been found to provide adequate infiltration rates and air-filled pore space for sporting fields (Baker and Richards 1993). However, shallow drained soils commonly used on Queensland community sporting fields and landscape sites tend to have higher clay contents, retain excess water and are poorly aerated with low drainage rates. Even soils with a high sand content have been found to suffer from reduced porosity. For example, drainage from a sandy loam soil profile was found to be inadequate with infiltration rates falling to 0.5 mm/h after only one season of usage (Baker and Canaway 1990). Similarly, soil profile mixes with less than 60% added sand which were subjected to simulated foot traffic produced infiltration rates and air filled porosities which approached zero (Rashid, Amin *et al.* 1988).

The AFLQ is currently interested in improving the quality of its Premier League sporting fields with a focus on improving playability and reducing the risk of player injury. These fields have been constructed with a wide range of soil materials (Raine and Eberhard 2004). To enable the identification of appropriate soil management treatments to improve the performance of these surfaces, a laboratory evaluation was undertaken to characterise the effect of irrigation applications and soil amendments on the physical and hydraulic properties of various soil profile materials. The specific objectives of this investigation were to:

- Evaluate the factors influencing the potential for structural degradation of soil surfaces;
- Evaluate the potential to modify surface hardness properties by the application of water (e.g. irrigation/rainfall) prior to playing on these surfaces; and
- Evaluate the potential benefits of applying soil amendments on soil structural properties influencing agronomic responses, playability and injury risk.

This report provides an overview of the soils and measurement methods used in the laboratory study, before reporting separately on the experiments undertaken to address each of these objectives.

Common Materials and Methods

Soil Selection

Three soils (Table 6) were selected for study as representative of the soil texture range identified during the earlier characterisation of soil profiles on the AFLQ Premier League sporting fields (Raine and Eberhard 2004). Field textures of the soils were determined using the method outlined in (McDonald and Isbell 1990). The loamy sand was obtained from a local landscape supplier and was similar to soil material commonly provided as topdressing for sporting fields. The sandy clay loam was collected from the surface horizon of an alluvial soil located in the upper Lockyer Valley. The clay soil was collected from the Agricultural Engineering Field Station located at the University of Southern Queensland. The soils selected for treatment were air-dried, crushed to pass through a 4 mm sieve and homogenously mixed before being stored in air-tight containers. A particle size analysis was conducted by immersion wetting the 5 g of air-dried soil in 30 cm³ of deionised water and applying approximately 100 J s⁻¹ of ultrasonic (20 kHz) energy for a period greater than 15 minutes. The suspensions were transferred to a 500 cm³ settling cylinder, made up to volume with deionised water and mixed homogenously. After the appropriate settling period, sub-samples were extracted with a pipette to determine the quantity of <2 µm and <20 µm equivalent spherical diameter particles. The sand sized fractions (Table 7) of the loamy sand were measured dry sieving a 1000 g sample for 90 minutes on a nest of sieves mounted on an Octagon 200 Variable Amplitude Test Sieve Shaker (Endecotts Limited, London, UK) at a vibration speed of 3000 revolutions per min with medium level amplitude.

Table 6. Physical properties of the selected soils.

Field Texture	Particle size distribution (%)			Air-dried volumetric moisture content (%)
	<2 µm	2-20 µm	>20 µm	
Loamy sand	1	2	97	0.2
Sandy clay loam	11	1	78	3.5
Light-medium clay	60	22	18	10.0

Table 7. Distribution of the sand sized fractions for the loamy sand.

Size Fraction (μm)	%
>1650	0.1
1180 - 1650	0.9
600 - 1180	11.8
425 - 600	13.7
300 - 425	24.7
150 - 300	34.3
75 - 150	11.3
53 - 75	1.6
<53	1.6

Measurement of Soil Structural Properties

Bulk density

The soil bulk density is regarded as an indicator of soil compaction as both measures are directly related without being affected by other soil parameters. The bulk density of the compacted soil core was calculated from the oven-dried equivalent mass of the soil and the measured volume of the soil in the core.

Shear strength

The shear strength of the soil surface (5 mm depth) was measured using a handheld shear vane manufactured by Geotest Instrumental Corp (Model E-285, Evanston, IL, USA). The vanes are pressed into the soil surface and a rotational force applied to the handle to shear the soil surface. The shear area can be adjusted using three different sized heads to accommodate for different levels of shear strength. The maximum shear strength of the soil surface is measured from the force required to shear the surface. The shear strength values reported in this work are in units of kg cm^{-2} which are equivalent to 98.1 kN m^{-2} .

Surface hardness

Surface hardness of the soil cores was measured using a 0.25 cm^2 flat tipped (5.6 mm diameter) impact penetrometer with the impact energy (9.81 J cm^{-2}) delivered by dropping a sliding hammer (1.0 kg mass) over a distance of 0.25 m. This penetrometer delivered the same energy per unit area as a drop penetrometer commonly used to assess surface hardness on sporting fields (e.g. Orchard, 2001). For field measurements, the hammer mass is dropped successively up to three times and the distance that the tip penetrates the soil surface is measured after each drop. However, due to the limited depth (60-70 mm) of the soil core samples in this trial, it was not always possible to obtain readings for each of the three consecutive drops.

Soil hardness was also evaluated by using a 11.46 cm^2 flat tip (38.2 mm diameter) probe attached to a load frame to apply a force of 2546 N or 222 N cm^{-2} to 58% of the sample area. The force was approximately equal to that applied to field soils by a 100 kg person standing on a five studded boot where the whole force was applied via the studs. The maximum depth of probe penetration during the application of the force was measured and termed the "initial deformation". As the force was released, the soil rebounds and the depth of penetration was again measured and termed the "long-term deformation".

In some of the treatments, the penetration resistance was also measured with a handheld penetrometer (Zoli Maurizio, Alfonsine, Italy). A 60° cone tip with either 2.5 mm or 3.5 mm diameter was pushed by hand into the samples to approximately 30 mm with constant speed. The maximum force applied was read from the dial gauge and converted to MPa.

Saturated hydraulic conductivity

Saturated hydraulic conductivity was measured by applying a constant head of water to the soil core samples. A length of PVC (70 mm length) was taped to the upper end of the PVC containing the treated soil core. Tap water was ponded in the PVC tube to a depth of approximately 60 mm above the soil core and allowed to drain until a steady state discharge was recorded (normally < 120 mins). The steady state discharge (flux) was measured and the saturated hydraulic conductivity calculated using Darcy's equation (Darcy 1856 cited in (Jury and Horton 2004)).

Total, air-filled and capillary porosity

The treated soil cores were saturated by placing them in a water bath so that the elevation of the soil surface was the same as the surrounding water level. After equilibration, the saturated soil cores were removed and weighed without drainage. The saturated soil samples were then placed on a low pressure (1 bar) suction plate and sequentially subjected to -40 and -80 cm head (equivalent to -4 and -8 kPa) applied by hanging column. Where the soil cores were amended with either Hydrocell flakes or biosolids, the samples were also placed on a 5 bar suction plate in a low pressure chamber and equilibrated at 33 kPa. The soil samples were weighed after equilibrium at each suction level and after final treatment were oven-dried before weighing. The total porosity of the treatment samples was calculated as the difference between the saturated and oven-dry weight of the soil. The air-filled (-4 and -8 kPa) porosity and the moisture content at 33 kPa were calculated using the measured weight at each equilibration level and the oven-dried mass.

Data Handling and Analysis

Five replications were conducted on all treatments except were specifically identified. An application specific database was developed using Microsoft Access to store and sort the measured and derived data. The database was subjected to several data coherence tests (identification of input errors, missing treatment series and measurements) to identify and rectify data entry errors. Where appropriate, a range of statistical analyses including analysis of variance, t-tests Tukey honestly significant difference tests and Tamhane's T2 tests were conducted using SPSS version 12.0.1 for Windows (SPSS Inc., Chicago, IL). All differences are significant at $P < 0.05$ unless otherwise indicated.

Effect of Moisture Content and Compactive Force on Soil Structural Properties

Introduction

Community based sporting fields are often constructed using locally sourced soil materials. While there is sometimes an attempt to top-dress these profiles with a layer of sand, the surface soil on sporting fields in the Brisbane area have been found to range from sands to medium-heavy clays (Raine and Eberhard 2004). A principal factor influencing soil structural degradation due to traffic is the compactive force (or pressure) applied. Similarly, the moisture content at which the force is applied has also been found to influence the magnitude of the resultant compaction. However, the majority of sporting field research has been conducted on light textured (i.e. sand) based soils and there is no information available on the effect of these factors on the structural degradation of soils commonly found on community based sporting fields. Hence, this experiment was conducted to quantify the influence of compactive force, and the moisture content at which the force is applied, on structural degradation of soils commonly found on local community based sporting fields.

Materials and Methods

The experimental treatments involved sub-sampling each of the three air-dried soils and adding known water volumes to produce a range of moisture contents (Table 8). The sub-samples were then loosely packed into PVC cores (50 mm inner diameter, 70 mm height) and variously compacted (Table 8) with either a static force or dynamic energy applied to the upper surface. Five replications of each moisture and compaction treatment were used. The bulk density of the compacted cores was calculated and measurements of penetration, hardness and shear force conducted.

Table 8. Moisture added and compaction treatments applied to the soil cores.

Soil texture	Moisture treatments (% vol water added)	Compaction treatments
Loamy sand	5, 10 or 15	8, 16 or 24 kg sample-1; 3 J cm ⁻²
Sandy clay loam	7, 10 or 15	8, 16 or 24 kg sample-1; 3 J cm ⁻²
Light-medium clay	5, 10 or 15	4, 8, 16 or 24 kg sample-1; 1 or 3 J cm ⁻²

Correlation analyses were used to identify significant relationships between the variables. A stepwise multivariate regression was conducted to enable the development of a quantitative predictive relationship and the prediction of soil behaviour from soil properties (eg texture) and environmental conditions (eg moisture, compaction).

Results

Bulk density

Bulk density was found to be highly correlated with soil texture and was typically found to increase with increasing moisture content and force applied (Fig. 22). However, at low moisture content and applied forces, bulk density was generally lower in higher clay content soils. The bulk density of the loamy sand under these conditions was $\sim 1.5 \text{ g cm}^{-3}$ while the sandy clay loam and clay had bulk densities of ~ 1.3 and $\sim 1.05 \text{ g cm}^{-3}$, respectively.

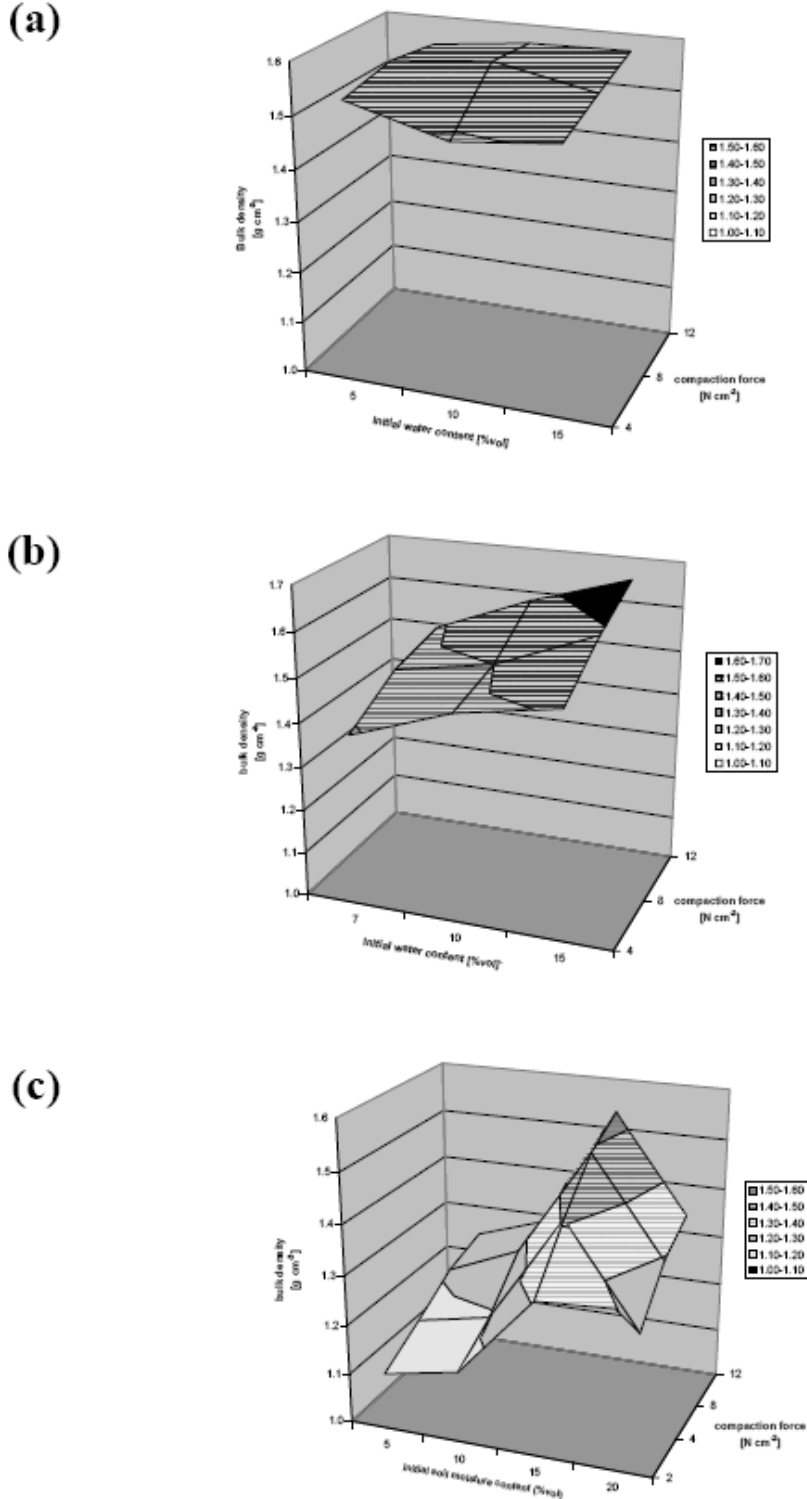


Figure 22. Effect of initial soil moisture content and compaction force/energy on bulk density of (a) loamy sand (b) sandy clay loam and (c) light-medium clay.

For the loamy sand, there was no significant effect of initial moisture content on compaction and a relatively small effect of increasing force applied on compaction (Fig. 22a).

However, for the sandy clay loam and clay both the moisture content of the soil when the force is applied and the magnitude of the force have a significant impact on the final bulk density (Fig. 22b & c). Compaction of the clay is particularly sensitive to moisture content with a compactive force of 8 Nm^{-2} producing densities of $1.2\text{-}1.3 \text{ kg cm}^{-3}$ at low (e.g. 5-10%) moisture contents but greater than 1.5 kg cm^{-3} when the initial moisture content was greater than 25% by volume (15% added). The apparent decrease in bulk density at high moisture contents (i.e. 20% vol added) for the clay soil is an artifice of the confined cores and the incompressibility of the water in the samples. The correlation between the bulk density and the clay content of the soil, water content prior to compaction and the compactive forces applied are presented in Table 9.

Table 9. Pearson's correlation between bulk density and clay content, compactive force applied and water content prior to compaction.

	Clay content	Water content prior to compaction	Compactive force applied
Bulk density	-0.801**	-0.428**	0.440**

** Correlation is significant $P > 0.01$ level (2-tailed).

The most important factor influencing the bulk density is the clay content of the soil. Initial moisture content and the compactive force applied had a smaller and more variable influence on the bulk density observed. This is consistent with (Taylor 1980) who also found that soil texture was the most reliable parameter to estimate soil physical characteristics. A stepwise multivariate regression was conducted for these parameters producing the relationship:

$$\rho_b = 1.337 - 0.007 * \text{clay} + 0.012 * \Theta_v + 0.012 * \text{compactive force} \quad (r^2 = 0.78)$$

where: ρ_b = bulk density [g cm^{-3}]

clay = clay content [%weight]

Θ_v = volumetric moisture content prior to compaction [%vol]

compactive force = force applied [N cm^{-2}]

This relationship highlights that increasing the clay content of the soil reduces the bulk density where as increasing the moisture content of the soil prior to compaction, and increasing the compactive force applied, both increase the bulk density.

Surface hardness

The hardness of the surface as measured by drop penetrometer was found to be largely influenced by the texture of the soil with the 0.25 cm² drop penetrometer penetrating more than 60 mm into the loamy sand cores on the first drop irrespective of the initial moisture content or the compactive force that had previously been applied to the core. However, for the sandy clay loam, the first drop penetrated less than 60 mm for all treatments except where the soil was very wet (15% vol added) and only lightly (i.e. 4 or 8 N cm⁻²) compacted (Table 10). At lower moisture contents, the application of higher compactive forces (and hence, bulk densities) resulted in a decrease in penetration. However, this effect decreased with increasing moisture content of the sample. The second drop penetrated more than 60 mm on all treatments of the sandy clay loam.

Table 10. Depth of penetration by a drop penetrometer on a compacted sandy clay loam.

Water added prior to application of compactive force (% vol)	Compactive force applied (N cm ⁻²)	Penetration depth (mm)
7	4	55
	8	43
	12	36
10	4	53
	8	52
	12	44
15	4	>60
	8	>60
	12	52

The moisture content of the soil at which the compaction occurs also appears to be the major determinant of drop penetration on the clay with both first and second drop measurements of less than 60 mm recorded on drier samples (i.e. 5 or 10 %vol added) but first drop measurements of more than 60 mm recorded for wet samples even after high levels of compaction (Fig. 23).

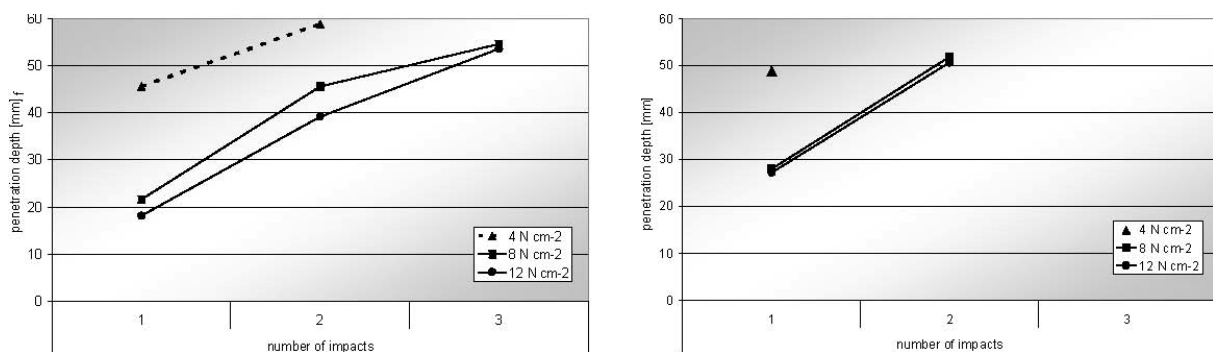


Figure 23. Drop penetrometer depth on a clay soil with (a) 5% and (b) 10% volume water added and previously subjected to either 4 (▲), 8 (■) or 12 (◆) N cm⁻² of compactive force.

The surface deformation as measured using the large tipped penetrometer driven by the load frame at constant speed/force is also highly correlated with the soil texture. Deformation (i.e. penetration) distance is smallest in the loamy sand and greatest in the clay (Fig. 24). The initial deformation is always higher than the long-term deformation regardless of the initial water content and the compaction force applied due to the rebound properties of the soil material. Absolute rebound (i.e. the difference between initial and long term deformation) normally increases with clay content and hence, is greatest in high clay content soils.

The soils were typically softer (i.e. larger deformation measured) when exposed to low compactive forces under relatively dry conditions (Fig. 24). For all soils, the standard deviation in deformation was higher in the samples exposed to low compaction at low moisture content (i.e. low bulk density soils) than in the soils where high compactive force had been applied. For the loamy sand, compaction and initial moisture content had relatively little impact on deformation (Fig. 24a). However, moisture content of the sandy clay loam strongly influenced the deformation irrespective of the compactive force previously applied to the sample although there was a slight increase in hardness (i.e. decrease in deformation) with increasing compactive force (Fig. 24b). The deformation level of the clay was generally higher than that of the other soils (Fig. 24c). There was little effect of moisture content over the range evaluated while hardness increased with compactive force. However, increasing moisture content beyond the range shown significantly increased deformation in the clay as these samples could not bear the force applied and the deformation measured by the penetrometer was greater than the depth of the cores.

