Improved Irrigation of Racecourses

Identifying management and equipment strategies for improving irrigation efficiency

Cranfield Centre for Sports Surfaces
School of Applied Sciences
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IMPROVED IRRIGATION OF RACECOURSES

IDENTIFYING MANAGEMENT AND EQUIPMENT STRATEGIES FOR IMPROVING IRRIGATION EFFICIENCY

Preface

This report is based on the findings of a four year research project conducted at Cranfield University, funded by the Horserace Betting Levy Board (through the British Horseracing Authority) and the Engineering and Physical Sciences Research Council[1] and on Technical Report SC040008 / SR Part I[2], prepared by Cranfield University for the Environment Agency. The support and contribution to this research of Fraser Garrity and Richard Linley of the British Horseracing Authority and Mr Geoff Stickels, is gratefully acknowledged.

The report is designed to help put into practice the findings of the research on racecourses and training gallops for the benefit of horseracing.

Report Authors

Dr Iain James, Lecturer in Sports Surface Engineering

Colin Mumford, Research Engineer

Alex Vickers, Consultant TurfTrax GMS Ltd
(Visiting Fellow and formerly Lecturer in Sports Surface Technology, Cranfield University)

With assistance from:

Dr Keith Weatherhead, Senior Lecturer in Water Resources and Irrigation

Dr Jerry Knox, Principal Research Fellow, Irrigation and Water Resources

School of Applied Sciences
Cranfield University
Cranfield
MK43 0AL UK

Email: i.t.james@cranfield.ac.uk

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[1] Mumford, C (2006). The optimization of going management on UK racecourses using controlled water applications. EngD Thesis, Supervised by Alex Vickers, Cranfield University, Cranfield UK. Available online at http://hdl.handle.net/1826/1742

[2] Knox, J W; Weatherhead, E W; Rodriguez-Diaz, J A (2007). Assessing optimum irrigation water use: additional agricultural and non-agricultural sectors. Technical Report SC040008 / SR Part I, Centre for Water Science, Cranfield University, Cranfield UK.

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Executive Summary

Achieving more effective use of our increasingly scarce water resources in England and Wales must be a priority for horseracing. Ongoing changes in water regulation and the longer-term threats of climate change are likely to result in increased volatility and costs in water supplies for irrigation.

This is further magnified in horseracing by the issue of going-management to minimise risk of injury to horses and jockeys and maximise racing performance.

This report is based on a number of studies at Cranfield University, including a four-year research project funded by the Levy Board through the British Horseracing Authority (BHA). It provides practical information and guidelines to racecourse managers and ground staff on:

1. The rationale for improving irrigation efficiency on racecourses
2. How to maximise the effectiveness of irrigation water use on racecourses
3. How to understand the inherent causes of variability around UK racecourses
4. How to develop quantified, transferrable strategies to produce uniform going around a racecourse by variable applications of water
5. Recommended improvements to irrigation equipment and infrastructure
6. Investment strategies for mitigating risks of restricted water supply for horseracing

This is achieved through the use of example scenarios and exercises to challenge current practice and information on the recommended “pathway to efficiency”.

The report makes the following nine recommendations to the industry and all racecourses:

1. Raise industry and course awareness of the need to improve water efficiency – improving water use efficiency:
    - reduces water use costs
    - is better for the environment
    - builds a basis for continued use of water for irrigation in the future

2. Encourage racecourses to follow the “Pathway to Efficiency” outlined in this document

3. Map and understand track soil, soil conditions, traffic and wear variability so that managers can:
    - manage variability, for example soil-specific water applications for managing going
    - identify areas of risk to protect and manage accordingly

4. Adopt site specific going management strategies
    - by managing irrigation on a site-specific basis – based on mapped information of soil variation – courses can aim towards safe consistent going for the whole of a track

5. Invest in irrigation equipment and infrastructure to:
    - meet legislative requirements (from the BHA and the Environment Agency)
    - optimise irrigation effectiveness
    - provide flexibility and control to manage going to reduce withdrawal from races and cancellations