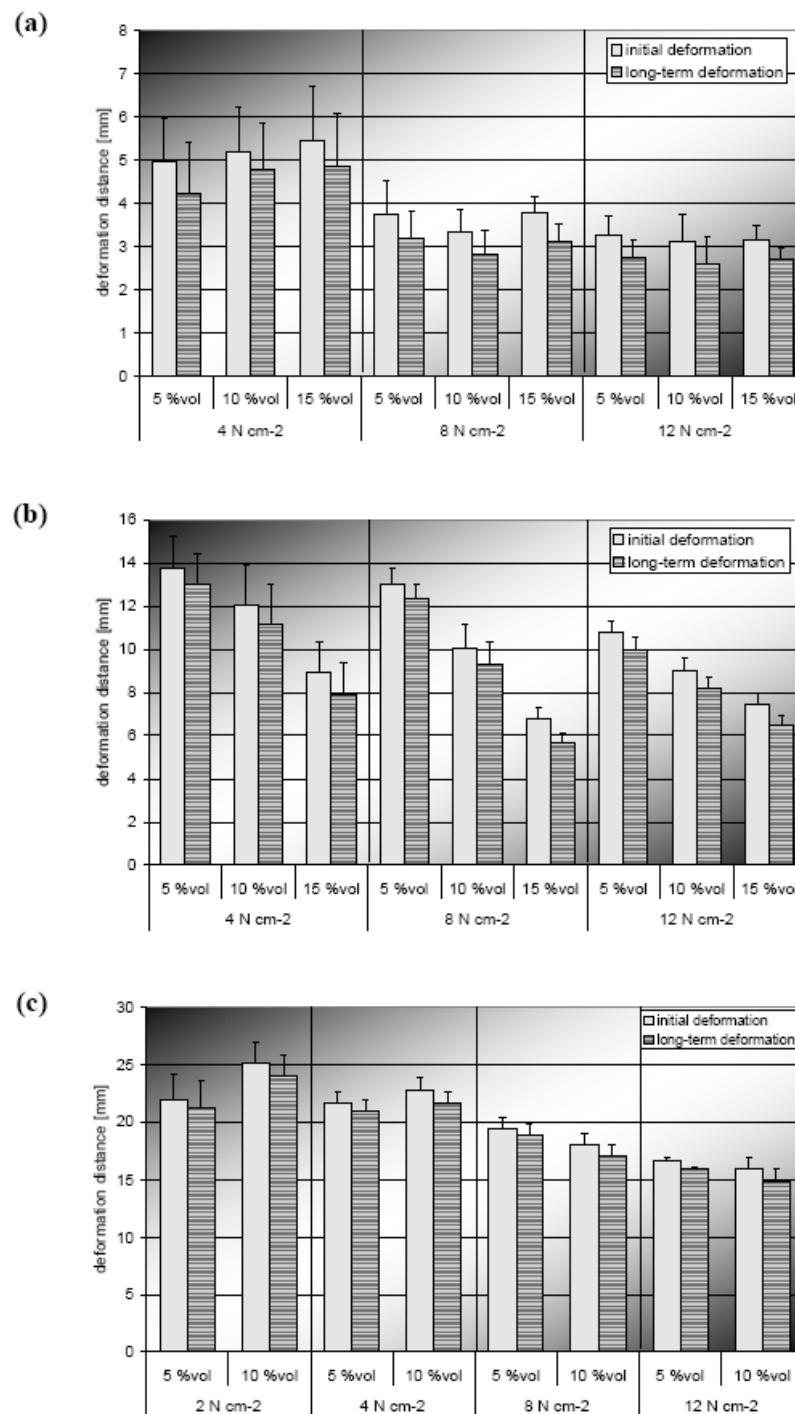


Figure 24. Deformation characteristics of (a) loamy sand (b) sandy clay loam and (c) light-medium clay as affected by soil moisture and compactive force applied.

Shear strength

The shear strength of the soil surface is predominantly influenced by soil texture with the loamy sand requiring a small force ($<0.1 \text{ kg cm}^{-2}$) to shear while the sandy clay loam and clay required larger forces of $0.1\text{-}0.35$ and $0.2\text{-}0.6 \text{ kg cm}^{-2}$, respectively (Fig. 25). The difference in shear strength due to initial moisture content was greater than the difference due to the compactive force applied for each soil. However, the nature of the change in shear strength with increasing moisture content varied between the soils. For the loamy sand, increasing the initial moisture content resulted in a surface with a higher shear strength (Fig. 25a). However, increasing initial moisture content reduced the shear strength of the surface on the sandy clay loam (Fig. 25b) and had comparatively little effect on the clay (Fig. 25c). The compactive force applied to the soil had no significant effect on shear strength in the loamy sand (Fig. 25a). However, increasing the compactive force applied significantly increased the shear strength of the soil for both the sandy clay loam and clay (Fig. 25b & c).

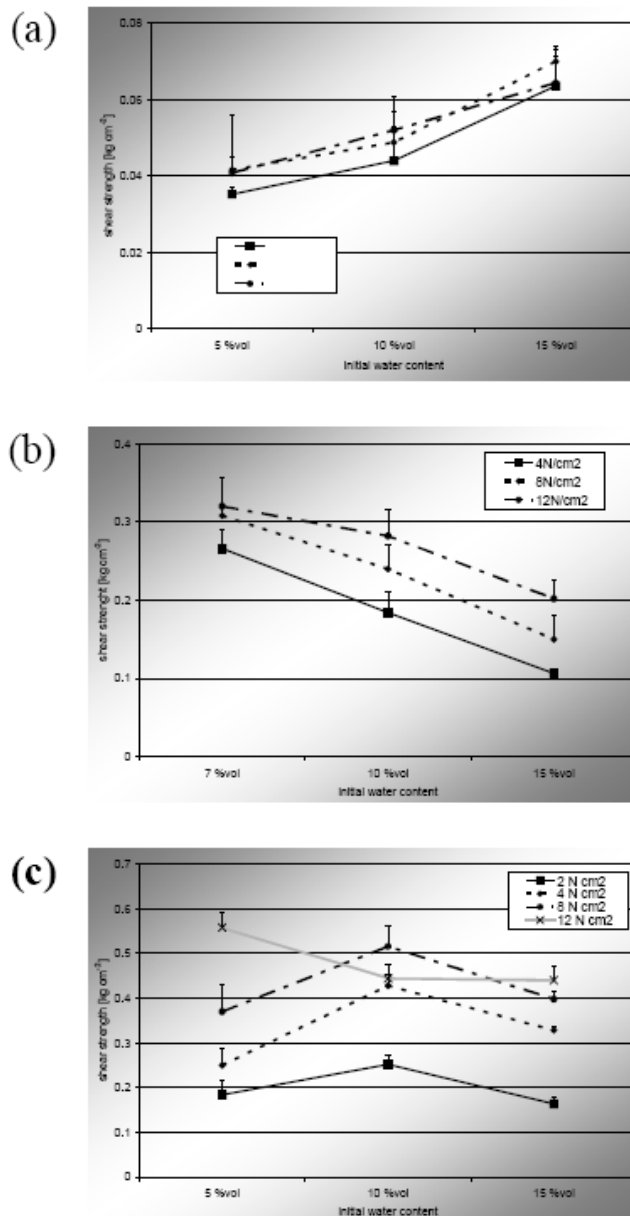


Figure 25. The effect of initial moisture content and compactive force applied on the subsequent shear strength of (a) loamy sand, (b) sandy clay loam and (c) light-medium clay

Discussion

This experiment investigated the effect of soil construction material and management factors which lead to the creation of degraded playing surfaces. The results confirm that soil texture has the dominant effect on surface hardness and shear strength. It also demonstrated that the structural degradation of soil surfaces is highly influenced by both the compactive force applied and the moisture content at which the force is applied. However, the magnitude, and in some cases the direction, of changes in the soil structural properties is heavily dependent on the soil texture.

The effect of management on the different soil materials highlights the need to identify and promote appropriate management practices for community based fields based on soil profile properties. For example, the bulk density, hardness and shear properties of loamy sand surfaces (i.e. commonly found on elite sporting surfaces) are not greatly influenced by either the application of compactive forces or the soil moisture content at which force is applied. Hence, these fields can be played on under wet conditions with a relatively low risk of resultant soil surface degradation. However, the density, and hardness of sandy clay loam and clay based surfaces are greatly influenced by both traffic and the moisture content of the field when the traffic is applied.

The management practices applied to recently laid or aerated sandy clay loam and clay soils will influence the period of time taken to compact the surface and the maximum density and hardness reached. The level of traffic appears to be the dominant factor influencing changes in hardness on these soils suggesting that it is important to manage playing load and rotate practice areas on fields with these soils. As the amount of traffic increases (i.e. the level of compactive force applied increases), the relative influence of initial moisture content on bulk density and hardness decreases. On high traffic fields or areas, the level of surface compaction created is likely to be high irrespective of whether there is a high soil moisture content. Hence, reducing traffic on high use fields would appear to be more effective in reducing the rate of soil compaction than manipulation of the soil moisture. However, areas subject to high traffic loads (e.g. goal mouths and centre squares) will rapidly deteriorate irrespective of soil moisture management and are more likely to require regular aeration or rejuvenation to maintain hardness values within acceptable ranges.

The effect of soil moisture management on minimising structural degradation would appear to be most beneficial low traffic fields or areas with sandy clay loam or clay soils. Under these conditions, minimising traffic during periods when the field is wet will greatly reduce the incidence of structural decline. The result of traffic management during wet periods on these soils would be a reduction in the requirement for aeration and rejuvenation and/or an increase in the period between when these practices are required.

Conclusions

Soil texture has a dominant effect on the bulk density, hardness and shear strength of the soil surface. Sand was found to have a high bulk density which was relatively unaffected by either the level of compactive force applied or the soil moisture content at which the force was applied. In all cases, the penetration hardness was low due to the single grain structure of the sand soil. Increasing the compactive force applied was found to produce a slight increase in shear strength and made the surface slightly harder as measured by deformation.

The influence of both traffic (i.e. compactive force applied) and soil moisture management on compaction and shear strength is greater for fields with sandy clay loam and clay soils. The level of traffic appears to be the dominant factor influencing changes in hardness suggesting that it is more important to manage playing load and rotate practice areas on fields with these soils. As the amount of traffic increases, the relative influence of initial moisture content on bulk density and hardness decreases. On high traffic fields or areas, the level of surface compaction created will be high irrespective of whether there is a high soil moisture content. However, restricting play on wet fields with sandy clay loam or clay soils, particularly where these fields do not normally experience high traffic loads, should significantly reduce the incidence of surface compaction and reduce the frequency of routine aeration treatments.

Effect of Water Application on Soil Surface Properties

Introduction

Surface hardness is commonly associated with the incidence of shin splints and an increased risk of shoulder and knee injuries problems (e.g. (Powell and Trotter 2000)). Many studies (e.g. (Baker 2001; Baker, Cook *et al.* 1999; Newell and Wood 2000)) have shown strong relationships between the soil physical properties of moisture content, penetration resistance and surface hardness on sand based profiles. Similarly, watering of sporting fields prior to use has been found to reduce surface hardness values and influence ball rebound (Mooney and Baker 2000). Hence, irrigation management is often used as a method to manage firmness and playability of the soil profile surface (e.g. (Powell and Trotter 2000)). However, the effect of moisture content on surface hardness would be expected to be both soil texture and density related, two factors which are highly variable on community based sporting fields in Queensland. Hence, there is a need to more clearly identify these relationships across the range of soil conditions encountered on community playing fields so that the benefit of alternative irrigation management practices appropriate to the soil conditions and sport being played can be quantified. This experiment was conducted to evaluate the impact of watering on the hardness, shear strength and impact penetration for a range of soil textures.

Materials and Methods

Air-dried samples of three soils (loamy sand, sandy clay loam and light-medium clay) were packed into soil cores as per the process outlined previously. A single compaction treatment was applied using either the static or dynamic forces as outlined previously to create bulk densities equivalent to those observed in the field for similarly textured soils (Raine and Eberhard 2004). A density of approximately 1.57, 1.49 and 1.45 g cm⁻³ was created on the loamy sand, sandy clay loam and light-medium clay, respectively. To simulate the impact of rainfall or irrigation on the physical properties of the soil surface after compaction had already occurred, the soil cores were then oven-dried at 105 °C for 48 hours before applying between 0 and 25 mm of tap water (electrical conductivity ~ 0.45 dS m⁻¹) to the soil surface (Table 11). There were five replications of each treatment. The wetted samples were covered with plastic and allowed to equilibrate for a minimum of 12 hours before the hardness, shear strength and penetration resistance of the soil surface was measured. Multiple impacts were used consistent with the practice of multiple impacts used in field evaluations using the drop penetrometer.

Table 11. Volumetric moisture content of the soil cores after water application

Soil	Water applied (mm)	Volumetric moisture content (%)
Loamy sand	5	9.6
	10	18.3
	15	26.9
	20	35.8
	25	41.5
Sandy clay loam	5	9.2
	10	18.2
	15	27.8
Light-medium clay	5	8.5
	10	17.6
	15	28.3
	20	35.4

Results

Surface hardness

The application of water to the soil cores was found to reduce surface hardness. Depth of penetration measured using the drop penetrometer was also related to soil texture with less penetration recorded on the clay soil (i.e. hardest soil) and greater penetration on the loamy sand (e.g. softest). The first drop penetration depth for the light medium clay and sandy clay loam ranged from 7-43 mm and 3-53 mm, respectively. However, the first drop on the loamy sand was greater than 60 mm for each water treatment. For the sandy clay loam and light-medium clay, successive impacts with the penetrometer increased the depth of penetration by progressively smaller distances.

Increasing the volume of water applied was found to significantly increase the penetration depth measured using the drop penetrometer on both the sandy clay loam and light-medium clay (Fig. 25). However, the effect of water application on hardness was not linear. For example, applying 5 mm of water to the clay soil produced no difference in the hardness of the soil measured using the drop penetrometer while adding 10 mm and 15 mm increased penetration depth by an additional 10 mm and 18 mm on the first drop, respectively. Adding 20 mm of water increased the penetration depth by an additional 37 mm. The effect of water application on the loamy sand was not able to be quantified using the drop penetrometer as the depth of penetration in all cases was >60 mm.

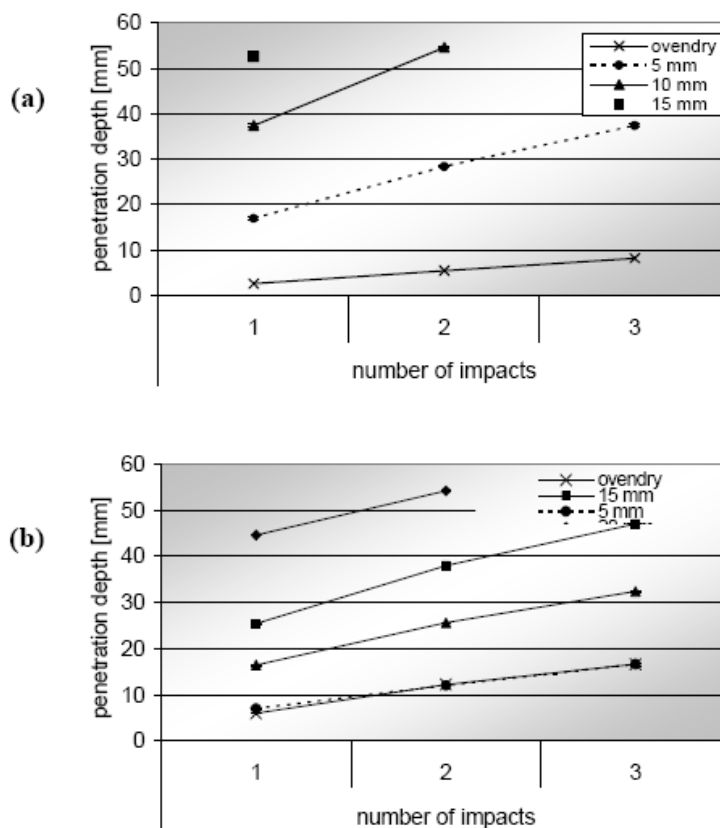


Figure 25. The effect of water application on the depth of impact penetration for oven-dried (a) sandy clay loam (bulk density = 1.49 g cm^{-3}) and (b) light-medium clay (bulk density = 1.45 g cm^{-3})

Increasing the volume of water applied to the clay soil was also found to produce a significant difference (Table 12) in surface hardness as measured using the handheld penetrometer (60° angle, 2.5 or 3.5 mm cone tip).

Table 12. Effect of water application on penetration resistance of a clay.

Water applied to oven-dried soil	Penetration resistance (MPa)
0 mm	>23.00 *
5 mm	20.76 ^d
10 mm	8.03 ^c
15 mm	3.28 ^{ab}
20 mm	1.17 ^a

* exceeded penetrometer scale

Surface deformation as measured using the large tipped probe driven by the load frame at constant force was highly correlated with soil texture (Fig. 26). The deformation of the loamy sand was comparatively small (i.e. <10 mm) irrespective of water content while deformation in the clay soil ranged from 2 to 32 mm. In all cases, the deformation was significantly affected by the amount of water added.

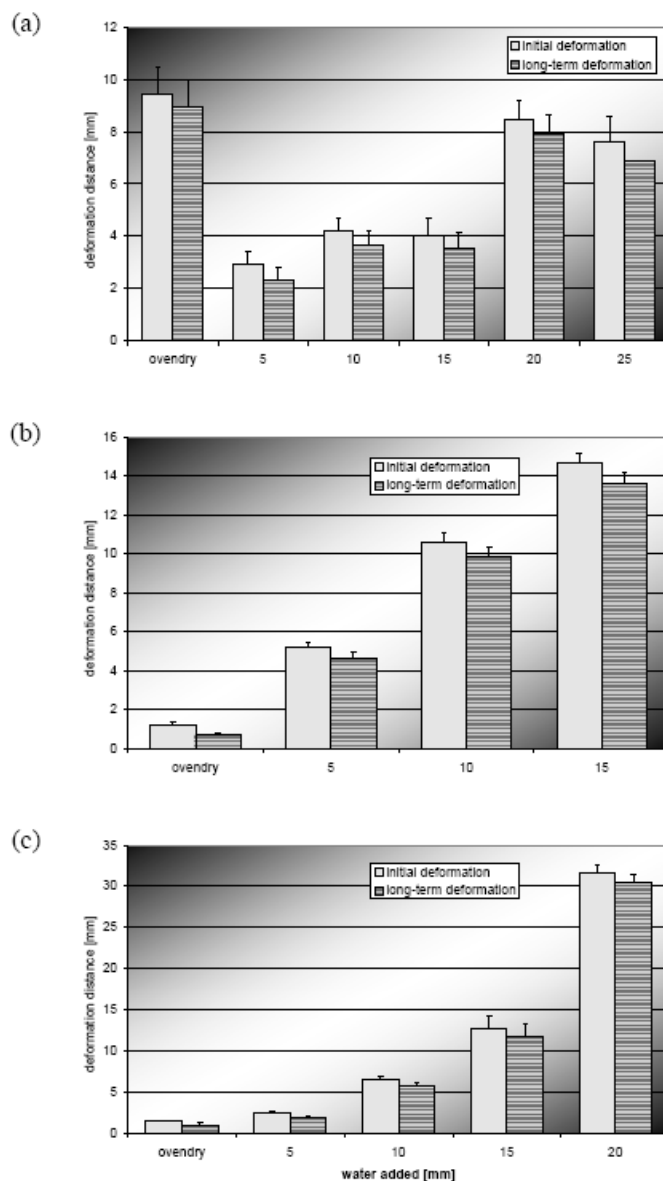


Figure 26. Effect of water addition on the surface deformation of (a) loamy sand (b) sandy clay loam and (c) light-medium clay

When the loamy sand is dry, it has little cohesive binding and a high level of deformation due to its single grain structure (Fig. 26a). Adding a small amount of water increased the cohesion between the sand particles resulting in a decrease in the deformation and an increase in surface hardness. There was little difference in deformation when between 5 and 15 mm of water was applied. However, there was a significant increase in deformation when more than 20 mm of water was added to loamy sand.

For both the sandy clay loam and light-medium clay, deformation was smallest in the dry soil and increased significantly with the addition of water (Fig. 26b & c). There was no significant difference between the deformation measured on the oven-dried treatment and 5 mm water applied to the clay. However, applying 5 mm of water to the sand clay loam did increase deformation. Where only small amounts of water (5-10 mm) were applied, the clay soil was found to deform less than the sandy clay loam. However, there was no significant difference in the deformation of each soil when 15 mm was applied. Applying 20 mm of water to the clay soil significantly increased deformation suggesting that the moisture content was approaching a critical consistency phase.

Shear strength

The shear strength of the dry light-medium clay was up to ten times greater than that of the sandy clay loam and almost 100 times higher than that of the loamy sand. However, the application of water to the soils significantly affected the shear strength of the surfaces (Fig. 27). The effect was greatest in the clay soil where the application of even small amounts of water (e.g. 5 mm) significantly reduced the surface shear strength and the application of 20 mm of water reduced the surface shear by an order of magnitude (Fig. 27c). There was no change in the shear strength of the sandy clay loam when only 5 mm of water was applied but shear strength was reduced by the application of 10 and 15 mm of water on this soil (Fig. 27b). The application of water to the loamy sand did not greatly influence the shear strength (Fig. 27a) with applications of between 5 and 20 mm of water resulting in a relatively small but significant increase in shear strength. However, there was no significant difference between the shear strength of the oven-dried loamy sand and the soil where 25 mm of water had been applied (Fig. 27a).

Discussion

Managing soil hardness by addition of water

The application of water to dry soil was found to significantly reduce both soil surface hardness and shear strength. However, the magnitude of the effect is a function of soil texture with a relatively small effect on sand based profiles and larger changes experienced on clays. A relationship between Clegg hammer and 1st drop penetrometer measurements has been identified (Henderson, *pers comm*) for a range of local sporting fields as part of the field benchmarking component of this project. Using this relationship (clegg reading = $18.321 * 1^{st} \text{ drop penetrometer (in cm)}^{-0.7468}$; $r^2 = 0.79$) and the desirable range of clegg readings for sporting fields (~7-15), the optimal range of first drop penetrometer readings would be between 1.3 and 3.5 cm. Values in this range were obtained for the clay soil when 10 and 15 mm of water was added (moisture contents of 17-25%) and for the sandy clay loam when 5 and 10 mm of water were added to oven dried soil (moisture content of 8-17%). The hardness of the loamy sand was below the maximum acceptable level irrespective of moisture content.

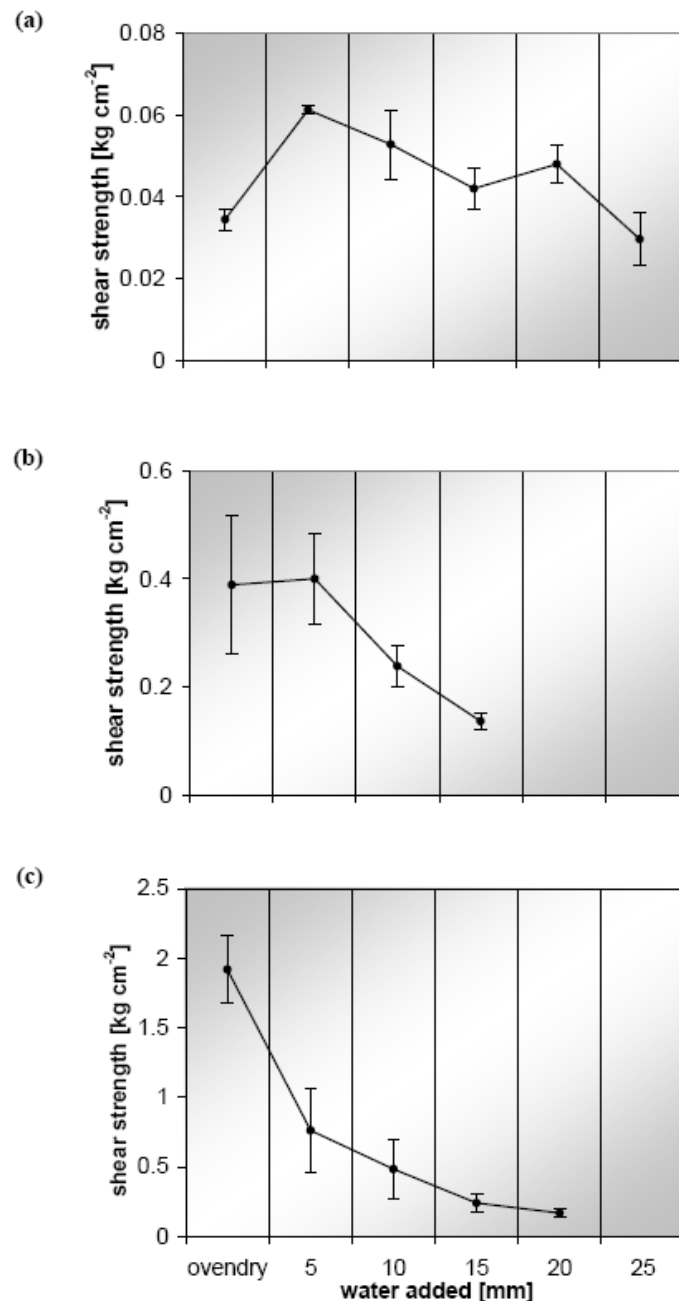


Figure 27. Effect on shear strength of water applied to oven-dried (a) loamy sand, (b) sandy clay loam and (c) light-medium clay

Effect of moisture on foot stability and traction

Traction and foot stability may become a problem where the shear strength of the soil surface is low while there is potential for ligament and muscle injuries when shear strength is too high. However, it should be noted that the shear strength experienced by players on sporting fields is a function of both the grass and soil surface. The shear strength of the sand based surfaces is very low due to the single grain structure and low cohesion between individual particles. This highlights one of the major player injury risks associated with the use of sand based profiles on sporting fields where there are low levels of stoloniferous surface grass cover due to either inappropriate establishment, grass selection or excessive wear. The application of water to sand based profiles increases inter-particle cohesion and hence, shear strength. Thus, where surface instability is a problem on sand based profiles, the application of small amounts of water could be used to increase traction. However, the effect is relatively small and over-application of water will reduce the effect. As the moisture content of the loamy sand approaches saturation, the water films around the particles enable

the particles to slip readily past each other and shear decreases to values similar to that of oven-dried soil (Fig. 27a). These results are consistent with traditional understanding of shear stresses in sands (e.g. (Craig 1992)).

Traction on fields with sandy clay loam or clay based surface layers is significantly greater than that of sand based surfaces except where excessive water has been applied (e.g. on heavy clay cricket pitches). For soils with even relatively small amounts of clay, shear strength increases rapidly as the surface dries. Hence, the application of small amounts of water to these soils can be used to reduce shear strength. However, when these surfaces are very wet (eg. 20 mm or more water added to the compacted light-medium clay) they have low shear strength and hence, would provide poor foot traction. This may present as a problem on clay based sporting fields during and after rainfall or where irrigation water has been applied immediately prior to play.

Potential for surface damage

One of the major factors influencing compaction is the moisture content of the soil when the compactive force is applied. Hence, when games are played on wet fields there is a risk that surface compaction will be further increased leading to exacerbated agronomic (e.g. reduced aeration, infiltration, grass cover) and surface playability (e.g. increased hardness) problems. This is one of the major reasons why fields may be closed during and/or after periods of rainfall. However, over-application of irrigation water prior to games in an effort to reduce hardness and influence traction also increases the risk of increasing surface compaction. The comparatively high deformation measurements associated with the clay soils indicates that the risk of exacerbating compaction and increasing surface unevenness is greater in clay than in sand based profiles. For clay soils, deformation increased dramatically after the application of 20 mm of water.

Conclusions

Application of water to sand based profiles only provides a benefit where the surface is particularly dry and exhibits a low shear strength resulting in inadequate foot stability and traction. The benefits are also likely to be greater on surfaces where there is little stoloniferous grass cover. Only a small amount of water (i.e. 5 mm) needs to be added to maximise the cohesive forces and shear strength. This water can be added immediately prior to playing without risk of inducing additional compaction.

For normally compacted sandy clay loams, extremely dry conditions can result in excessive surface hardness. In these cases, an application of 5-10 mm of water should be sufficient to produce a surface moisture content of 7-17% and reduce the hardness to below critical levels. Applying larger amounts of water to sandy clay loam surfaces with little grass cover immediately prior to play may result in the surface exhibiting low shear strength and inadequate foot stability and traction.

Dry clay soils exhibit very high hardness values raising the risk of impact injuries. However, wet clay soil has a low shear strength which reduces foot stability and traction. Wet clay soils also have a high deformation potential which raises the risk of longer term agronomic and structural degradation. Hence, management of clay soils requires keeping the moisture content within an optimal range. For the normally compacted clay soil used in this work it appears that the moisture should be in the range of 17 to 28 % volume. However, it should be noted that clay based soils should rarely dry out below 10% volumetric moisture content under field conditions and hence, the application of 5-10 mm of water should be sufficient to achieve the optimal surface soil moisture content. For clay soils, irrigation water should be applied at least 24 hours prior to play to reduce the risk of deformation and additional surface compaction.

Evaluating the Potential to Improve Soil Structural Properties using Soil Amendments

Introduction

Soil amendments may be used to improve both agronomic and playing conditions. They may be either physical or chemical in nature and generally aim to reduce compaction, maintain infiltration and drainage rates, and/or improve turf establishment and resilience. The most common physical amendments applied to sporting fields are sand and peat while the most common chemical amendment is gypsum. Physical amendments may be either applied as topdressing or incorporated into the soil profile.

Topdressing evens the surface of the field, helps prevent thatch build up by providing a more favourable environment for micro-organisms, and prolongs the effects of aeration. Sand has been the most commonly applied topdressing material. However, the benefits of topdressing are highly variable with some treatments not affecting turfgrass quality (e.g. (Dunn, Minner *et al.* 1995)). Annual top-dressing with a soil material similar to that of the growing medium may enhance root development. However, use of inappropriate topdressing materials may act to reduce infiltration, internal drainage, aeration and root penetration. Topdressing with crumbed rubber has been found to reduce compaction and hardness, maintain infiltration rates and increase surface temperature (Rogers, Vanini *et al.* 1998). Crumbed rubber additions to the soil profile have also been found to enhance the physical properties of soils susceptible to compaction and add resiliency to sports turf (Groenevelt and Grunthal 1998).

Where physical amendments (e.g. sand, crumbed rubber) are incorporated into clay soils they act by increasing the average particle and pore size. Physical amendments (eg. peat, zeolite, clay, light expanded clay) are also commonly incorporated into sand soils to increase water holding capacity and nutrient retention. For example, incorporation of 5% peat by volume to sand profiles was found to increase the water storage capacity by up to 15% (Münster 1998).

Given the range of potential amendment options, methods of application and the effect of texture on the potential benefits associated with different amendments, this experiment was conducted to evaluate the benefits associated with the use of some of the more promising soil amendments.

Materials and Methods

Three different soil amendments were evaluated on each of the loamy sand, sandy clay loam and light-medium clay soils. Hydrocell was evaluated as an incorporated amendment while crumbed rubber was evaluated only as a top-dressing. Biosolids were evaluated as both incorporated and top-dressed amendments.

Commercially available Hydrocell flakes (Fytogreen Aust Pty Ltd, Mt Eliza, Victoria) between 6 and 13 mm in diameter were uniformly mixed at a rate of 15% by volume into each of the three soils. A commercially sourced biosolid product (Amgrow Sports Field Revitalizer) which consisted of 80% composted organics, 15% composted biosolids and 5% composted chicken manure was obtained from Envirogreen Pty Ltd (Stapylton, Queensland). This product (Table 13) was passed through a 1 mm sieve and uniformly mixed with each soil at a rate of 50% by volume. Five replications of the loamy sand, sandy clay loam and light-medium clay soils amended with either the Hydrocell or biosolid were loosely packed into PVC tubes (50 mm internal diameter and 70 mm height) and compacted to densities normally encountered under field conditions by applying either 8 N cm^{-2} , 12 N cm^{-2} or 1.05 N cm^{-2} , respectively.

Table 13. Nominal properties¹ of the Amgrow Sports Field Revitalizer

Bulk density	1.03 g cm ⁻³
Organic matter	13 % (by weight)
Infiltration rate	13 mm min ⁻¹
particles >20mm	<0.1 % (by weight)
particles 10-20mm	<0.1 % (by weight)
pH	7.3
Electrical conductivity	1.4 dS m ⁻¹
Permeability	20 cm hour ⁻¹

¹ Data provided by supplier

Loamy sand, sandy clay loam and light-medium clay soil cores which had not been amended were also compacted using the same force and energy treatments as above and used for the topdressing treatments. Two different types of crumbed rubber and two different rates (10 or 20 mm) of topdressing were evaluated. The crumbed rubber products evaluated were (i) Crown III (Reclaim Industries, WA) which has a particle size of 0-2 mm and (ii) bulk crumbed rubber with a particle size of 0-6 mm supplied by Chip Tyre Pty Ltd, Ipswich, Queensland. Biosolid topdressing treatments applied at either 10 or 20 mm thickness to a normally compacted sandy clay loam soil core were also evaluated. After topdressing, the cores were subjected to an additional compaction to simulate conditions under normal field traffic. The loamy sand and sandy clay loam cores were subjected to 3 J cm^{-2} while the clay soil was subjected to 1 J cm^{-2} . The lower level of compaction was applied to the clay soil as 3 J cm^{-2} was found to induce a high level of compaction which did not differentiate between treatment effects on this soil. A control treatment involving each of the unamended soils without topdressing but subjected to both the initial and subsequent compaction treatments was also constructed. Measurements on the soil and topdressed treatments included hardness, shear strength, penetration resistance as well as saturated hydraulic conductivity and water/air filled porosity at different suction levels. The effect of compaction on the bulk density and saturated hydraulic conductivity of the crumb rubber treatments was also investigated.

Results

Effect of incorporated amendments

Soil hardness

Incorporating biosolid at a rate of 50% by volume significantly reduced the bulk density of each soil with the bulk density decreasing with increasing clay content (Table 14). Incorporation of the Hydrocell flakes also produced a small, but significant, reduction in the bulk density of the loamy sand and sandy clay loam but had no significant effect on the bulk density of the clay soil. There was no significant difference in the penetration resistance measured using a handheld penetrometer on an unamended clay soil and a biosolid amended clay soil (Table 15). Penetration resistance was significantly reduced on this soil by the addition of Hydrocell.

Table 14. Effect of incorporating amendments on soil bulk density

Soil	Amendment	Average bulk density ^A (g cm ⁻³)	Change in bulk density (%)
Loamy sand	Unamended	1.57 ^c	
	50% biosolid	1.25 ^a	-20.4
	15% Hydrocell	1.55 ^b	-1.3
Sandy clay loam	Unamended	1.49 ^c	
	50% biosolid	1.11 ^a	-25.5
	15% Hydrocell	1.46 ^b	-2.0
Light-medium clay	Unamended	1.45 ^b	
	50% biosolid	1.07 ^a	-26.2
	15% Hydrocell	1.44 ^b	ns

^A $P < 0.05$ within column for individual soil type only

Table 15. Effect of incorporated amendments on penetration resistance of a clay profile as measured with a handheld penetrometer

Treatment	Penetration resistance (MPa)
Control – no amendment	3.96 ^b
50% biosolid	4.10 ^b
15% Hydrocell	2.68 ^a

Depth of impact penetration was primarily related to soil texture with the lowest penetration in the clay soil and highest in the loamy sand soil. For all treatments, the depth of penetration by the first drop impact on the loamy sand was greater than 60 mm. For the sandy clay loam, there was no significant difference in the depth of first or second drop penetration between unamended, biosolid or Hydrocell treatments (Fig. 28a). Biosolids and Hydrocell flakes incorporated into the light-medium clay typically increased the depth of penetration indicating that these treatments reduced soil hardness (Fig. 28b). However, while there were significant differences in hardness between the unamended soil and the Hydrocell treatment for each of the three drop impacts, the biosolid amended soil displayed a significant difference for only the second and third drop impact on the clay soil (Fig. 28).

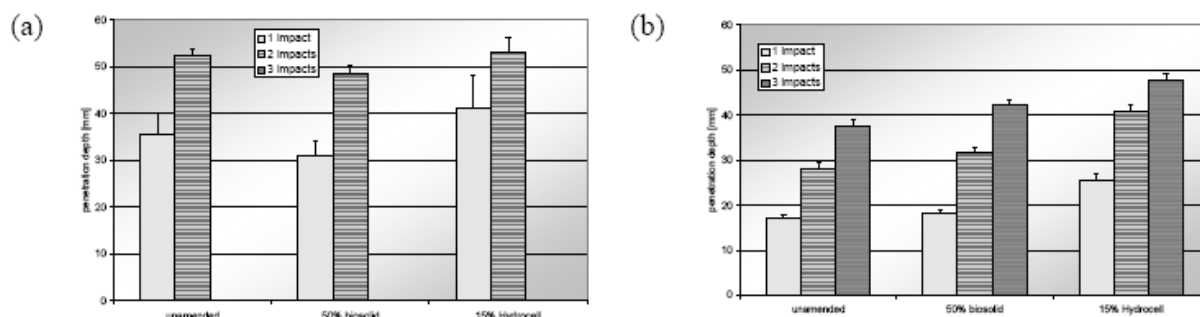


Figure 28. Effect of amendment incorporation on the depth of impact penetration for (a) sandy clay loam and (b) light-medium clay

The incorporation of biosolids or Hydrocell resulted in an increase in the amount of deformation produced by the application of 222 N cm^{-2} force (Fig. 29). Biosolids produced the largest change with an approximate 300% increase in deformation compared to the deformation measured in the unamended loamy sand and a 48% increase in deformation compared to the unamended clay. Rebound in the biosolid amended treatment was also greatly increased and ranged from 14% of the initial deformation in the clay soil to 24% of the initial deformation in the loamy sand. Incorporation of Hydrocell flakes increased deformation by approximately 71% in the loamy sand and by 42% in the clay soil. Amendment with Hydrocell had no effect on rebound for any of the soils.

Shear strength

The effect of amendment incorporation on shear strength was variable between the soils. Incorporation of Hydrocell had no significant effect on shear strength in the loamy sand and sandy clay loam but significantly reduced the shear strength of the light-medium clay (Fig. 30). The incorporation of biosolids did not produce any significant difference in shear strength compared to the unamended soil profile for any of the soil textures. However, there was a significant difference in shear identified between the Hydrocell amended profile and the biosolid amended profile for both the sandy clay loam and clay soils.

Soil-water retention and porosity

The incorporation of biosolids significantly increased the total porosity of each soil and moisture held at low suctions (Table 16). The increase in moisture retention was greatest in the loamy sand with the biosolid mix increasing moisture content from 12 % to more than 30% at 8 kPa with a relatively small decrease in air-filled porosity from 26 to 20%. While there was no increase in moisture holding capacity in the clay soil at 8 kPa due to the incorporation of the biosolids, air-filled porosity increased from 5 to 12%.

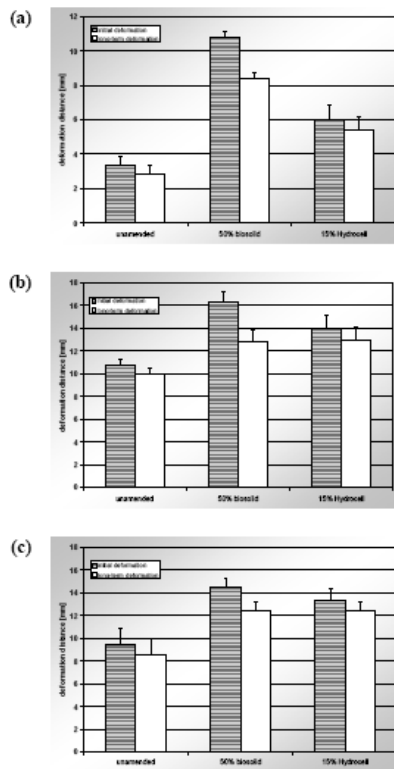


Figure 29. The effect of incorporated amendments on deformation of (a) loamy sand, (b) sandy clay loam and (c) light-medium clay

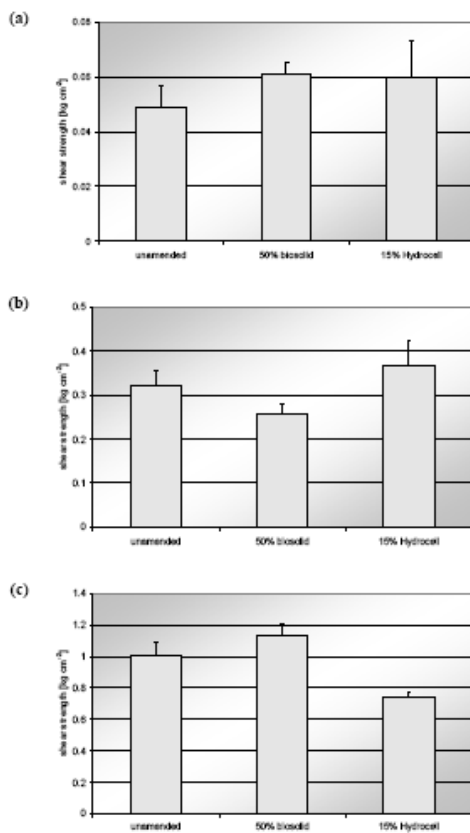


Figure 30. Effect of incorporated amendments on the shear strength of (a) loamy sand, (b) sandy clay loam and (c) light-medium clay

The Hydrocell incorporation produced a significant increase in total porosity in both the loamy sand and clay soils however, there was no difference in total porosity in the sandy clay loam. There was also no significant difference in the amount of water held at either 4, 8 or 33 kPa due to the incorporation of Hydrocell for any of the soil textures except for a small reduction noted in the loamy sand at 8 kPa (Table 16). The incorporation of Hydrocell significantly increased the air-filled porosity in the sandy clay loam and clay soils at both 4 and 8 kPa. However, there was no effect of Hydrocell incorporation on air-filled porosity in the loamy sand (except at 8 kPa) nor in any of the soils at 33 kPa.