6. Invest in weather measurement equipment, such as a weather station so that:
    - precise application rates can be determined that account for recent precipitation, soil moisture deficit and current evapotranspiration
    - best irrigation water use can be demonstrated and recorded for the regulator

7. Schedule irrigation properly
    - peak evapotranspiration is at the warmest times of the day so schedule irrigation outside these periods
    - account for recent precipitation and soil moisture deficit
    - understand soil infiltration rates and how these are affected by compaction and capping in all soils and shrink swell cycles in clay soils

8. Invest more in on-course storage facilities for high-flow (winter) surface abstraction and rainwater harvesting (and even water recycling) to ensure security of supply and ease environmental / financial stresses

9. Invest more in routine calibration, servicing and maintenance of irrigation equipment
    - poorly calibrated, and or maintained equipment, can result in water wastage or under application of water
    - improper servicing/maintenance reduces equipment service life and therefore equipment cost

10. Invest more in training of individuals to ensure best practice
    - Trained staff are more motivated, will perform better and will be less likely to cause mistakes
    - Training on the principles and applications of the "Pathway to Efficiency" is essential for improving water use efficiency and reducing costs

11. Be aware of the importance of the Health and Safety in terms of justifying water use in both renewal of licences and periods of severe water restriction. This is in terms of jockey safety as well as horse safety.

1 Introduction

There are three key reasons for irrigating racecourses:

1. *To maintain a quality grass sward for racing and presentation*
2. *To achieve appropriate going conditions for fair racing.*
3. *To protect the health and safety of jockey and horse*

However, under increasingly water scarce summer conditions, all water users, including horseracing, have to demonstrate they are using water efficiently.

1.1 Current irrigation water use

As part of this project, all 59 racecourses in the UK were asked to complete a survey questionnaire on their current irrigation practices. Of the 48 respondents, 96% used irrigation. The results confirmed that water was applied in the summer months for all three of the above reasons, but it is also applied in pre-season applications to jump courses to ensure safe and suitable racing conditions at the start of the jump season (Figure 1).

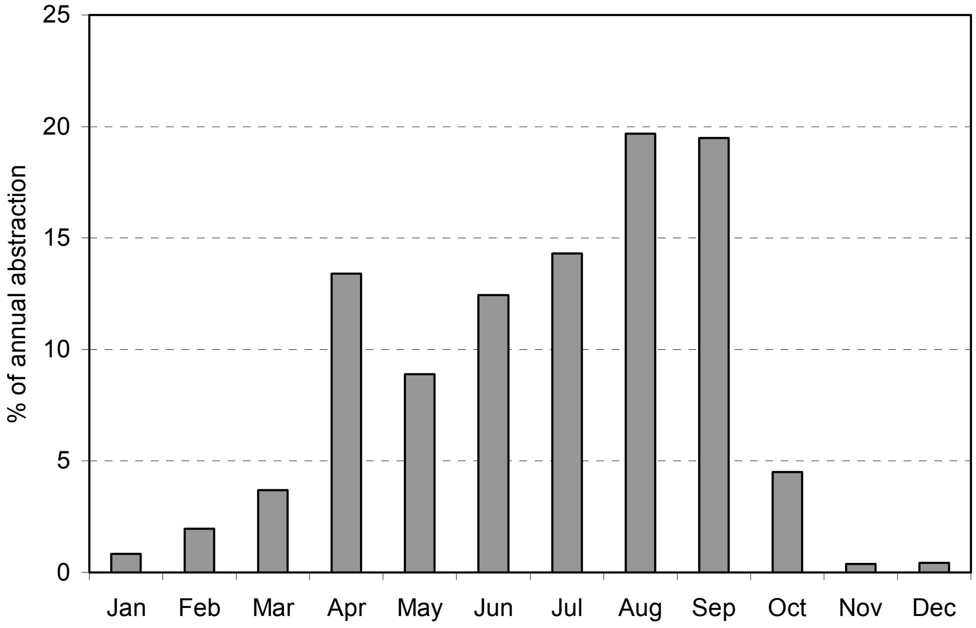

Figure 1 Seasonal timing of water abstraction for irrigation of racecourses in England and Wales in 2003 (expressed as a percentage of total abstraction) (from [2]).