Table 16. Effect of incorporated amendments on porosity and moisture content of (a) loamy sand, (b) sandy clay loam and (c) light-medium clay

Soil	Treatment	Total porosity	4 kPa		8 kPa		33 kPa*	
			Moisture content	Air-filled porosity	Moisture content	Air-filled porosity	Moisture content	Air-filled porosity
Loamy sand	Unamended	38.4 ^a	13.1 ^a	25.3 ^b	12.3 ^b	26.1 ^b	4.7 ^a	33.7 ^a
	50% biosolid	52.9 ^c	32.8 ^b	20.5 ^a	32.2 ^c	20.6 ^a	23.7 ^b	39.2 ^b
	15% Hydrocell	40.6 ^b	13.9 ^a	26.7 ^b	9.2 ^a	31.4 ^c	5.1 ^a	35.5 ^a
Sandy clay loam	Unamended	39.8 ^a	31.0 ^a	8.8 ^a	23.6 ^a	16.2 ^a	19.3 ^b	20.5 ^a
	50% biosolid	53.4 ^b	39.6 ^b	13.8 ^b	37.6 ^b	15.9 ^a	30.1 ^a	23.3 ^a
	15% Hydrocell	41.0 ^a	28.8 ^a	12.3 ^b	22.8 ^a	18.3 ^b	20.2 ^b	20.8 ^a
Light-medium clay	Unamended	46.7 ^a	45.2 ^a	1.6 ^a	42.1 ^a	4.6 ^a	40.2 ^a	6.5 ^a
	50% biosolid	56.0 ^c	54.2 ^b	5.8 ^c	48.3 ^b	11.7 ^c	38.7 ^a	15.6 ^b
	15% Hydrocell	49.9 ^b	46.2 ^a	3.6 ^b	41.4 ^a	8.5 ^b	43.0 ^a	6.8 ^a

^A $P < 0.05$ within column for individual soil type only

* average and statistic on 3 replications only

Hydraulic conductivity

The effect of incorporating amendments on saturated hydraulic conductivity appears to be heavily dependent on the soil texture. Incorporation of biosolids reduced the saturated hydraulic conductivity in both the loamy sand and sandy clay loam but significantly increased the saturated hydraulic conductivity in the light-medium clay (Fig. 31). Conversely, the addition of Hydrocell produced a significant reduction in saturated hydraulic conductivity for the loamy sand and light-medium clay soil but a significant increase in conductivity for the sand clay loam (Fig. 31).

Effect of applying topdressed amendments

Surface hardness

Topdressing with crumbed rubber typically protected the underlying soil from the applied compactive force (Table 17). The difference in bulk density between the treatments topdressed with crumbed rubber and the untreated soils was between 0.1 and 0.2 g cm⁻³. For the loamy sand, there was no difference in bulk density of the underlying soil irrespective of the crumb size or the depth of topdressing. However, for the sandy clay loam, topdressing with 20 mm of crumbed rubber was much more effective at preventing compaction of the underlying soil than using 10 mm depth. There was no difference between the effectiveness of the 0-2 and 0-6 mm size crumb on the sandy clay loam. There was no difference between either crumb size or the depth of crumbed rubber topdressing on the bulk density of the underlying light-medium clay. However, increasing thickness did reduce the size of the change in density due to compaction after topdressing (Table 18). Increasing the thickness of the crumbed rubber also reduced penetration resistance on the clay soil for the small crumb size (0-2 mm) but had no effect for the 0-6 mm crumb material (Table 18).

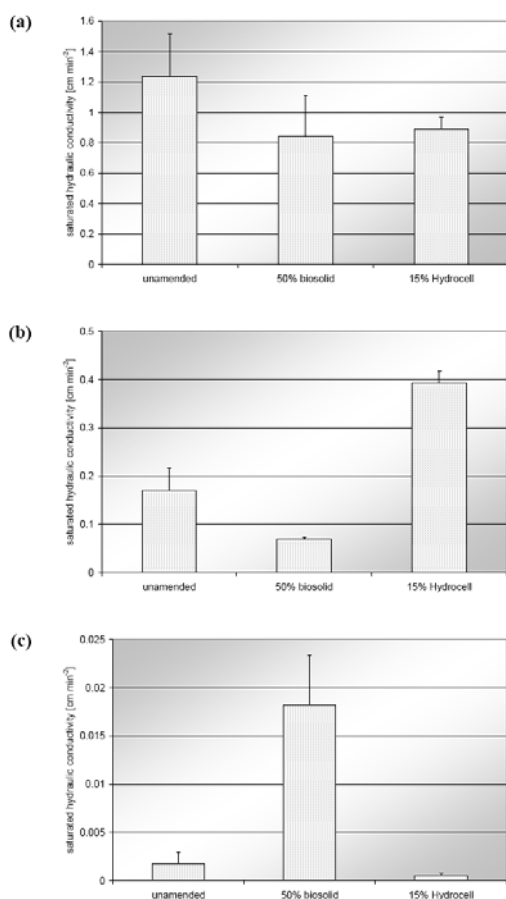


Figure 31. Effect of soil amendments on saturated hydraulic conductivity of (a) loamy sand, (b) sandy clay loam and (c) light-medium clay

Table 17. Effect of topdressing with crumbed rubber topdressing on the bulk density of the underlying soil

Soil	Size of crumbed rubber (mm)	Depth of topdressing (mm)	Average bulk density (g cm^{-3})	Increase in bulk density due to compaction after topdressing (%)
Loamy sand	no amendment	0	1.72 ^b	9.3 ^d
	0-2	10	1.66 ^a	3.8 ^a
	0-2	20	1.64 ^a	4.4 ^{ab}
	0-6	10	1.64 ^a	7.1 ^{bcd}
	0-6	20	1.64 ^a	6.1 ^{ac}
Sandy clay loam	no amendment	0	1.74 ^c	18.2 ^d
	0-2	10	1.70 ^b	15.2 ^c
	0-2	20	1.56 ^a	11.0 ^{ab}
	0-6	10	1.70 ^b	12.8 ^{bc}
	0-6	20	1.64 ^a	10.4 ^a
Light-medium clay	no amendment	0	1.57 ^b	9.9 ^d
	0-2	10	1.45 ^a	5.8 ^c
	0-2	20	1.48 ^{ab}	3.0 ^a
	0-6	10	1.50 ^{ab}	5.2 ^{bc}
	0-6	20	1.48 ^{ab}	3.5 ^{ab}

^A $P < 0.05$ within column for individual soil type only

Table 18. Effect of topdressing and on penetration resistance of a clay profile as measured with a handheld penetrometer

Product	Depth of topdressing (mm)	Penetration resistance (MPa)
Control	0	9.37 ^c
Crown III (0-2 mm)	10	8.25 ^{bc}
	20	6.87 ^a
Bulk (0-6 mm)	10	7.19 ^{ab}
	20	9.01 ^c

Application of the crumbed rubber as a topdressing also protected the underlying soil making it softer as measured using the impact drop penetrometer (Fig. 32). First drop impacts on the loamy sand typically penetrated the entire sample depth (max. 60 mm) so the effect of crumb rubber topdressing was unable to be established for this soil. However, increasing the depth of topdressing from 10 to 20 mm protected the underlying sandy clay loam from compaction and significantly increased the penetration depth measured. There was no significant difference in penetration depth due to the crumb size used in the topdressing. For the clay, there was no significant difference in depth of penetration due to either crumb size or depth of topdressing (Fig. 32b).

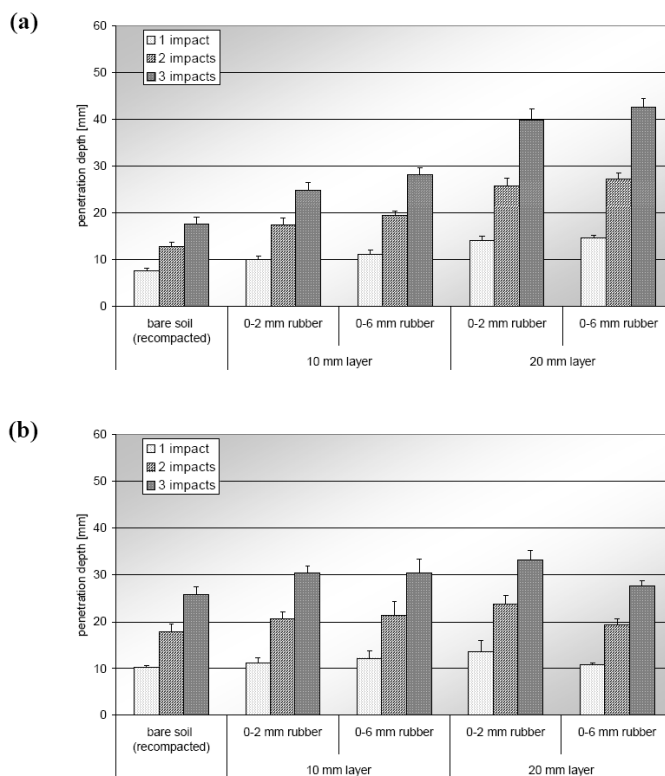


Figure 32. Effect of crumb rubber topdressing on impact drop penetrometer depth of underlying soil for (a) sandy clay loam and (b) light-medium clay (measured after removing the topdressing)

The effect of topdressing with crumbed rubber on the deformation characteristic of the underlying soil varies depending on the texture of the underlying soil, the crumb size used and the depth of topdressing applied (Fig. 33). On a loamy sand, only the application of 20 mm of the coarse (0-6 mm) crumb rubber had any significant effect on the deformation characteristic of the soil (Fig. 33a). However, as there is relatively little deformation experienced on sands in any case, and the absolute difference measured was small, it would be difficult to justify applying crumbed rubber topdressing to improve deformation characteristics on a sand. Applying a topdressing of crumb rubber to either the sandy clay loam or clay protected the underlying soil from compaction and increased the deformation characteristic (Fig. 33). For both soils, increasing the depth of topdressing significantly increased the level of protection achieved. In general, the coarser (0-6 mm) crumbed rubber was more effective at protecting the underlying surface but the differences were only significant for the 20 mm depth of topdressing applied to the clay soil.

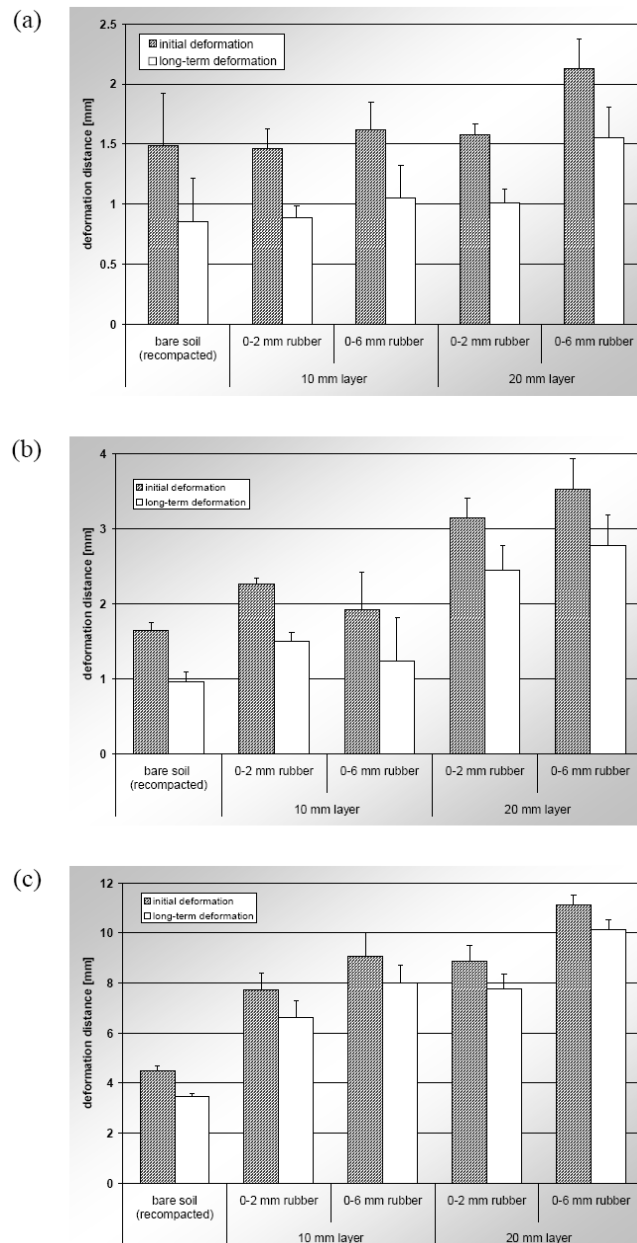


Figure 33. Effect of topdressing with crumbed rubber on soil surface deformation of the underlying (a) loamy sand, (b) sandy clay loam and (c) light-medium clay (measured after removing the topdressing)

Under field conditions, the players experience the characteristics of the topdressed material overlying the soil profile. Where surface deformation was measured with either biosolids or crumbed rubber topdressing in place, the topdressing was shown to provide significantly greater deformation than bare soil after compaction. (Fig. 34). In all cases, increasing the depth of topdressing significantly increased product effectiveness. However, the biosolid application provided only a relatively small improvement over the bare soil with the 20 mm biosolid application having higher hardness (i.e. less deformation) than the 10 mm crumbed rubber treatments. The coarser (0-6 mm) crumbed rubber treatments produced marginally higher deformation than the finer (0-2 mm) crumbed rubber at both the 10 and 20 mm depth of application. Only the application of a 20 mm thick layer of 0-6 mm crumbed rubber produced an initial deformation approaching that of the uncompacted bare soil.

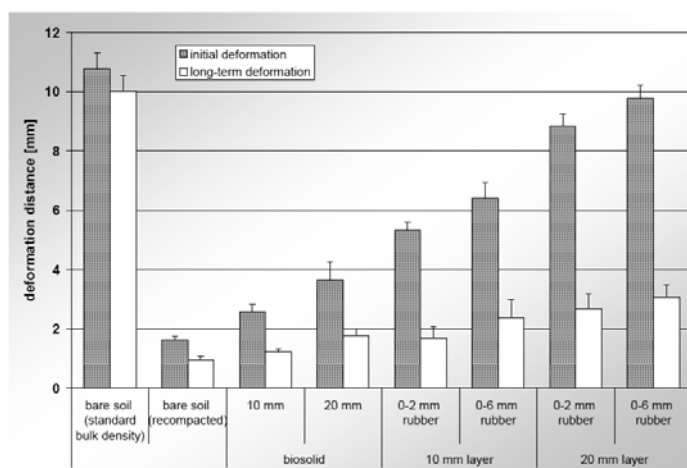


Figure 34. Effect of topdressing material on the deformation of a sandy clay loam (measured with topdressing in place)

Shear Strength

The application of crumbed rubber as a topdressing had no significant effect on the shear strength of the underlying soil surface after compaction. There was no differences between soil textures nor between crumbed rubber size or depth of application (Fig. 35).

Soil-water and porosity

The effect of topdressing with crumbed rubber on the porosity and soil-water properties of an already pre-compacted soil profile varies with soil texture and the size of the crumb rubber used (Table 19). In general, total porosity increased with increasing depth of crumbed rubber application and there was no significant difference due to the size of the crumbed rubber used. However, where 20 mm of crumbed rubber was applied, the use of the coarser (0-6 mm) crumbed rubber produced a significantly higher total porosity in the sandy clay loam but a lower total porosity in the clay soil compared with the use of the finer (0-2 mm) crumbed rubber. For a loamy sand, application of crumbed rubber as a topdressing typically reduced moisture holding capacity and increased the air-filled porosity at both 4 and 8 kPa. However, where 20 mm on the 0-6 mm crumbed rubber was applied, there was no significant reduction in moisture holding or change in air-filled porosity compacted to the bare soil. For the sandy clay loam and clay soils, application of crumbed rubber as a topdressing significantly increased both moisture holding at 4 kPa but had no effect at 8 kPa. For the sandy clay loam, air-filled porosity was increased at both 4 and 8 kPa. However, for the clay, the air-filled porosity at 4 kPa increased under the crumbed rubber but there was no effect at 8 kPa.

The high rates of saturated hydraulic conductivity measured after compaction ($27.4 - 82.4 \text{ cm min}^{-1}$) of the crumbed rubber (Table 20) confirms that even under compacted conditions crumbed rubber topdressing should not limit the rate of infiltration or internal drainage within the profile. Topdressing with crumbed rubber had no significant effect on the saturated hydraulic conductivity of an underlying loamy sand (Fig. 36a). However, for the sandy clay loam, hydraulic conductivity was significantly higher under topdressed treatments compared to the bare compacted treatment (Fig. 36b). For this soil, increasing depth of topdressing maintained higher hydraulic conductivity with no significant difference due to the size of the crumb rubber used. However, for the clay soil, topdressing with 0-2 mm crumb rubber resulted in significantly greater saturated hydraulic conductivities than using the 0-6 mm crumb size (Fig. 36c). There was no significant difference between the bare compacted clay and the clay topdressed at either 10 or 20 mm depth with the 0-6 mm crumbed rubber.

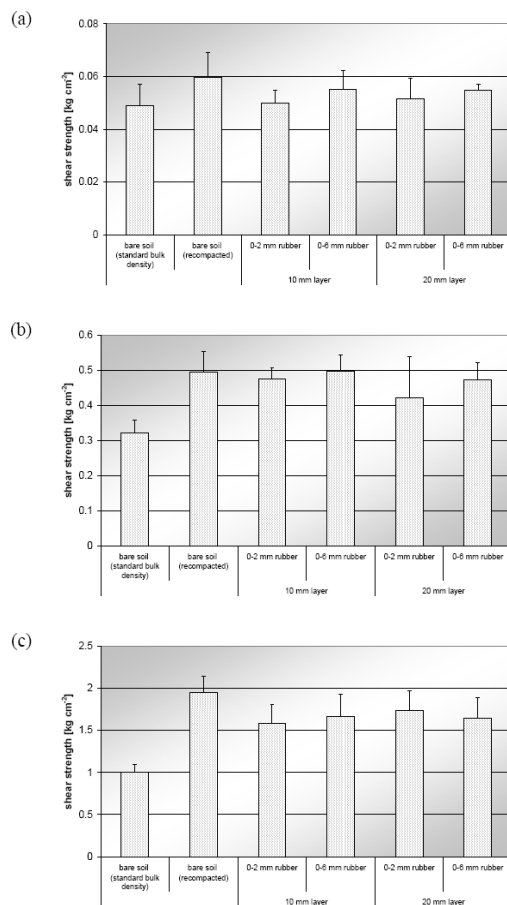


Figure 35. Effect of crumbed rubber topdressing on the shear strength of the underlying (a) loamy sand, (b) sandy clay loam and (c) light-medium clay (measured after removing the topdressing)

Table 19. Effect of topdressing with crumbed rubber on soil-water properties and porosity of underlying soil

Soil	Depth of topdressing (mm)	Size of crumbed rubber (mm)	Total porosity	4 kPa		8 kPa	
				Moisture content	Air-filled porosity	Moisture content	Air-filled porosity
Loamy sand	0	na	32.19 ^a	15.48 ^b	16.71 ^a	14.81 ^c	17.37 ^a
	10	0-2	32.68 ^a	11.66 ^a	21.02 ^b	11.00 ^a	21.68 ^{bc}
	10	0-6	32.06 ^a	11.25 ^a	20.81 ^b	10.76 ^a	21.30 ^{bc}
	20	0-2	35.30 ^b	11.98 ^a	23.32 ^c	11.35 ^{ab}	23.95 ^c
	20	0-6	34.47 ^b	14.95 ^b	19.52 ^{ab}	14.16 ^{bc}	20.31 ^{ab}
Sandy clay loam	0	na	29.18 ^a	27.63 ^a	1.55 ^a	24.70 ^a	4.48 ^a
	10	0-2	38.05 ^c	32.56 ^c	5.48 ^c	24.69 ^a	13.36 ^c
	10	0-6	38.04 ^c	32.42 ^{bc}	5.62 ^c	24.93 ^a	13.10 ^c
	20	0-2	34.54 ^b	31.17 ^b	3.37 ^b	23.91 ^a	10.64 ^b
	20	0-6	44.21 ^d	35.49 ^d	8.72 ^d	24.34 ^a	19.88 ^d
Light-medium clay	0	na	40.25 ^a	38.99 ^a	1.26 ^a	38.28 ^a	1.97 ^a
	10	0-2	42.27 ^{ab}	41.00 ^b	1.27 ^a	38.93 ^a	3.35 ^{bc}
	10	0-6	42.93 ^b	41.02 ^b	1.91 ^a	40.04 ^{ab}	2.89 ^{ab}
	20	0-2	45.64 ^c	44.66 ^c	0.98 ^a	41.33 ^b	4.31 ^c
	20	0-6	42.69 ^b	40.92 ^{ab}	1.76 ^a	39.13 ^a	3.56 ^{bc}

^A $P < 0.05$ within column for individual soil type only

Table 20. Effect of compaction on density and hydraulic conductivity of the Crown III (0-2 mm) and bulk (0-6 mm) crumbed rubber topdressing amendments

Product	Compaction	Bulk density (g cm ⁻³)	Saturated hydraulic conductivity (cm min ⁻¹)
Crown III (0-2 mm)	No compaction	0.44	75.4
	Compacted at 3 J cm ⁻²	0.58	27.4
Bulk (0-6 mm)	No compaction	0.48	152.8
	Compacted at 3 J cm ⁻²	0.61	82.4