The survey also investigated where irrigation water was sourced (Table 1) and how it is applied (Table 2). Table 1 highlights the fact that whilst most water is directly abstracted from surface water or groundwater, there are a number of racecourses that rely on public mains supply (relatively expensive, at least £0.50 - 0.80 /m^3 as opposed to £0.02 - £0.05 /m^3 for abstracted water) and there are few racecourses harvesting water (Table 1). The way that water is applied also varies, with reel and boom systems popular on flat racing tracks, where hurdles/jumps do not obstruct, but with static/hand-move sprinklers and rain guns being the most common choice on jump courses (Table 2). Modern hose reel and boom systems are capable of negotiating certain fence configurations (see Section 4 below).

Table 1 Proportion of respondents using various water resources for irrigation on UK racecourses (adapted from [1] and [2]).

Water source	*Racecourse type* *Flat*	 *Jump*
Surface water (rivers, streams)	34	53
Groundwater (boreholes)	44	34
Public mains supply	18	10
Rain water harvesting	4	3
Water re-use	0	0
Other	0	0
Total	**100**	**100**

Table 2 Application equipment (% split) used for irrigation on UK racecourses (adapted from [1] and [2]).

Application method	*Racecourse type* *Flat*	 *Jump*
Static or hand move sprinklers	27	46
Hose reel fitted with rain gun	1	17
Hose reel fitted with boom	53	31
Hose and hand held spray gun	0	0
Pop up sprinklers	18	6
Other	0	0
Total	**100**	**100**

In 2003, a very dry year in irrigation terms, 521,288 m^3 of water was abstracted on the 34 courses with abstraction licences; this represents 61% of the total licensed volume.[2]

In comparison to golf course irrigation, horseracing is thus a relatively small user of irrigation water. In 2003 the total licensed abstracted water volume was 8.4% of that of golf [2], because of the much smaller areas irrigated nationally. Both are minor users compared to agricultural irrigation, which itself uses only 1% of abstraction nationally.

However, like agricultural irrigation, horseracing and golf are consumptive users, and irrigate mostly during times when water resources are scarcest, in the driest months of the driest years, precisely when the water resources are most restricted.

1.2 Water abstraction licensing legislation

Water is a scarce resource, even in the UK. There are many demands for water – including public supply, sanitation, energy, food production and industrial uses. Managing and allocating water resources are the responsibility of the Environment Agency (EA) in England and Wales and of the Scottish Environmental Protection Agency (SEPA) in Scotland (It should be noted that the abstraction licensing regimes adopted by the EA and SEPA are quite different).

In England and Wales, the Water Act 2003[3] requires abstractors of water, such as racecourses, to use water effectively so that waste is minimized, and where possible, water consumption is reduced. Failure to do so could lead to non-renewal of a water abstraction licence[4]. Clearly this would have severe financial implications for the racecourse and its stakeholders.

If protecting abstraction licenses is not motivation enough, then it is worth considering the financial benefits from more effective water use. Abstraction of water from rivers and boreholes costs money. Where mains water is used, the cost savings are even more significant. If licences are removed or the permitted quantities are insufficient due to waste, then there is a risk of either (1) having to import water in tankers or (2) fixture cancellation due to firm ground – the cost of either of these can be extremely high.

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[3] HMSO. (2003) *Water Act 2003: Chapter 37* see <http://www.legislation.hmso.gov.uk/acts/acts2003/20030037.htm> (accessed 4th April 2005).

[4] Weatherhead, K. (2004) 'Changes to Irrigation Water Abstraction Management in England and Wales', *UK Irrigation*, **32**, 2-5.