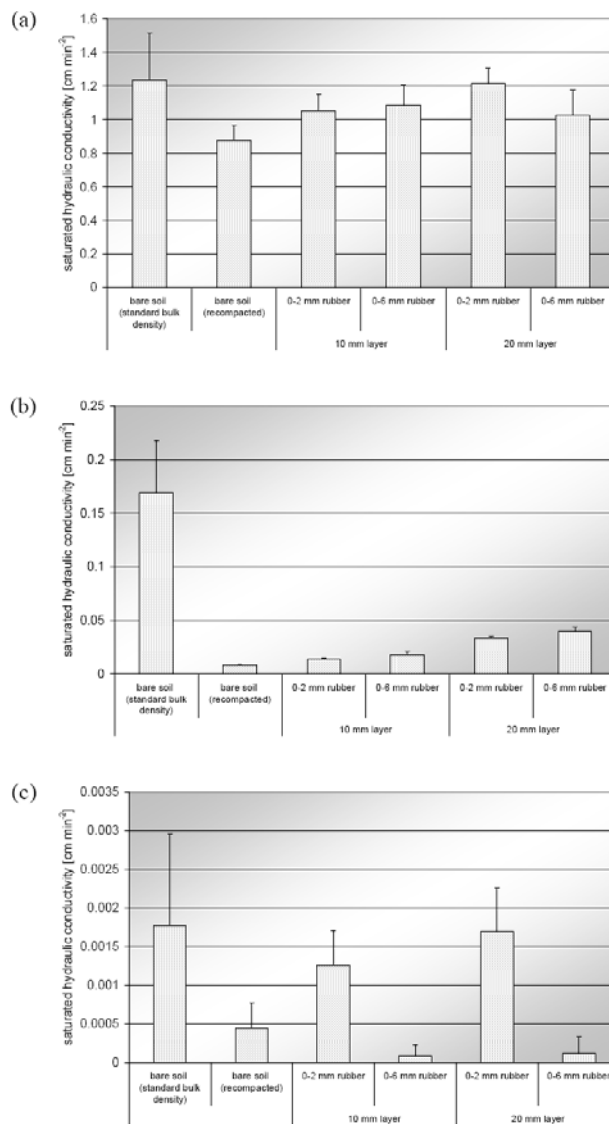


Figure 36. Effect of topdressing with crumb rubber on saturated hydraulic conductivity of underlying (a) loamy sand, (b) sandy clay loam and (c) light-medium clay

Discussion

Incorporation of Hydrocell flakes

The incorporation of the Hydrocell flakes produced no significant change in the water holding capacity for any of the soils. This is contrary to the claims of the supplier and may be due to the low internal strength of the flakes which appeared to compress under the compactive force applied. This is consistent with observations of Hydrocell injected into the non-irrigated Morningside training field and suggests that while Hydrocell may increase moisture holding under uncompacted conditions (eg. loose soil in pots), it would not be expected to increase soil moisture holding capacity under normal compactive conditions experienced on sports fields. However, the incorporation of the Hydrocell produced a significant decrease in the penetration resistance (Table 15) and increase in the impact penetration depth (Fig. 28) while creating only a marginal decrease in bulk density (Table 14). This suggests that the Hydrocell flakes may be acting like a lubricant in reduce the resistance to penetration. This may provide some benefit to assist in root penetration under field conditions. However, it seems likely that as the flakes dry out or age that the lubricant effect will deteriorate. Hence, further research would need to be conducted to evaluate the magnitude, longevity and potential agronomic benefit of this effect.

Use of biosolids

The incorporation of biosolids had no significant effect on penetration resistance or shear strength for any of the soils but significantly reduced the hardness of the surface as measured by deformation. The increase in deformation due to biosolids incorporation was greatest in lighter textured soils with significant increases also in the magnitude of rebound (difference between initial and long term deformation). This suggests that biosolids amended soils (particularly loamy sands) would be expected to feel softer and more “springy” under foot. Hence, incorporation of the biosolids should not adversely affect playability on sporting fields at the rate evaluated and may reduce injury rates.

The bulk density of the biosolid amended soil was reduced in proportion to the lower density of the applied organic material. However, incorporation of biosolids had a significant beneficial effect on the total porosity and moisture holding capacity irrespective of soil texture. The readily available water capacity between 8 and 33 kPa increased by approximately 1% in the loamy sand, 3% in the sandy clay loam and 7% in the clay. Incorporating biosolids into the clay soil greatly increased the saturated hydraulic conductivity and the air-filled porosity under potentially waterlogged conditions (e.g. 4 kPa). However, the benefits were less obvious in the lighter textured soils with a slight reduction in hydraulic conductivity for both the loamy sand and sandy clay loam. These results suggest that incorporated biosolids should improve root zone conditions on sporting fields, particularly for clay based profiles.

The evaluation of biosolids as a topdressing material indicated that this product provides only a limited potential to reduce structural degradation of the underlying soil. The porosity and soil-water benefits noted above for incorporated biosolids would not be expected to occur where the product is topdressed.

It should also be noted that there was no evaluation of the nutritional benefits or degradation rates of the biosolid material used in this study. However, degradation would be expected to increase with increasing temperature, moisture and the presence of appropriate microbes. Hence, further research could be considered to evaluate the magnitude and longevity of agronomic benefits associated with incorporating biosolids under normal field conditions.

Topdressing with crumbed rubber

The application of crumbed rubber topdressing was found to substantially protect the underlying soil from subsequent compactive forces and improve agronomic conditions within the root zone. Penetration resistance of the soil underlying the topdressing was lower (e.g. Table 18) and soil softer as evidenced by larger depths of impact penetration (Fig. 32). In general, the greater the depth of crumbed rubber applied to the surface the larger the benefits measured. The soil structural properties of total porosity, moisture holding and air-filled porosity were all significantly greater under crumbed rubber topdressing compared to a bare soil control treatment (Table 19). There was typically no difference in the agronomic or playability benefits observed between the 0-2 mm and 0-6 mm crumbed rubber products. However, the saturated hydraulic conductivity of the underlying clay soil was significantly greater under the 0-2 mm crumbed rubber compared to the 0-6 mm product (Fig. 36c).

Deformation and rebound of the crumbed rubber surface increased with depth of topdressing (Fig. 34). Topdressing with 20 mm of crumbed rubber was found to produce deformation values between 9-10 mm with rebound of approximately 7 mm (Fig. 34). While these values were measured with an underlying sandy clay loam soil, they would not be expected to vary greatly with variations in underlying soil texture. Hence, topdressing with 20 mm of crumbed rubber would be expected to provide a softer surface than typically experienced on either sand based profiles or dry, compacted clay based profiles. Hence, crumbed rubber could be expected to reduce the risk of impact injuries experienced under bare soil conditions and may also be important in regard to watering of sporting fields during the playing season. With crumb rubber as a topdressing, there should be a reduced need to water prior to playing in an effort to reduce surface hardness. Removing or reducing this watering requirement would reduce the risk of compacting the underlying soil and maintain better growing conditions for the turf.

Conclusions

The effect on soil physical properties of incorporating or topdressing various different amendment products has been evaluated. The incorporation of Hydrocell flakes into the soil profile was not found to provide agronomic or playability improvements under the compacted conditions likely to be experienced on sporting fields. No further evaluations are recommended for this product. However, the incorporation of biosolids into the soil profile does appear to provide some agronomic and playability benefits. Agronomic benefits associated with improved soil-water capacity and internal drainage appear to be greatest on clay based profiles. It is recommended that further research into the longevity and magnitude of benefits associated with the incorporation of biosolids be conducted under field conditions.

Topdressing with crumbed rubber was found to be an effective strategy to protect the underlying soil structure from compactive forces likely to be experienced in the field. Biosolid topdressing produced only marginal protective benefits on the underlying soil. Crumbed rubber deformation measurements suggest that it will typically provide a softer surface with greater rebound potential than existing soil based surfaces. These characteristics would be expected to reduce player injury risk. Hence, it is recommended that the agronomic and playability benefits of topdressing with crumbed rubber be evaluated under playing conditions.

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Soil profile improvement (field studies)

Introduction

In our project laboratory study, (Eberhard and Raine 2004) found crumbed rubber topdressing to be an effective strategy for protecting the underlying soil structure from compactive forces, and recommended their field evaluation. A proprietary process of topdressing crumb rubber to enhance and protect sports surfaces is promoted in Australia by a commercial supplier (Reclaim Industries 2006).

In the laboratory studies, (Eberhard and Raine 2004) found incorporation of organic bio-solids improved soil water capacity and internal drainage in clay profiles, and reduced surface hardness in all soil types. Topdressing with these organic materials was not as effective.

In an initial 'look-see' at crumb rubber topdressing in 2004, we applied two different recycled rubber products in the central corridor on the 50 m circle. The materials readily settled into the turf crowns, and were relatively undetectable to the casual observer. In this initial demonstration we found the material could be topdressed with no adverse impact on turf growth, ground performance, and with no comments from ground users. Applying a 20 mm depth of rubber lasted longer than a 10 mm application. Crumb rubber reduced Clegg reading by around 10 G_{max} (data not presented), and improved turf growth in late autumn and early spring. In this initial test, crumb rubber applied to goal squares at Morningside became scattered through play, due to insufficient initial turf growth to bind the product.

We ascertained that the most obvious initial use for the crumb rubber is trying to retain turf cover in the goal squares as long as possible into the season. In 2005, demonstrations were installed on the southern goal squares at two grounds (Mt Gravatt and Redlands), at commercial scales and application methods, and were monitored for impacts on general ground performance and impacts on turf persistence.

Crumb rubber reduced ground hardness by 10 G_{max} , although measurements for both treated and untreated goal squares ranged from 80-110 G_{max} (good-acceptable). In these experiments, the biggest impact of crumb rubber was on turf cover retention. Each of two demonstration grounds had an initial 90% turf coverage in goal squares when the rubber was installed (April). By June, turf coverage on rubber-treated goal squares fell to 65%, whereas untreated goal squares were 36% (Mt Gravatt) and 54% (Redlands). By August, turf coverage on treated goal squares was still 50%. On untreated squares turf coverage had disappeared at Mt Gravatt (6%), and fallen to 33% at Redlands.

Although rubber installation was encouraging, the main problems remaining were:

- Goal squares centres and rear lines were still denuded;
- Much retained turf coverage was undesirable species (e.g. *Eragrostis* sp.)
- Once turf cover fell below a critical level (60-70%?) rubber was easily displaced by play, with protective benefits lost.

Based on the recommendations from the laboratory findings, and the initial crumb rubber evaluations, we decided to conduct detailed field studies in 2006. We carried out replicated field evaluations of crumb rubber and sand topdressing, and organic compost incorporation, on playing surface condition and wear resilience in goal squares of two AFLQ sports fields; the major findings of which are detailed here.

Methodology

In February 2006, we renovated goal squares (11 m * 8 m) at northern and southern ends of Morningside and Sherwood sports fields in Brisbane. We removed any existing grass cover, and divided the goal squares into a patchwork of 8 sections, each 2.75 m by 4 m (Fig. 37). Half the sections had 5 cm of topsoil removed, with 0.6 m³ of specially prepared compost (28% organic carbon, 1.4% Total N) added, and the new profile mixed by rotary hoe to a

depth of 10 cm. The non-composted sections were just rotary hoed to 10 cm. We added 15 kg complete fertiliser (Dynamic Lifter Lawn Food[®]) to each goal square before rotary hoeing, to try and eliminate nutrient effects. We laid Tif Sport[®] sod as our renovation turf cover, and rolled it during turf establishment over the next few weeks. In early March 2006, on half the sections, we hand-spread a 10 mm layer of graded top-dressing sand, and on the other half, a 10 mm layer of Crown III[®] crumbed rubber (0-2 mm). We repeated these topdressings a fortnight later.

At the end of all this preparation we had goal squares with sections having:

- No compost underlay, and sand top-dressing
- Compost underlay, and sand top dressing
- No compost underlay, and rubber topdressing
- Compost underlay, and rubber topdressing

These treatments were replicated twice in each goal square (Fig. 37)

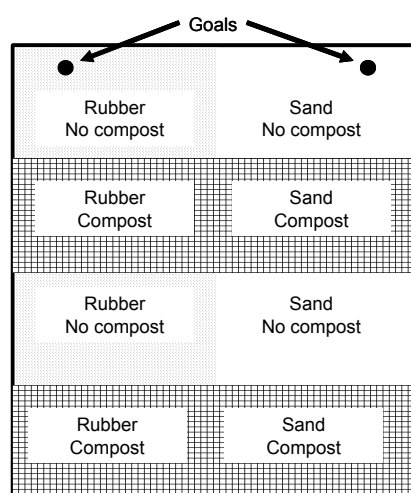


Figure 37. Layout of compost and crumb rubber treatments within AFL goal squares.

From April to September 2006, we measured surface hardness, moisture content, grass coverage and grass height, every month during the AFLQ playing season. We took 5 measurements of each parameter in each of the 8 plots within each goal square. We measured hardness using a 2.25 kg Clegg Hammer[®], recording the reading on the 4th drop. We measured volumetric moisture content of the immediate turf surface using an MP406[®] moisture probe, inserted 6 cm into the turf surface. Turf coverage and species composition was estimated within a 50 cm * 50 cm quadrat, while turf height was calculated using a floating disc.

Results

Ground hardness

Morningside oval is inherently softer than Sherwood oval, due to soil type differences, better irrigation capacity, and an earlier start to the renovation cycle. In both Morningside goal squares, hardness averaged an excellent 86 G_{max} , only fluctuating from 60-100 G_{max} during the season. Compost-treated areas were consistently 10 G_{max} softer than the untreated areas, whilst the crumb rubber had minimal effect on this oval.

At Sherwood oval, softness benefits from compost incorporation were more marked. In both northern and southern goal squares there was a hardness peak in mid-May, followed by a return to April values in early June. These hardness levels then remained consistent until slight increases in mid-September (Fig. 38). The southern goal was consistently harder than the northern goal. It also suffered a dramatic spike in hardness readings in mid-May, associated with a dramatic reduction in surface moisture content (see Fig. 39).

On all occasions, the compost-treated sections were significantly softer than untreated sections. The benefit averaged 20 G_{\max} at the northern goal, but was worth 45 G_{\max} in the harder southern goal, and a very important 77 G_{\max} during the mid-May peak hardness. On average, crumb rubber only reduced hardness by 6 G_{\max} in the Sherwood goals

We analysed data across all sites and times where hardness exceeded 110 G_{\max} (only occurred at Sherwood). On those occasions, compost incorporation resulted in sections 40 G_{\max} softer than the comparable soil only areas; whereas substituting rubber topdressing reduced hardness by 17 G_{\max} compared to sand areas.

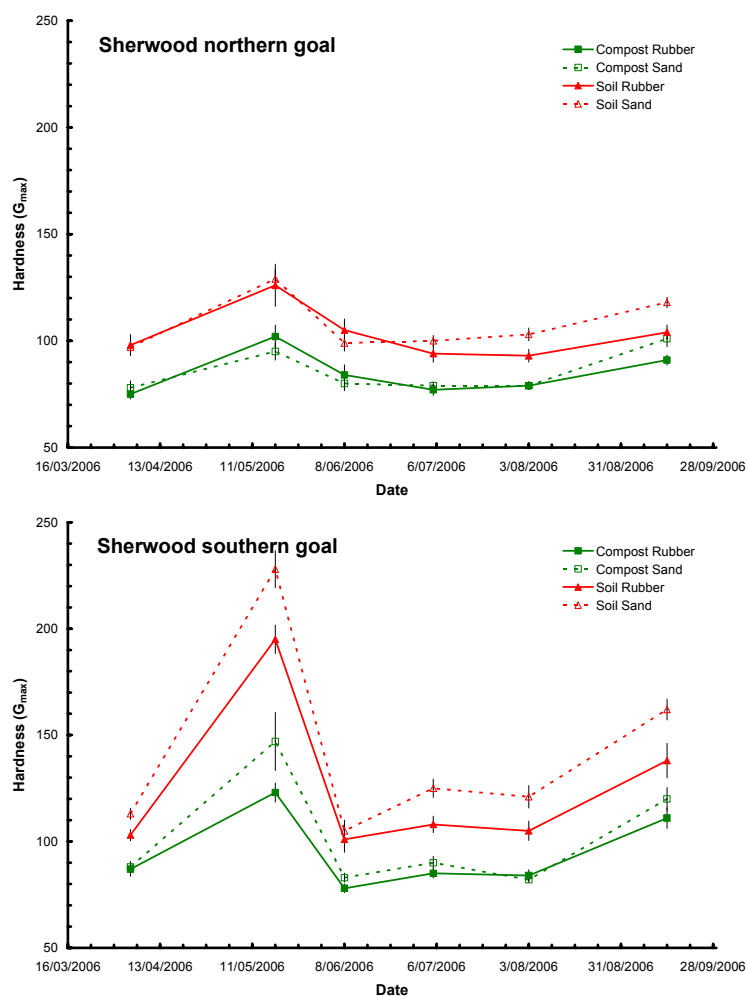


Figure 38. Compost underlays and crumb rubber topdressing reduce hardness in Sherwood goal squares. Vertical lines show standard errors of the respective means.

Surface soil moisture

At Morningside, effective irrigation meant surface moisture levels were relatively consistent across the season (example in Fig. 39). The situation was similar in the northern Sherwood goal square, particularly from June onward. However, an irrigation failure in the southern Sherwood goal at Sherwood meant soils moisture was severely depleted by the mid-May assessment (Fig. 39).

Across all goal squares, areas with compost incorporated had significantly more surface moisture (average 4.2% greater) than untreated sections. Areas top-dressed with rubber were on average 1.4% drier than sand-treated sections, however this effect was less consistent than the compost effect, and only consistently significant on the northern Sherwood goal square.

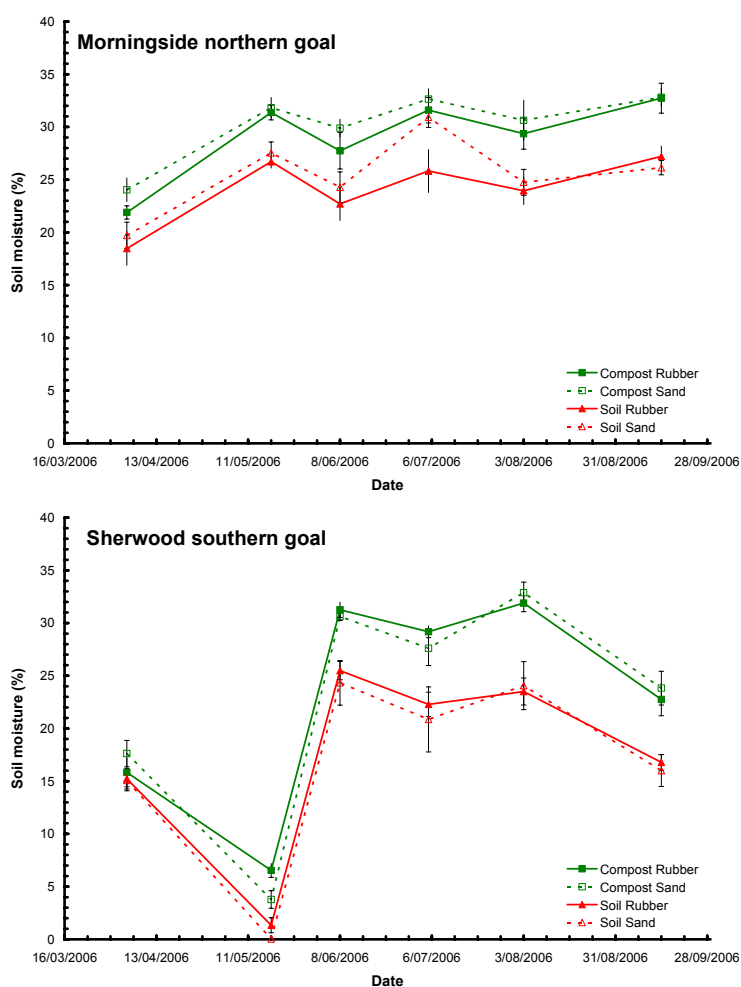


Figure 39. Surface soil moisture content in sample Morningside and Sherwood goal squares. Vertical lines show standard errors of the respective means.

Turf height

There was a progressive reduction in turf height from autumn into winter (Fig. 40), with a much more gradual decline continuing through to the end of the season. The decline in height was a function of reduced mowing heights during winter, and also loss of overall turf cover (and hence more bare areas with zero turf height readings, bringing down the average). There were no significant effects of either topdressing material or compost incorporation on turf height.

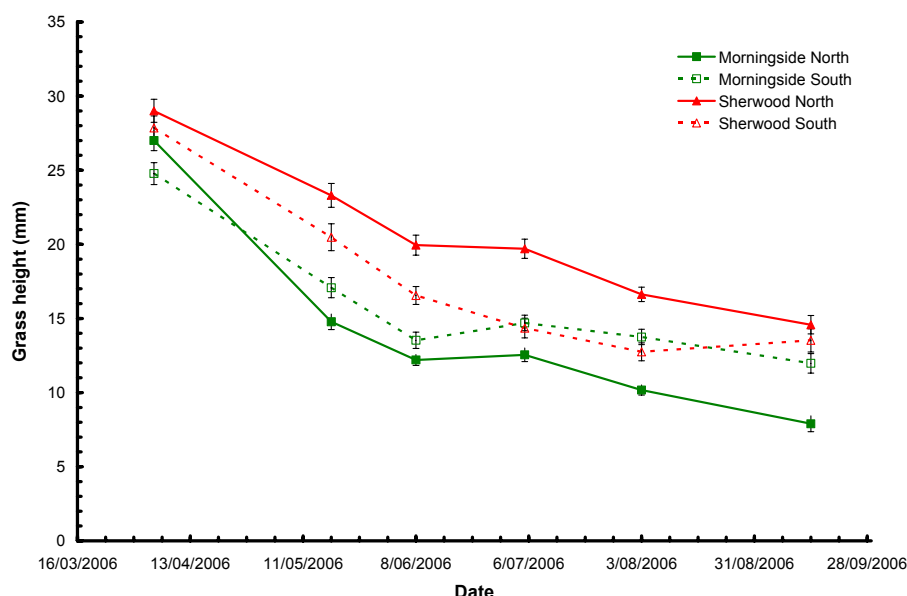


Figure 40. Average turf height declines during the football season. Vertical lines show standard errors of the respective means.

Turf cover

The turf coverage story appeared to be very site dependent, due to a combination of agronomic, environmental and ground usage factors. Turf coverage was also a very variable measure, resulting in substantial differences within treatments.

The southern Morningside goal seemed to give a 'classic' seasonal turf deterioration and recovery picture. Topdressing with rubber retained turf cover at around 80% into June, with a decline to around 50% in late winter, and recovery to 70% by the end of the season (Fig. 41). The sand top-dressed areas declined more quickly early in the season, dropped to 30% mid-winter, and improved much more slowly by the end of the season. There was no effect of compost incorporation on turf persistence or recovery.

At the northern Morningside goal, rubber was also beneficial early in the season; however there was a much more rapid decline in cover compared to the southern counterpart (Fig. 41). There was also a benefit from compost compared to soil underlay early. During winter however, there was a severe loss in turf cover that no treatment prevented. Similarly, recovery at the end of the season was very slow, with no treatment significantly advantaged.

The northern Sherwood goal behaved similarly to its southern Morningside counterpart, although the benefit of the rubber was less marked, and there was some compost benefit as well. Because of the irrigation issue, there was a marked initial deterioration of turf cover in the southern Sherwood goal (Fig. 42), with least deterioration in areas treated with rubber top dressing and/or compost underlay. Levels then persisted through winter, and recovered toward the end of the season.

Across all the sites, the crumb rubber topdressing improved turf coverage by 13% during autumn / early winter, with less benefit later into the season. The benefit from compost incorporation was around half that value.

It is apparent that there is a critical level of turf cover, below which there is insufficient grass to hold the top-dressed rubber in place. We analysed the data and compared rubber and sand sections where the turf cover on the rubber treated sections was continually greater than a selected critical value. We thus discounted comparisons where there was likely to be little rubber remaining on the 'rubber-treated' plots. We did not use the April data (minimal time for turf wear to take place). Using critical values of 45% turf cover, up to 70% turf cover, as the amounts required to hold the rubber in place, did not change the rubber benefit; i.e. 13-15% better turf cover compared to the sand standard.

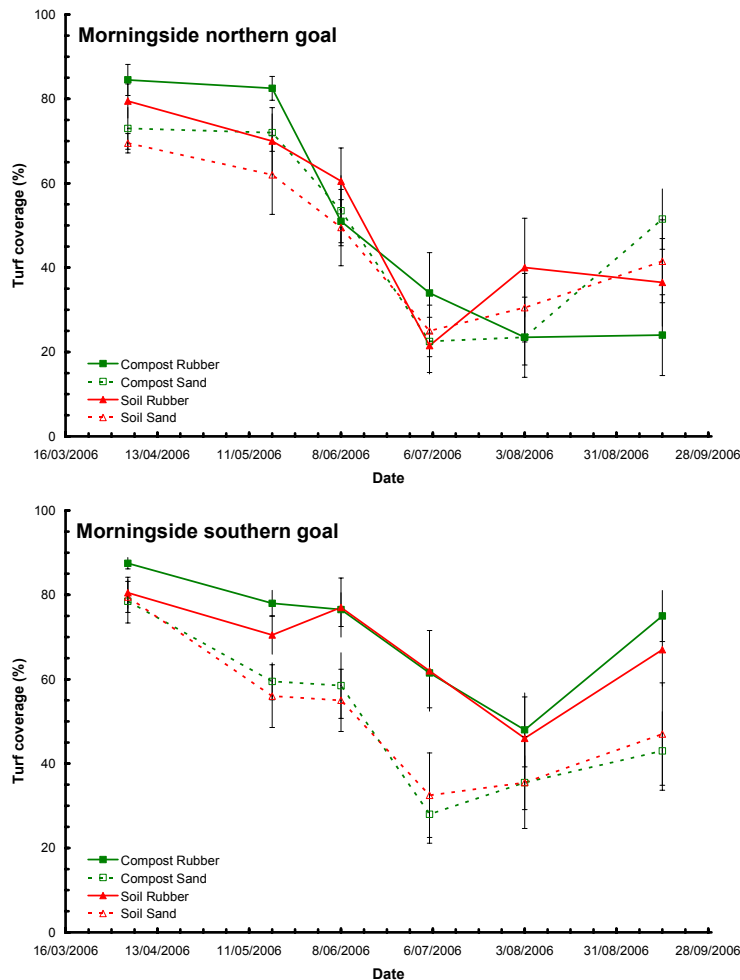


Figure 41. Crumb rubber top-dressing and compost underlays have variable effects on turf cover persistence through a football season. Vertical lines show standard errors of the respective means.

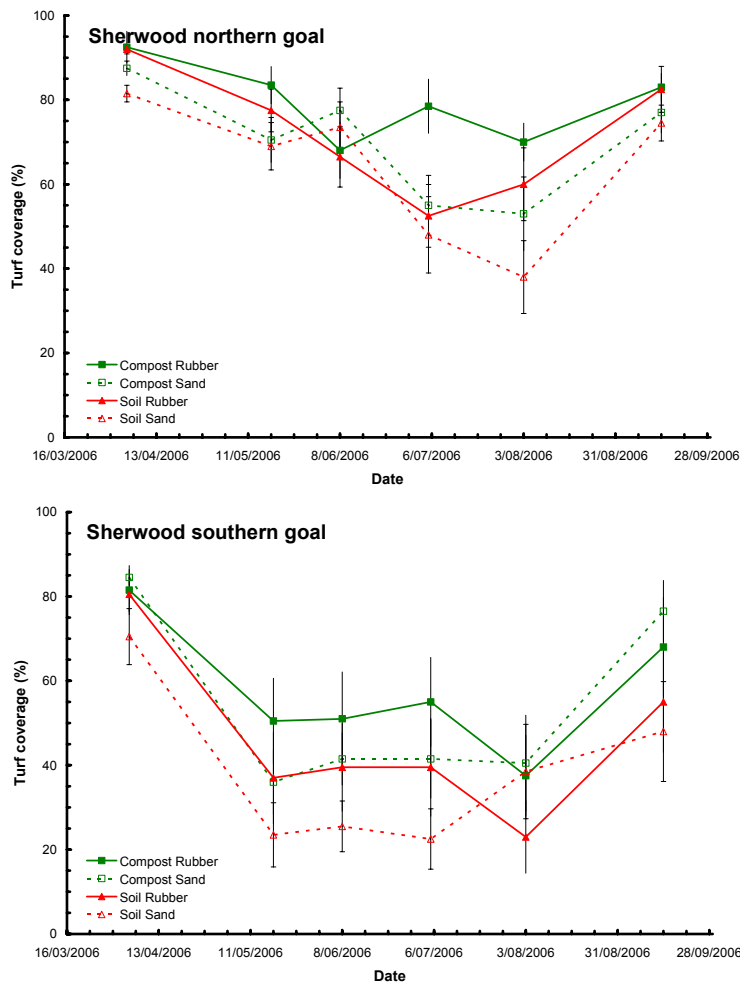


Figure 42. Crumb rubber top-dressing and compost underlays have variable effects on turf cover persistence through a football season. Vertical lines show standard errors of the respective means.

Discussion

Compost incorporation prior to laying turf was more effective at reducing surface hardness (as measured using the standard Clegg Hammer[®] process) than was crumb rubber. Other project research indicates that hardness levels less than 130 G_{max} are currently acceptable for community, sub-elite level Australian Rules football; values of 160-180 G_{max} are of significant concern, and values of 200 G_{max} or more result in ground closures. Because the relative benefits of compost underlay (and to a lesser extent crumb rubber) increase with hardness, these treatments become more important in moderate-severe hardness situations. For example, during the dry surface conditions of mid-May, at the southern Sherwood goal composting reduced hardness from 230 G_{max} down to 150 G_{max} , alleviating a potentially dangerous situation. The crumb rubber had a corresponding, but smaller benefit. These results confirm the project laboratory studies (Eberhard and Raine 2004).

The compost underlay also provided increased surface moisture holding capacity (a factor potentially contributing to softer surface). Although only small on average (around 5% volumetric), this moisture retention increase may be of significance for sites with restricted irrigation (due to infrastructure or legal constraints), and also during dry weather and droughts, such as we are currently experiencing. It does not appear that the crumb rubber treatment offered any moisture retention benefits on these soils.

The use of incorporated compost underlays and crumb rubber topdressing to improve turf resilience was much less clear-cut. Overall, compost underlay seemed to have only a minor benefit, potentially more important at Sherwood (due to improvement in moisture retention?) At the southern Morningside goal, the rubber topdressing was clearly advantageous, allowing better persistence of turf cover into winter, and rapid late season recovery. The northern Morningside goal cover deteriorated rapidly in June/July, irrespective of treatment. This was probably due to more use than the southern goal, e.g. during training, or for junior half-field games. At the Sherwood southern goal, the May irrigation failure crashed out the cover, although the rubber top-dressed section was better covered (but still below par). At the northern Sherwood goal, rubber topdressing retained cover in the presence of a compost underlay.

Although both top-dressed rubber and compost improved cover retention, the only occasion turf cover was kept above 70% for the whole season was the rubber/compost treatment in the northern Sherwood goal squares. At the three other sites, turf cover in this high input treatment declined to values of 50%, 40% and 25% in later winter.

A practical issue became apparent when we returned to ascertain turf recovery at the end of 2006. Ground scarification had removed almost all the crumb rubber from the goal squares, meaning that there was unlikely to be any persistent benefit. Secondly, the turf had regrown to completely cover the goal squares. Although we did not make any measurements, there were no visible treatment effects from either compost or rubber. The only areas that remained worn/bare were the umpire tracks behind the goals.

An Australian Rules goal square including surrounds is roughly 100 m². The materials costs to renovate this area were approximately \$300 for new turf, \$175 (+ delivery) for compost, and \$480 for crumb rubber (or \$100 for sand). Apart from these costs, additional renovation inputs are the costs for old turf removal, compost spreading and incorporation, turf laying, rubber spreading and surface levelling.

From our studies, for renovation of high wear areas, we would recommend the incorporation of compost materials as an underlay, as it provides a buffer against excessive hardness in adverse moisture or compaction conditions. Although we did not investigate the impact of slumpage as the organic matter decomposes, we suggest this could be addressed by topdressing with similar material and aeration. The crumb rubber may provide some benefit in turf retention during the early football season, and on the margins of the high wear areas. It will not prevent turf deterioration due to overuse, or bad agronomic practices. Ground managers will need to evaluate cost/benefits of crumb rubber topdressing, versus selective returfing and intense goal square management.

From our studies it is obvious that agronomic issues (particularly irrigation and aeration), and use management (training, casual use) have a greater impact on turf persistence than either compost or crumb rubber amendments. Priorities for high wear areas should include where possible:

- Specific irrigation to allow targeted watering of these areas, to promote rapid turf recovery;
- Attention to regularly aerating, to reduce hardness and promote rapid turf recovery;
- Management to minimise non-game use of high wear areas – obvious techniques are temporary or moveable goals;

There is currently work looking at wear tolerance of different grass species, and recovery from different wear intensity/frequency combinations. This will be a significant contribution to improved management of these key areas on sports fields.

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Industry capacity building

Introduction

The project intended to provide adult learning and capacity building opportunities throughout various industry sectors (curators, field managers and sports administrators, service providers and research providers), through formal, informal and 'hands-on' engagement. There were specific components for project team and collaborator learning; development of training packages and protocols; specific industry training and communication activities, and awareness and information provision to the general public. The industry and general public training and communication activities are detailed within the chapter on Technology Transfer, and are therefore not repeated here.

Team capacity building

Team skills audit

Consultant Neil Power conducted a team (Craig Henderson, Neil Power, Peter Broomhall, Nick Jeffrey, Larry Cooper, Stephen Raine and Kaylene Bransgrove) skills audit, and compared the outcome with National Accreditation Standards. He indicated the team had an excellent spread of R&D project management skills, knowledge of irrigation and soil management, industry experience in turf and sports field construction and management. Opportunities for increasing individual team members' skills in core areas such as irrigation performance assessment/scheduling and basic soil science were identified, and a team capacity building program prepared.

Additional formal team training

Four key members of the project team (Nick Jeffrey, Larry Cooper, Kaylene Bransgrove, Julie Stanton) completed a Train the Trainer program in the first 12 months of the project.

Kaylene Bransgrove, Larry Cooper, Angelina Gilbert, Nick Jeffrey and Neil Power successfully completed Irrigation Auditor Certification courses.

Angelina Gilbert completed a Soil and Irrigation update course in May 2004.

Neil Power developed a package for submitting a Recognition of Prior Learning Diploma for Nick Jeffrey; however this process was not completed by the time of publishing this final report.

Engagement training

Throughout the project, we ensured project team members developed skills and knowledge through active project and industry engagement. Project staff increased their project and organisational skills by being made responsible for key project components. For example, Nick Jeffrey was responsible for conducting and reporting on all the ground amelioration activities; Larry Cooper for the ground assessment and benchmarking; Kaylene Bransgrove for the literature review and irrigation auditing; Craig Henderson for irrigation programming research, field amendment studies, and general project management and reporting; and Neil Power for the development of the training program and training resource materials. Project team members picked up core skills in researching, applying and reporting on the knowledge and techniques required for their particular components.

All project team members were required to present their relevant project components at the industry activities outlined in the Technology Transfer chapter. This certainly involved several team members being outside their comfort zones, presenting to large audiences (often more than 100 people), commonly with international and national industry experts, at local, regional and international events. Not only did this help team members gain confidence in themselves and their work, it also helped build the project profile.

General industry capacity building

Curator skills audit

Between October 2003, and March 2004, Neil Power surveyed three groups of community sports field curators, to determine the training requirements of the sports field development maintenance sector (Power 2003).

School groundskeepers

Around 190 school groundskeepers (facilities officers) were interviewed in 12 centres from Cairns to the Gold Coast, with around 165 responding to a training requirements questionnaire. In addition another 10 groundskeepers provided personal responses. The centres included Gold Coast, Brisbane South, Brisbane North, Toowoomba, Nambour, Hervey Bay, Rockhampton, Emerald, Mackay, Charters Towers, Townsville and Cairns.

At the time, there were around 1000 (full time equivalent) school facilities officers employed across 1290 Queensland State Schools servicing the sports grounds needs of 443,000 school children in Queensland. In addition there were a further 455 private schools with total enrolments in excess of 48,000 students, most of which provide sports field facilities. This sample represented between 10% and 15% of the estimated combined school groundskeeper population.

Less than 15% had any horticultural qualifications. These groundskeepers had an average of between 4 to 5 years of sports field maintenance experience, with no specific training in sports field maintenance. None had any specific sports field training in the last 8 years. The last known seminar specifically for community level sports fields was held in 1996 at Bond University under the patronage of the Royal Australian Institute of Parks and Recreation (now Parks and Leisure Australia). Around 30 school sports fields from Kuranda to Southport were also inspected as physical verification of issues.

Of more than 200 school groundskeepers less than 20% aerated, less than 25% undertook soil tests, less than 50% fertilised and no one knew about water use efficiency measures. Mowing heights were regionally based, such that Gold Coast and South Brisbane groundskeepers mowed in the 20 mm to 50 mm (greenkeeper style) range, North Brisbane groundskeepers mowed the same species in the 40 mm to 60 mm range, while Tropical North Queensland groundskeepers mowed a range of species (including green couch) in the 50 to 100 mm range. None had an appreciation of their grasses rooting depth capability.

Less than 30% belonged to any groundskeepers groups. Formal groundskeeper groups existed on the Gold Coast, Toowoomba and Brisbane North. They met around 4 times a year at supplier sponsored events. In addition to State School specific employment conditions, most new information was provided by commercial industry suppliers of machinery, irrigation equipment, fertilisers and chemicals. The only user-sponsored information appeared to that gleaned from the networking opportunities.

The responses to the questionnaire indicated the strongest desire to receive further training in soils (75%), irrigation (67%), nutrition and sports turf management (63%), at the trade level.

Brisbane City Council leased sports fields

Of the 30 groundskeepers interviewed, there was an average of 9.6 years of sports field maintenance experience. Only around 33% had any horticultural qualifications (Certificate 3 Trade level Green keeping). None had specific sports field formal training, and in particular, none demonstrated an understanding of water use efficiency.

In examining field conditions of around 80 fields, it was apparent that more than 75% would benefit from rudimentary training in soils, sports turf maintenance (including mowing, weed control, aeration, machinery maintenance, topdressing, fertilising, irrigation / water management and player management), risk management and budgeting. Training in remediation and field construction issues would be required in the medium term (three to five

years). Pest control (other than weeds) and scarification were not likely to be an issue for most of the community based fields in the medium term (three to five years).

AFLQ State League Curators

Groundskeepers involved with maintenance of the 12 fields benchmarked within the project were interviewed. It should be noted that as the project ran, the level of groundskeeper involvement increased. In addition, a number of the fields have a range of curatorial influences. Most commonly, a highly experienced person provides specialist and technical services while routine tasks (such as mowing and watering) are undertaken by others, including contractors.

At the time of the audit, the maintenance of the 12 fields was the direct responsibility of at least 11 people. Seven had been formally trained to at least Certificate 3 level in horticulture, one to Certificate 4 level, while three had not received any formal training. During their training, only one person from interstate had specialised in sports fields while undergoing formal horticulture training. Most (nine) were working unrecognised at Certificate 4 (supervising trade) or Diploma (line manager) level, while two were better described as operating at the Certificate 2 (Trade Assistant) level.

The average horticultural experience of this group was between 11 and 12 years, with an average sports field experience of between 9 and 10 years. Five had attended an informal sports field training event, with two involved in national cricket curatorial training roles.

The nature of the project skewed the curator audit results so as to be atypical of community sports field curators. The training outcomes required for this group was logically pitched at a higher level than that of school groundskeepers and sporting clubs. A range of topical higher level refresher / new information courses was thought to be useful to most of this group. This included topics such as Managing Soil Health, Managing Sports Field Water Systems, Developing Sports Turf Nutrition Programs, Assessing New Products and Services, Risk Management for Sports Fields and Managing Sports Field Use.

Industry training structure

Development process

As his core contribution to the project, Neil Power developed a prioritised draft set of competencies and training support materials, based on project research and benchmarking results, along with a review of relevant turf industry surveys. Within the project, and as part of his normal consultancy business, he presented these ideas and materials at an extensive range of forums and venues.

Apart from the relevant activities noted in the Technology Transfer chapter, he gave a general project overview and specifically outlined the Training Package Development at more than 70 events, involving at least 800 people directly. Groups included sports field curators and school curators in coastal Queensland between Coolangatta and Cairns; Sydney, Melbourne, Dandenong (Victoria), and a specific consultation tour through Parks and Leisure Australia to metropolitan and regional communities in south-west Western Australia.

He also consulted with turf and sports field experts such as Dr Bob Carrow from the USA, Professor Tim Colmer (University of Western Australia), Dr David Aldous (University of Melbourne).

Neil Power also engaged with organisations such as Brisbane City Council, Greater Dandenong City Council, Sutherland Shire Council, and discipline organisations such as Parks and Leisure Australia, and the Australian Water Association.

By December 2006, Neil Power had developed a comprehensive document 'Careers in Turf Management' (Power 2006). Because it is a potential IP product, it is not included in this final report; however the Table of Contents and sample page are presented in Appendix 1.

Arrangements for implementation of the training program were initially with the Registered Training Organisation Hortus, however in September 2005 they indicated they were no longer providing auspicing in Park Facilities Inspection competencies (this is the relevant sports field risk management competency). Neil Power then undertook negotiations with the University of Queensland to provide accredited training and professional development short courses in sports field management. With ongoing changes to government requirements for Registered Training Authority procedural requirements, and significant adjustments within the Faculty of Natural Resources, Agriculture and Veterinary Science and Vocational Training Units within the University of Queensland, formal training structures and courses have yet to be fully implemented. Pilot programs in 'Water Efficient Sports Field Management' and RPL for risk management in public open space have been undertaken.