1.3 *Highlighting the problems*

The following illustrative scenarios are for hypothetical track irrigating a 7 ha area. They are not based on any course in particular.

Scenario 1. Applying more water than necessary

In agricultural irrigation, it typically costs £0.05 /m^3 in charges to abstract water, with a marginal cost of £0.20 /m^3 to apply it. The cost of public mains water is typically £0.80 /m^3, with a similar marginal application cost. The marginal costs of application in horseracing are likely to be greater due to fewer economies of scale. A racecourse where water use optimisation has not been properly considered could easily apply 20 to100% more water than necessary, whether due to poor management, poor or inappropriate equipment or poor servicing.

Table 3 compares the additional costs for two scenarios assuming overwatering of just 20%, based on data provided in [2]. The direct marginal costs of over application might seem relatively small, however there are additional costs of over application whether over the whole course or localised. These include the risk of ground that is too soft, water-logging if it rains, localised flooding, compaction, turf quality reduction due to flooding, pollution from run-off and poor soil structure. All of these factors have a cost to a racecourse. Furthermore they are of significant cost to the environment which can have direct and indirect penalties.

Table 3 Examples of the marginal cost of over-application assuming a 20% over-application

Example	Soil type	Rainfall	Typical application		20% over application	Marginal cost of over application	
			Depth mm	Volume$^{(a)}$ m^3	Volume$^{(a)}$ m^3	Abstracted water$^{(b)}$ £ pa	Mains water$^{(c)}$ £ pa
Silt loam soil in NW Eng.	Fine sand/ silt loams	High	155	10850	13020	542	2170
Sand soil in SE Eng.	Coarse sand soils	Low	265	18550	22260	927	3710

(a) assuming a typical irrigated area of 7 ha; (b) assuming a typical cost of £0.25 /m^3 applied; assuming a typical cost of £1.00 /m^3 applied.

Scenario 2. Under-watering

It may be tempting to under-water, since this appears to save on both marginal cost and effort. However, under watering carries risks of firmer ground, resulting in increasing risk of injury to both horse and jockey. There is also a direct risk of mass withdrawal of runners and/or cancellation in these circumstances. Under-watering followed by heavy application to “catch-up” can result in a soft surface over a firm subsurface, within the depth of hoof-turf interaction, with an additional risk to horses and riders.

Scenario 3. Non-uniform watering

Non-uniform watering can be as a result of poor or inappropriate equipment, poor equipment set-up or a lack of equipment maintenance. The risks are from non-uniform going around the course – which is a potential hazard when racing as it becomes difficult for horses and jockeys to adapt to racing conditions and results in greater injury risk.

(This unintended non-uniform watering should not be confused with targeted applications to different management zones within the racecourse in order to manage variable soil conditions to produce uniform going; see Section 3 below).

Scenario 4. Insufficient water availability

This could be caused by over-abstraction to the licensed limit before the end of the season, severe water shortages within a catchment or restrictions imposed by water companies or the regulator. The consequence is usually that racecourses have to switch supply to other, more expensive sources of water such as public mains water. In extreme circumstances, such as those experienced in Sutton and East Surrey in 2006, water abstraction from mains water for irrigation can be stopped by emergency measures imposed by water companies. That particular example resulted in some sports facilities and golf courses having to import water using road tankers. The cost of the alternative – fixture cancellation – is equally substantial.

Scenario 5. Not being able to account for precipitation because of poor equipment
A racecourse knows that it needs to apply a net of 9 mm of irrigation in the 5 day period running up to a race (accounting for evapotranspiration). They also know that within that period 4 mm of rain is forecasted to fall.

If that racecourse is equipped with modern, effective equipment such as travelling booms or sprinkler systems, and a well designed and constructed water supply infrastructure system, then the course can wait for that rainfall and account for it by reducing application rates or applying full rates in a shorter period of time (within limits defined by infiltration rates and the rate at which water will distribute through the soil profile – i.e. you shouldn't apply large volumes of water immediately prior to racing – this is discussed in more depth below).