As part of the project commercialisation discussions, it would be useful for the equity partners to determine how to proceed with utilisation of the training structures and competencies outlined in the 'Careers in Turf Management' and underlying competencies documents.

Development of training reference manuals

By March 2004, Neil Power developed a Sports Field training package outline (Power 2003), leading on from the skills and needs analysis of the target audiences. This included reviewing source materials and National Training Competencies for suitability for incorporation in training materials, along with actual project research results. Most material discovered in this initial review focussed on cool season greens grass management with relatively high resource requirements, therefore new material, based on warm season grasses and low resource inputs, was required.

During the subsequent two years, Neil Power collected project and external information, examples of current 'best-practice', and consulted with scientists and field managers, to put together training materials. By March 2007, he had produced 3 draft volumes relevant to managing community standard sports fields. Due to a change in personal circumstances, he was not able to complete the manuals to final versions. We have since completed each of the three documents to versions where they could be used as resource materials for training programs, induction for new staff, or reference materials for generating targeted extension programs (Power 2007a; Power 2007b; Power 2007c).

The three resource manuals are titled:

- Community-standard sports fields – I. Managing the field
- Community-standard sports fields – II. Managing the surface
- Community-standard sports fields – III. Managing the soil

Because they are each potential IP products, they are not included in this final report; however the Table of Contents and sample page are presented in Appendix 2.

As part of the project commercialisation discussions, it would be useful for the equity partners to determine how to proceed with use or publication of these resource manuals, e.g. as part of licensing agreements, or alternatively as stand alone publications.

References

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General project discussion

The initial project aims were to:

- Demonstrate potential best practice management strategies for AFL grounds in QLD
- Review current world practice and performance benchmarks relevant to community standard fields
- Develop methodologies for surface benchmarking and define relevant performance standards
- Focus on understanding existing soil profile conditions, and where pertinent, modifying them to improve field performance standards
- Focus on improving irrigation system performance on community-standard fields
- Evaluate soil profile amendments in the laboratory and the field
- Build industry capacity and develop platforms for ongoing improvement

In reviewing outcomes against each of those project aims, we argue that targets have all been met or exceeded, with important industry outcomes clearly identifiable.

Demonstrate best management strategies

At the start of the project, Nick Jeffrey was Head Curator with the Brisbane Lions Football Club, responsible for maintaining their training ground at Coorparoo. Using the field equipment purchased through the project, he commenced amelioration activities on the targeted Premier League AFL grounds in the Brisbane metropolitan area. He also oversaw general maintenance duties on several of those grounds.

The amelioration and maintenance operations were implemented on the basis of his experience, as well as suggestions from the project team following the literature review and initial project benchmarking results. Examples include aeration frequency and depth, mowing heights, improvements in irrigation system operation, and ongoing manipulation of irrigation programs.

Within the first 18 months of the project, improvements in ground conditions were apparent (see Benchmarking Chapter), and being favourably commented on by field users, players coaches and spectators. The impact of this success and growing project awareness snowballed over the following few years. The condition of the AFLQ grounds continued to improve, against a background of worsening drought and subsequent restrictions on irrigation.

On the basis of the rapid improvement in ground condition, other organisations outside the project requested assistance to bring their fields up to similar standards. The requests for advice and assistance became such that AFLQ purchased another set of renovation implements; employed Nick Jeffrey as their State Facilities manager (along with another three field staff), and markedly expanded their renovation and maintenance activities, to attempt to meet this emergent need. This has been a massive injection of AFL Queensland's own funds (several hundred thousand dollars per annum), on the basis of the proven performance of the strategies adopted within the project.

At the same time, Nick Jeffrey has been made responsible for advising and assisting in the preparation of facilities for national standard games, such as pre-season competition games in Cairns, and 'home' games for the North Melbourne club at Carrara on the Gold Coast.

Apart from organising project extension events to demonstrate and discuss practices, members of the project team are also regularly ask to address other sporting organisations, as outlined in the Technology Transfer Chapter. This has been particularly important in relation to the drought and subsequent water restrictions.

Nick Jeffrey and Craig Henderson were specifically requested by the Queensland Water Commission to provide advice leading to best practice guidelines underpinning the Level 5 (and beyond) water restriction regulations.

Detailed descriptions of 'best practice' options are outlined in the Literature Review and benchmarking chapters, and explicitly detailed in the manuscript on surface management (Power 2007).

Review current world practice

The Literature Review (Bransgrove 2004) provided in this final report comprehensively reviews best practice benchmarking, renovation and maintenance best practice, current in 2004. It furthermore establishes a framework for additional information and recommendations, as new technologies are tested and evaluated. Thirdly, it is an easily-read, introductory document, for people new to the sports field management sector.

Methodologies for benchmarking and performance standards

On the community-standard fields, we clearly identified hardness as the number one priority likely to affect player safety and surface performance. AFL now institutes a rigorous benchmark for assessing hardness, using a standard Clegg Hammer procedure; 3 readings greater than 20 G_{max} mean ground closure. In our benchmarking studies, we identified that with good ground amelioration and ongoing maintenance, hardness levels consistently less than 130 G_{max} were readily achievable. On many fields in the latter stages of project, values of less than 110 G_{max} were possible for extended periods of time.

We also identified a ground auditing procedure using a range of methods that could indicate trends in ground condition over time (see Appendix 1); particularly relevant to more insidious increases in compaction levels, or gradual decline in turf coverage or species composition.

Surface soil moisture was also identified as a key modifier of surface condition. In our project, we clearly identified the interdependencies of surface hardness and compaction levels on surface soil moisture. A significant part of the 'art' of sports ground management is the manipulation of irrigation frequencies and amounts with people usage intensities, frequency and locations. Whilst moist soil is generally less hard, it can become more compactable, leading to a downward spiral in surface condition. We clearly identified the need to consider irrigation, aeration and ground usage as interdependent variables, which need to be considered as a whole, and not in isolation.

On these community standard, natural soil fields, we also identified that issues of torsional resistance and shear strength were less important than hardness and turf cover. This is in comparison with elite, sand based fields, where these properties are more important.

Influence of natural soil profile on surface condition and management options

As would be expected from the nature of their construction (often cut and fill on slopes, or remediated land-fill sites), the community-standard sports fields have very variable soil profiles both between and within sites. Our soil coring showed surfaces varying from sand to clay, overlying sandy-loams, through ash, or heavy clays. They were also very variable in water holding capacity and hydraulic conductivity, pH, bulk density and surface soil strength. Surface roughness was found to be more due to turf characteristics than any underlying soil character.

The key implication of the soil profiling study was that there could be no single recipe for soil improvement across these sports fields. Any soil amendment practices would require an initial site survey, to understand the extent of the variation in surface and underlay materials.

Similarly, because of the soil variability, developing a precise formula for irrigation frequency and amount is unlikely to be possible. It is more useful to provide information and education to the responsible irrigator on soil properties and their influence on water movement and retention. They can then over time intuitively develop their individual irrigation systems and programs, able to cope with the idiosyncrasies of their particular fields.

Irrigation improvement

System improvement

In this project, we clearly identified irrigation installation and maintenance as a key issue for community-standard sports fields. It was apparent that a 'lowest common denominator' approach had set benchmark prices for irrigation installations, and it was very difficult for designers and installers to provide adequate system performance at that price.

In our project, we set benchmark performance objectives of irrigation distribution uniformity of 75-80%, and minimum precipitation rates of 8-10 mm/hr. During the project, we have seen commercial irrigation suppliers endeavour to meet these objectives, but it is very difficult to achieve in the current pricing regime.

More promising is the provision of industry best-practice irrigation guidelines (Cape 2006), which several of our team were involved in developing and reviewing. These guidelines clearly lay out specifications for irrigation performance, and a flow chart for customers to ensure quality irrigation outcomes. In numerous papers and presentations, we have outlined the critical elements to look for in irrigation auditing, and have had feedback from numerous people who have looked at their own systems, and been surprised at their initial poor performance.

We are aware that several irrigation suppliers have taken on our project results and adjusted their designs to improve irrigation performance. They have also been in a better position to assist with retrofitting existing systems, by changing rotors and nozzles that are better suited to the pressure regimes and sprinkler spacings in the installed designs.

Program improvement

In reviewing and testing new irrigations strategies, it became very clear that a regularly used sports turf had different inherent irrigation demands to conventional agricultural crops, or even a non-trafficked turf. We discovered that our most successful practice (in terms of maximising irrigation efficiency and turf/surface performance) was between the current practice (irrigating several times per week), and watering when it appeared the turf was starting to stress.

We found that by implementing a schedule of regularly irrigating on a weekly basis (which could then be programmed around the use requirements of the client clubs), we got efficiency benefits of deeper water volumes, but didn't run the risk of poor turf recovery, or over-hard surfaces. We were (counter-intuitively) also able to make better use of rain as a substitute for irrigation.

We discovered that by being much bolder at keeping the irrigation system turned off for longer periods after rain, we were able to use 30-50% less water than the benchmark 5 ML/ha for most irrigated sports fields around Brisbane.

From our irrigation studies, we feel that the three most powerful water-saving devices in the curator's armoury are:

- Good knowledge of irrigation principles and equipment;
- Total control over when the irrigation is turned on and off, and when the ground is used or closed;
- On automated systems, a sensitive and reliable rainfall sensor, and preferably a remote device that can turn the irrigation off, even when not at the ground.

Influencing policy

Because of our irrigation work within the AFL project, we were in a good position to provide convincing arguments for effective water restriction protocols in south east Queensland. In conjunction with other sporting bodies, we were able to argue a shift from purely irrigation time-based restrictions, to the adoption of Water Efficiency Management Plans and a more 'volumetric' approach to reducing irrigation. The major benefits of this approach were it enabled curators to prioritise irrigation activities, and make sure each irrigation was actually effective.

This lobbying approach has meant that most south east Queensland sports fields (to date) have remained open for use, whilst under much less severe water restriction regimes, their southern counterparts have been steadily withdrawn from use because of safety concerns.

Soil profile amendments

Laboratory studies

The project's laboratory studies identified that the amount of people use (and machinery traffic) was the prime determinant of compaction levels and subsequent surface hardness. This is more pronounced with sandy loam to clay soils, and is particularly a problem if they are highly moist at the time of the traffic.

They also confirmed our benchmarking observations in the fields, that many of our surfaces were softer at higher moisture contents. The laboratory studies did suggest that irrigation to reduce hardness only needs to be 5-10 mm. For the finer textured soils in particular, irrigation should be applied at least 24 hrs prior to any use. Even so, without ongoing restoration of porosity through renovation, compaction levels will continue to increase with use, as will hardness for any given moisture content.

On the soils tested in the laboratory, there was no benefit from incorporating water-absorbent gels; however incorporation of significant amounts of composted bio-solid organic matter did make them softer, and less 'compactable'. Similarly crumb rubber was the best performing topdressing material for reducing hardness and surface compaction.

These laboratory studies were very useful in narrowing down the amendments we needed to evaluate in the field. By doing the initial screening under controlled conditions, we were able to reduce the amount of R&D effort and expense required to evaluate the 'best-bet' options. These studies also provide background information on the key variables to look for when evaluating the bio-solid and crumb rubber products – a cross-check on the field results.

Field studies

Incorporating compost into the soil (immediately before laying turf sod) reduced surface hardness by 40 G_{\max} in moderate hardness situations, and up to 80 G_{\max} in peak hardness conditions. A 20 mm-thick, crumb rubber topdressing reduced hardness by 15-30 G_{\max} in comparable situations.

It should however be noted that both amendments had minimal hardness impact under good surface conditions; i.e. if the field was being properly managed, the difference was not important.

Compost underlay only had a minimal effect on turf persistence into the winter football season. In optimal situations, crumb rubber enhanced early season turf cover persistence and later season recovery. However, it could not prevent rapid turf deterioration under conditions of intense use, or caused by agronomic issues such as irrigation failure. Although both compost and crumb rubber amendments can improve surface conditions in high wear areas, they do not alleviate the need for specific, in-season agronomic attention and ground use management. Amendments are not a panacea for poor management practices.

The economics mean that these soil amendments are probably only applicable to small areas of high wear. Even then, curators would seriously need to evaluate the cost/benefit, compared to returfing of a small area (if it's going to become bare no matter what the treatment), or intense use monitoring, irrigation, nutrition and aeration management.

Building industry capacity

As previously mentioned, the most outstanding example within this project of building industry capacity has been the emergence of AFLQ and (Nick Jeffrey in particular) as key players in sports field management in Queensland.

In 2002 Nick was curating the training facility for the very successful Brisbane Lions Football Club. Now, Nick Jeffrey is State Facility manager for AFL Queensland, and is responsible for providing advice to AFL affiliated sports fields from Coolangatta through to Cairns, and into western Queensland. He audits all these grounds several times per year, and is responsible for providing advice on improvement, or occasionally (and unfortunately), organising the closure of the grounds until their condition reaches an acceptable standard. He is also involved with advising, on behalf of the national AFL organisation, the preparation of the ground at Carrara for national competition games.

As previously mentioned, AFLQ have an ongoing commitment to building up equipment and people resources, to service an increasing demand for renovation and sports field maintenance activities throughout Queensland. They are currently contemplating buying a third set of renovation and maintenance equipment. They have also been one of the most pro-active organisations in coping with the current drought, accessing alternative funding sources for emergency water supply tanks. Just recently they successfully obtained a grant to install wireless irrigation controllers, so Nick Jeffrey can operate several of their irrigation systems around Brisbane from a central location (to rapidly react to approaching weather events, or unintended system operation).

Outside the AFL structure, Nick Jeffrey is regularly asked to provide advice to other sporting codes, organisations, councils and schools, on upgrading and maintaining their sports fields. Craig Henderson and Nick Jeffrey were requested to provide assistance to the Sports Federation of Queensland and their affiliated bodies on coping with drought and water restrictions. As a consequence, they were also engaged by the Queensland Water Commission to provide expert advice on the sports field components of the Level 5 water restrictions and accompanying best practice guidelines.

As a result of ongoing discussions with the Queensland Government's Department of Sport and Recreation, Nick was engaged to present best practice information to sporting groups throughout southern Queensland; from Gayndah through to Beaudesert.

As outlined in the Technology Transfer Chapter, during this project we have conducted well over 100 industry extension activities, and directly encountered a cumulative total of several thousand industry practitioners. The level of engagement has ranged from project and concept awareness, through to specific advice and training in issues such as ground renovation, surface benchmarking, and irrigation auditing. We have frequently received positive feedback from these events, as well as requests for follow up information and advice, suggesting significant levels of industry interest.

By formulating a training platform and training resource materials (along with the extensive catalogue of materials published within the project), there is significant potential for ongoing expansion of industry capacity beyond the project. Given the momentum built up within AFL Queensland, as well as increasing effort within Sports Turf Institute (Australia) and the DPI&F Lifestyle Horticulture R&D team, it is inevitable that industry capacity building will continue beyond the completion of this project. To make the most from the generated project resources however, it would be very useful for the project partners to develop a strategy for using the project products, either in a self-funding commercial capacity, or alternatively as input resources for allied project activities.

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Technology transfer

During the project we conducted a program of ongoing communication and extension activities. Our published information output included 9 articles in industry journals and general media, 7 papers delivered to national and international conferences, 11 website articles, 15 formal presentations to regional industry forums, 10 field day handouts and newsletters, 8 reports on specific project components, and 22 confidential reports to project partners (see Bibliography).

We also conducted over 70 separate extension events as outlined below. As well as these group events, we provided individual advice and consultative effort to approximately 30 sports fields outside the project collaborative organisations. Neil Power and Nick Jeffrey also advised and discussed issues with numerous schools, sports groups, and individual ground managers as part of their day-to-day business.

More project results are being presented at an international Turfgrass Conference in Beijing, China, and at the forthcoming National Turfgrass Conference in Cairns, Australia in July 2007.

Ongoing technology transfer activities will be arranged as part of the commercialisation strategy to be developed by the intellectual property owners (Horticulture Australia Limited, Department of Primary Industries and Fisheries, AFL Queensland, Brisbane Lions, and International Turfgrass Consultancy), in mid 2007.

Extension activities

2003/4

Media event 10 July 2003, attended by Queensland Minister for Primary Industries, Henry Palaszczuk. Segments appeared on that night's ABC News, Sports Tonight editions. Articles appeared in local press over the ensuing days.

Presentations on project to: Groundskeepers at IAA seminars in Townsville, Brisbane, Melbourne and Adelaide, and to AFLQ club coaches in June July 2003.

Sports field benchmarking instrumentation and ground assessment notes provided at Industry Field Day, 6 November 2003, Morningside Ground.

Night forum with Morningside Football Club coaching staff and key players re: project activities and specific ground performance issues; 3 March 2004.

Discussion of project by Nick Jeffrey (Brisbane Lions Head Curator), at AFL sponsored elite curators workshop in Melbourne, July 2004.

Presentation on project to Turf Producers Australia National Conference including handout at Redlands Research Station on 20 April 2004.

Presentation on project to Department of Primary Industries and Fisheries Senior staff at Redlands Research Station:

Senior Executive Team (including the Director-General) on 21 May 2004.

Delivery Management team on 6 August 2004.

Presentation on project to TAFE Gold Coast Horticulture group at Redlands Research Station on 6 August 2004.

Presentation on project to Australian Landscape Industry Association at Redlands Research Station on 6 August 2004.

Major field day presentation (3 hrs) to 61 delegates from the World Leisure Congress in Brisbane (conducted at Morningside Oval on 15 September 2004), including presentations by project team and external industry stakeholders; handouts provided.

Major field day presentation (3 hrs) to 30 delegates from the International Crop Science Congress in Brisbane (conducted at Redlands Research Station on 29 September 2004), including presentations by project team in conjunction with DPI&F turf group; handouts provided.

Invited presentation on irrigation component of project, to inaugural Cooperative Research Centre for Irrigation Futures Workshop and Conference, in Sydney, 20-22 September 2004.

2004/5

Multiple presentations at industry workshop 'Turf Management in Community-Based Sports Fields' at Redlands Sporting Club on 19 October 2004, attended by 60 industry registrants, including curators, Council groundsmen, commercial suppliers, and regulatory support (e.g. QLD Government Sport and Recreation officers).

Multiple presentations at Turf Industry Field Day at Redlands Research Station on 21 October 2004, attended by over 90 industry registrants, including curators, Council groundsmen, commercial suppliers, and turf industry support.

Discussions of sports field irrigation principles and current benchmarking findings at National CRC Irrigation Futures urban irrigation workshop in Sydney, 29 October 2004, attended by scientists, water authorities, and urban field managers from across Australia.

Project team workshop to update project findings and discuss future activities, held at Redlands Research Station on 4 November 2004.

Interactive irrigation audit training and performance improvement with project team, including curator Nick Jeffrey and industry supplier Wayne Garrett, at Mt Gravatt sports ground, on 14 December 2004 and 15 February 2005.

Poster at Statistical Science Conference, held at Thredbo, 6-11 February 2005, presented by biometrician Janet Giles.

Additional 20 project presentations by Neil Power to various groups and organisations in 2004/early 2005.

Inclusion of project information in Queensland turf industry review by David Aldous and Neil Power.

Presentation to Marsupial Landscaping – landscaping consultant group from Sydney on methods of monitoring playing surface condition on 5 May 2005.

Presentation by Neil Power to Irrigation Association National Conference on Water use efficiency on Brisbane sports fields on 18 May 2005.

Presentation by Craig Henderson on 'Irrigating sports fields - the Bad and the Ugly, but where's the Good?' to Water Technology in Agricultural Practice Discussion Group & CRC Irrigation Futures.

Presentation by Neil Power and Craig Henderson on AFL project results and irrigating urban sports fields to Singaporean landscape consultants, 28-29 September 2005.

Scoreboard reports and irrigation audits for each of the 12 project grounds provided to AFL Queensland for distribution and any feedback requested.

Specific hardness graphs for Gabba and Coorparoo given to Brisbane Lions officials and curator, feedback received and some action eventuating.

Other presentation and training activities (provide by Neil Power in 2005):

Two presentations have been made to a total of around 200 Lifestyle horticulture industry people on water conservation.

Active participation in three national lifestyle horticulture workshops relating to urban lifestyle horticulture water issues, including two developing a national approach to water restrictions (including sports fields) and developing urban irrigation sustainability (including sports fields).

2005/6

PowerPoint presentation (using animations) to demonstrate current status and trends for critical field benchmark indicators compiled for each ground. Delivered to AFLQ Chief Curator, to present to AFLQ senior management and ground managers pre-season 2006.

National draft objective sports field playing surface safety standards were developed based on a review of a suite of Sureplay[®], national and international parameters during December 2005 and January 2006 and demonstrated on two Gladstone community based sports fields. Subsequently Gladstone City Council has adopted the draft standards as the basis for sports playing surface assessment. The draft standards were circulated for comment to sports field practitioners in Queensland, New South Wales, Victoria, South Australia, Western Australia and Singapore.

Workshops for budding scientists (40 high school science students) held on 6 October 2005 in "Fresh Futures" project sponsored by DPI&F and AgForce; presenting information and interactive workshop on project.

Tour by project team and collaborating curators of project demonstrations (irrigation comparisons, crumb rubber topdressing), and ameliorated/benchmarked sports fields on 8 November 2005.

Contribution by project team at 'Healthy Soils for Great Turf' workshop, Redlands Research Station, 20 February 2006.

Contribution on sports field irrigation by project team member Kaylene Bransgrove, to national workshop developing irrigation guidelines for urban open space, Brisbane, 3 March 2006.

Discussion of irrigation demonstration results with collaborating AFLQ curators at demonstration ground (MT Gravatt) on 20 March 2006.

Field presentation of project results and outcomes to HAL leaders Sarah Pennell and Gerard McEvilly, accompanying industry people, collaborative and general staff, whilst visiting Redlands Research Station on 30 January 2006.

Brief discussion of project and collaborative opportunities with John Neylan (AGCSA technical manager) on 8 February 2006.

Discussions with Keith McAuliffe, CEO New Zealand Sports Turf Institute, on opportunities for collaborative activities and extension of project results through their organisation, on 20 March 2006.

A presentation on the impact of water restrictions on sport fields was made to a national audience of approximately 60 Parks and Sports fields managers at the Parks and Leisure Australia National Conference in Hobart October 10th & 11th 2005. Interviews on the subject were aired on ABC National News in Hobart on the 10th October 2005 and recorded for ABC's PM program on the 11th October 2005.

A meeting was held on the 25 October 2005 with 4 senior representatives from the Queensland Government Department of Sport and Recreation to assist in developing funding options to improve water use efficiency in Queensland sports fields.

A presentation was made on the 11 November 2005 to approximately 50 south east Queensland public open space managers including sports fields on planning for permanent water restrictions in sports fields. A similar presentation was made on the 1 December 2005 to approximately 30 south east Queensland sport and recreation officers on the Gold Coast.

Training was provided individually leading up to and as a group on the 22 November 2005 to 8 sports field curators / manager / grounds persons in interpreting and monitoring soil moisture data loggers installed in 4 community based sports fields.

A meeting was held on the 30 November 2005 with SEQWater representatives on the lack of effectiveness of current Water Efficiency Management Plan (WEMP) requirements for sports fields.

A presentation was made on the 19 January 2006 to 6 council and 15 community based sports field curators in Gladstone on water efficient sports field maintenance and playing surface standards.

Workshops were held in Sydney (February 2006) and Melbourne (March 2006) to review various subjective and objective playing surface safety standards.

A presentation was made on the 6 March 2006 to 10 senior Singapore National Parks Board (NParks) staff on tropical / subtropical sports field maintenance and development issues.

Information and photos supplied for irrigation article in Golf and Sports Turf magazine publication, 3 July 2006.

Paper and presentation on 'Lifting the game on community sports fields ' to Irrigation Association of Australia National Conference, 9-11 May 2006.

Key address on 'Managing community standard AFL sports fields' presented by project team to 22nd Australian Turfgrass Conference, 20 July 2006, including 5 PowerPoint presentations.

Presentation at field day of 22nd Australian Turfgrass Conference, 21 July 2006, including field day flier.

Posters and fliers presented at QLD Turf Producers Association Annual Conference, 24-26 September 2006.

Keynote presentation at 'Water for community sport forum' organised by the Sports Federation of QLD, and attended by 200 community sports representative, on 20 September 2006.

Presentation on 'Irrigating for sport' to irrigation scientists and practitioners, Toowoomba, 14 August 2006.

2006/7

Presentation on 'Renovating high wear areas on sports fields to researchers and ground managers, Toowoomba, 16 October 2006.

Workshops for budding scientists (60 high school science students) held on 27 July 2006 in "Fresh Futures" project sponsored by DPI&F and AgForce; presenting information and interactive workshop on project.

Project newsreel-style footage used at a 'Behind Agriculture' corporate presentation at the Brisbane Royal Show, 10 August 2006.

Detailed discussion by Nick Jeffrey with middle management from state government agencies Sport and Recreation Queensland, and Education Queensland, on project findings in relation to playing standards and resource requirements for community and school ovals, 6 September 2006.

Extensive discussions with Department of Natural Resources Mines and Water staff and Minister, the Department of Primary Industries and Fisheries staff and Minister, Environmental Protection Agency staff and the newly created Water Commission staff and Commissioner. Outcome was retention of access to irrigation water for active use areas during water restrictions, and funding for infrastructure and training.

Paper 'Establishing environmental, social and economic benchmarks for community based sports fields in south east Queensland'. Presented at a workshop 'Sustainable Urban Irrigation Workshop Using a Triple Bottom Line Approach'" conducted with Dr Penny Davidson at the National Parks and Leisure Conference Sydney, September 2006. Also presented at workshop with University of Queensland 3rd year horticulture degree students on 9th October 2006.

Presentation on 'Dos and Don'ts of community sports fields maintenance' to south-east QLD Rugby League Annual Conference, 19 November 2006, with 80 registrant in attendance.

Presentation on 'Managing community standard sports fields to AFLQ Junior Division, Annual Conference, 28 October 2006, with 50 registrants in attendance.

Major sports management update to south-east QLD community field curators and administrators, Morningside oval, 2 November 2006, with 105 registered attendees.

Presentation on 'Dos and Don'ts of community sports fields maintenance' to 20 registrants at a Townsville Sports and Recreation Forum on 27 February 2007.

Presentation on 'Dos and Don'ts of community sports fields maintenance' by Nick Jeffrey to 30-50 registrants at 13 Sport and Recreation Forums at Esk, Boonah, Ipswich, Nanango, Gayndah and 8 Brisbane regional sports clubs, between April and June 2007.

Presentation on 'Irrigation lessons from community sports field research' to 85 registrants at a DPI&F Turf Forum at Redlands Research Station on 6 June 2007.

Significant consultation in February/March 2007 with the Queensland Water Commission, on the implementation of Level 5 restrictions (and beyond) for south east Queensland, and the provision of draft sports field management guidelines for consultation with sporting organisations and representative bodies.

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General project recommendations

Commercialisation

Original Equity agreement

Within the first 6 months of the project, we formulated an agreed equity agreement, based on cash and recognised in-kind contributions to project. The original equity partners under this arrangement were Horticulture Australia Limited (36.6%), DPI&F (29.1%), AFLQ (20.7%), Brisbane Lions (13.1%) and ITCG (0.5%).

The Equity Split applied to the project in the following manner. DPI&F, under the agreements with HAL and the Collaborators, owns the Project Results, and distributes any income received from exploitation of those results proportionate to the Equity split. Examples were income from licensing benchmarking operations to commercial operators. There was no licensing of other project income during the life of the project.

Trademark application

The project successfully obtained a trademark (Trade Mark 1046436) for Sureplay[®], the details of which are included in Appendix 3. All information and extension materials have been branded with the Sureplay[®] trademark since early in the life of the project, in anticipation of the trademark being accepted. The State of Queensland holds the Trade Mark on behalf of the project equity partners.

Future commercial arrangements

It is recommended that the Sureplay[®] project equity partners organise a meeting as soon as possible, to discuss any potential licensing or other commercial arrangements utilising IP or products developed as part of the project. The most likely candidates for commercialisation are through sales of resource manuals, consultancy utilising the resource manuals (and any other project materials), and any commercial arrangements with training partners. Development of the project materials to a financially saleable publication, or facilitation of commercial training ventures, will require commitment of further resources from the equity partners.

Coordination and relationship with governments, regulatory authorities and funding organisations

A major breakthrough in this project was the development of relationships between: (i) organisations responsible for managing sports fields, (ii) organisations imposing regulations on sports fields; and (iii) organisations providing funding and investments into sports fields.

Although it only really gathered momentum during the final months of the project, these relationships had major ramifications for community-standard sports fields. For example the water restrictions imposed on sports field irrigators would potentially have been very different, without the science-based advice that the regulatory authorities were willing to take on board from project team members. A potentially adverse result may have been much more significant curtailment of sports field use than has currently been observed.

Another example is engagement with Sport and Recreation Queensland, who provide significant grants and funding investment into sports fields and their management. It appears that as a result of our findings on irrigation installations, they are looking to develop a more performance-based method of grant evaluation. They may also be looking to encourage more resourcing into research, and evaluation of the cost/benefit of proposed technologies.

Future relationships

At all levels of the sports field management industry; from the individual curator, through their representative sporting and professional associations, and umbrella groups such as Sports Federation Queensland, or Parks and Leisure Australia, the project is evidence that relationship building with regulators and funding groups can achieve positive, sector wide outcomes. The project recommends that messages based on good science, ongoing industry engagement and evidential evaluation have more chance of getting a positive hearing.

Hardness risk assessment

The project found that hardness was the prime turf-related index of surface condition, likely to impact on the safety and performance of community-standard fields. Its importance is exacerbated by drought conditions. The project also discovered that some fields are more prone to becoming hard than others.

Although we have done some initial research identifying soil type, bulk density and moisture content as prime causal factors, it would be helpful if this could be further quantified. This would assist planners and operators concentrate their efforts and resources on high risk fields, and high risk areas within fields. In our project, we identified high risk areas by ongoing hardness measures over an extended period of time. If a one-off test could be developed to quantify the risk of developing adverse hardness levels, this would simplify identification of this particular hazard.

Turf wear tolerance and recovery

Apart from hardness, the other major surface issue we encountered was the loss of turf cover in high wear areas. We found that amendments such as crumb rubber could assist in the management of moderate wear; however bare areas still developed during winter and into spring. Although we know that good agronomic practices can improve wear recovery, initial studies by DPI&F at Redlands Research Station are indicating cultivar differences in wear tolerance and recovery (Roche 2006). It appears there are also some interesting interactions between wear intensity and frequency, which could have significant impact on optimising use patterns to reduce wear. As wear management and turf persistence was still a critical factor at the end of this project, it is recommended that research and evaluation in this area of activity is supported. Our experiences also suggest that involving curators and sports managers in the research process early will enhance adoption, as well as help focus the important issues for ongoing investigation.

Irrigation investment evaluation

In our project, we discovered that there is marked room for improvement in both irrigation systems and practices throughout the industry. On our demonstration fields, we achieved good turf cover whilst supplying irrigation at 50-70% of the industry benchmark.

Because of the drought (and consequent regulatory restrictions, and loss of conventional water access), irrigation supplies and practices have become critical in the community-standard sports field sector. At the same time, we seen an explosion in the number of grant schemes in operation, and investments in various 'water saving' infrastructure, devices and protocols (including those advocated by this project)! Thirdly, one of the requirements of ongoing water access in south east Queensland has been specific field metering, and generally much better recording of irrigation volumes applied to sports fields.

This means that there is now a ready-made environment for assessing the performance of a whole range of initiatives and investments (in irrigation infrastructure, new technologies, and practice change), on irrigation used and the resultant turf surface. Such an analysis would potentially be complicated by confounding factors such as other agronomic practices, initial surface condition etc. However, it would seem an ideal opportunity to conduct such an evaluation; as a guide to both current investment recommendations, as well as areas for further investigation.

Industry capacity building

Within and outside this project, in the last 3 years there has been tremendous interest from the sports field management sector in seeking out knowledge. Attendances at events have been outstanding, generally in the order of 80-100 people (or more) at any well publicised event. In our project, we have found most on-ground people and support industries very willing collaborators. Organisations with a charter to interact with this sector can only be encouraged to continue dialogue, and preferably to conduct hands-on activities with them, as a path to rapid learning and use of new technologies and ideas.

We also found that the umbrella organisations, such as Sports Federation of Queensland, or the sports governing bodies (e.g. AFL Queensland), were very useful contacts. They already have an inherent network of information flow through their organisations for other purposes. Provided you can get them on-side, rapid dissemination of awareness-style information through to many grass roots people is achievable. They can also be very powerful advocates for the implementation of new systems or technologies, either through a granting/subsidy system, or participatory/affiliation requirement.

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Appendix 1

Sample pages from Careers in Turf Management Document

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Careers in Turf Management

Level 5 Grounds Manager

The greens manager is likely to have significant responsibilities in managing sports turf establishment and maintenance activities.

These responsibilities include:

- managing business operations
- planning sports turf establishment
- designing sports turf playing surfaces
- managing turf health
- preparing estimates, quotes and tenders
- developing turf surface preparation standards
- monitoring budgets and financial reports.



Grounds managers have often developed extensive knowledge and skills by working as head groundspersons. They can progress to the position of grounds manager when they have shown that they can successfully manage turf operations.

To obtain a **Diploma in Horticulture (Turf)** you will need to demonstrate that you possess the necessary knowledge and skills and that you can apply your knowledge to industry standards.

Contact your state parks or turf industry association or Rural Industry Training Board for further information. For further details on how you may obtain a qualification refer to the [Qualification](#) and [Assessment](#) sections below.

Please Note

The main activities of a Grounds Manager include staff management, business administration, turf facility planning and design, monitoring budgets and financial reports.

Careers in Turf Management

RTF20803 Certificate II in Horticulture (Turf)
A total of 17 units of competency must be completed (SurePlay 17)
Select 9 units from Group A below (<i>including the 4 designated compulsory units</i>)
Select 5 additional units from Group A and/or B below
Select 3 additional units from Group A, B and/or C below
GROUP A (<i>*units in italics are compulsory</i>)
RTC2307A Operate machinery and equipment
RTC2401A Treat weeds
RTC2404A Treat plant pests, diseases and disorders
<i>RTC2701A Follow OHS procedures*</i>
<i>RTC2702A Observe environmental work practices*</i>
RTC2704A Provide basic first aid
<i>RTC2705A Work effectively in the industry*</i>
<i>RTC2801A Participate in workplace communications*</i>
RTE2606A Maintain pressurised irrigation delivery systems
RTF2015A Prepare turf surfaces for play
RTF2019A Renovate grassed areas
RTF2020A Assist with turf construction
RTF2023A Support turf establishment
RTF2504A Determine basic properties of soil/growing media

Appendix 2

Sample pages from 'Community-standard sports fields – II. Managing the surface' document



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MOWING

The mower is the single most important tool for the sports turf manager. The type of sport being played, type of mower, operator skills, mower maintenance, frequency, grass heights and pattern of cutting all influence the quality of the growing surface, water use and cost of maintenance.

Type of mower

There are two types of mowers generally used on sports fields. They are reel and rotary mowers.

While reel mowers are the equipment of choice for greenkeepers maintaining elite sports fields, the more utilitarian rotary mower are more commonly used by community sports field curators.

Reel mowers provide a finer cut and higher quality finish than rotary mowers however they are generally more expensive and time consuming to maintain and require very even surfaces. Reel mowers are not effective on uneven, weedy or coarser grass fields. In making a choice between buying a reel (cylinder) mower and improving the irrigation and aeration of the fields; you will get more value out more frequent aeration and then improving the irrigation system before purchasing a reel mower.



Type of sport and mower

Another consideration is the type of sport being played. Small ball sports codes such as cricket, hockey and to lesser extent softball and baseball may be highly dependent on consistent ball roll. This is of concern particularly where a player has to stop or catch a fast moving hard ball where unanticipated deviation may injure the player. In this circumstance, it is advisable to ensure that there is as even a playing surface as possible. This is best achieved with a closely cutting reel mower.

For large ball sports such as Soccer, Rugby League, Rugby Union, Australian Football League, touch football and American Football, ball deviation is not as critical and mowing with a rotary mower can provide a satisfactory surface for all but at the elite level (national or international training and competition).



Size

The size and operating mode of the mower is the next consideration. Size is important. Many sports field curators and administrators elect to purchase smaller ride on mowers to minimise capital expenditure. These mowers may take up to five hours per hectare to mow an area. The major cost of maintaining most sports turf surfaces is labour, even if it is volunteer labour. The time it takes to mow once with too small a mower may be better spent mowing more frequently or undertaking other vitally important maintenance operations such as aeration and irrigation maintenance.

For any continuous sports turf area 5,000m² (half hectare) or more in area generally requires a ride on mower with a tight or zero turning circle for efficient operation and a minimum of 900mm cutting deck. Between 10,000m² (one hectare) and 100,000m² (10 hectares) of continuous sports turf area generally requires a ride on mower with a tight or zero turning circle for efficient operation and a minimum of 1500mm cutting deck, preferably front mounted for clear visibility of the cutting width.

Where there are multiple high quality sports fields being maintained more than around 100,000m² (>10 hectares) then a gang mower arrangement may be considered with cutting widths upward of 2400mm.

Generally speaking a ride on mower with a 1500mm to 1800mm front mounted cutting deck will provide the best value for money for areas from 2 hectares to 20 hectares.

Cost effectiveness

Once the value of labour is considered, then the selection of mowers needs to account for reliability, machinery maintenance costs and ease of operation.

It is worth noting that commonly used tractor slashers rarely produce a reasonable quality playing surface suitable for most sports. Also when their turning circle, surface travel speed, capital and operating cost is accounted for, they are generally slower and more expensive to operate on sports turf.

Frequency

Mow as often as you can to minimise the amount of leaf removed at any one time. The more leaf removed the less photosynthetic leaf area available to convert the sun's energy into storage for root and leaf recovery growth.

It is often used as a rule of thumb that no more than $\frac{1}{3}$ of the leaf surface is removed at a mowing. However, this is a myth evolved from pasture research undertaken more than 50 years ago on a cool season grass (Kentucky blue grass) in a small greenhouse by a USDA scientist (Brede, 2000). The reality in south east Queensland's climate is that the peak grass growth season is also the holiday season and as may be seen in Table 3, the taller the grass, the faster it grows and recovers from stress.

Generally, this means the field may be cut up to three times a week during the summer, if you can afford the time and resources. Higher mowing heights don't need as frequent mowing. During winter, mowing may be reduced to as infrequently as once a fortnight.

Do not drastically or suddenly change the cutting height. If the grass has become too tall, re-establish the recommended height by mowing more frequently for a while and gradually lowering the mowing height of successive cuttings, until you reach the desired height.



During periods of drought, it is often preferable to mow less frequently at a greater height of cut as this will reduce moisture loss through the cut surface and shade the ground surface against evaporative losses. The additional leaf area may also provide the energy for the turf roots to extract moisture from deeper in the soil reservoir.

One interesting feature of consistent more frequent mowing is that the leaf morphology (shape) adapt over time to most effectively intercept sunlight. In these circumstances, the grass develops a smaller and flatter leaf.

This carpet grass (*Axonopus* species) grown at the Hong Kong Cricket Club has changed its leaf shape to a smaller more prostrate arrangement to better capture sunlight in response to constant mowing for a lawn bowls surface.



Height

Mowing is one of the most abused and least understood turfgrass management practices. Shorter mowing reduces leaf surface (the plant's energy factory) to such a degree that the plant may have to draw food from its root reserves to initiate new growth. Repeated defoliation reduces the root system, and the plant will be weakened and unable to cope with adverse weather conditions. It is important to know the correct mowing height for your variety.

Sporting code requirements

The height of cut will primarily depend upon the type and level of sport to be played on the turf playing surface. Small ball sports generally require lower mowed heights than large ball sports. Soccer also appears to rely on an even surface although it appears that the sport does not necessarily need as low a grass height as hockey and cricket (#excluding the turf wicket). Table 7 below lists some generic mowing ranges for south east Queensland sports field grasses.

Table 7: Mowing height recommendations

Some community sports field mowing height recommendations				
Species	Cricket#	Hockey	Soccer	Other football
Green couch (<i>Cynodon dactylon</i>)	12mm to 30mm	12mm to 20mm	20mm to 40mm	30mm to 75mm
Queensland blue couch (<i>Digitaria didactyla</i>)	12mm to 30mm	12mm to 20mm	20mm to 40mm	30mm to 50mm
Seashore paspalum (<i>Paspalum vaginatum</i>)	12mm to 40mm	12mm to 20mm	25mm to 50mm	30mm to 50mm
Kikuyu (<i>Pennisetum clandestinum</i>)	12mm to 40mm	12mm to 20mm	20mm to 40mm	40mm to 75mm
Soft buffalograss (<i>Stenotaphrum secundatum</i>)	Not suitable	Not suitable	Not suitable	50mm to 100mm

Appendix 3

Sureplay[®] Trade Mark Details

Trade Mark Details

Trade Mark Details

Trade Mark : 1046436

Word: SUREPLAY
Image: FOOTBALLER'S LEGS KICKS
FOOTBALL TOWARDS GOALPOST
Lodgement Date: 16-MAR-2005
Sealing Due: 17-FEB-2007
Date of Acceptance: 28-JUL-2006
**Acceptance
Advertised:** 17-AUG-2006
Class/es: 41, 42
Status: Accepted - Opposition period expired
Kind: n/a
Type: Composite
Owner/s: **The State of Queensland**
**c/- Department of Primary Industries And
Fisheries**
80 Ann Street
BRISBANE,4000,QLD
AUSTRALIA



Address for Service: Department of Primary Industries & Fisheries
Attn: Maarit Termonen
Legal Officer
Corporate Capability
GPO Box 46 BRISBANE
4001,QLD
AUSTRALIA

Goods & Services

Class: 41 Providing agricultural and horticultural training

Class: 42 Scientific research into the construction, repair and maintenance of sports playing surfaces; scientific research into horticulture in relation to sports field surfaces

Indexing Details - Word Constituents

PLAY SURE

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