If that racecourse is using tow-lines or hand-moved sprinklers with low capacity infrastructure, this approach will not be possible and it will not be possible to manage the risk of waiting for rainfall – thus the issues of over- or under-application outlined in the above scenarios could exist.

2 Using water effectively

In order to maximise the efficiency of water use, racecourses need to understand fully irrigation scheduling, improve equipment and equipment maintenance and improve water storage on racecourses. These actions are inter-linked and can be represented as a "pathway to efficiency".

An understanding of the fundamental principles of the soil water balance is first required.

2.1 The soil water balance

Consider the soil water balance (Figure 2):

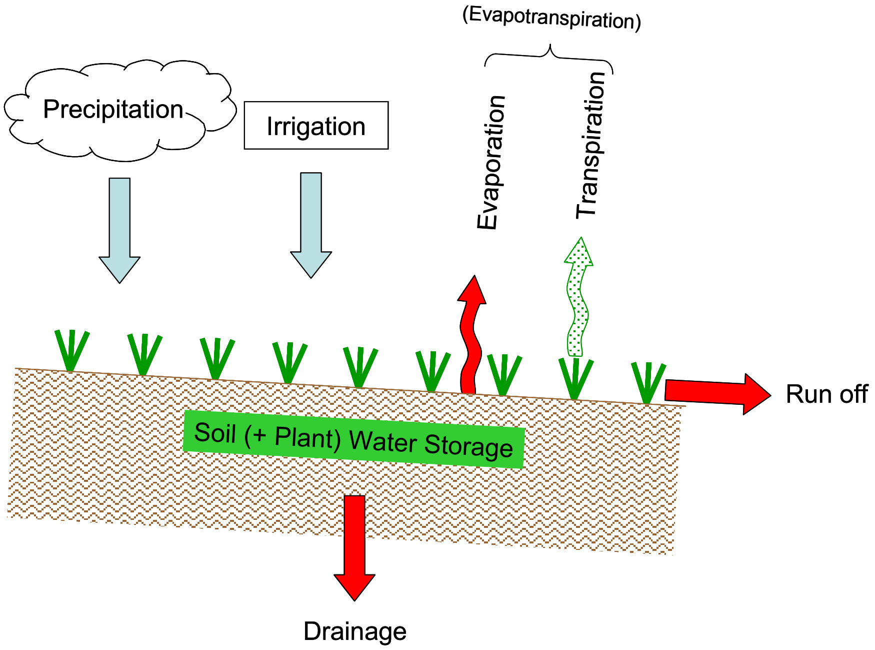

Figure 2 A simplified water balance model

The aim of irrigation is to ensure that there is enough water in the soil to achieve both the required going and the correct plant health. The input pathways for water are from precipitation (mostly rainfall) and from irrigation. The losses that can be controlled in irrigation scheduling are drainage through the soil profile and run off over the surface. Water will also be removed by evaporation and by transpiration (water movement through the plant). Losses by evaporation can be partly mitigated, e.g.

by irrigating in cooler conditions overnight. Evaporation and transpiration are commonly combined as evapotranspiration (ET). ET, like rainfall, varies with location and time of year (see Appendix 8.1). Figure 9 in Appendix 8.1 shows that in July in the southeast of the UK, ET can reach 3.8 mm d^{-1} in conditions similar to horseracing turf,

When replacing this water with irrigation, there is a danger that if too much water is applied, too quickly, there will be losses from drainage and run-off and localised heavy ground. Likewise if not enough is applied then drought and firm ground will result.

To maximise the effective use of water you must make sure that:

1. sufficient water is applied to achieve the desired going and healthy turf conditions
2. the inputs are no bigger than needed
3. wastage through runoff and drainage is kept to a minimum

2.2 The pathway to efficiency

In principle, efficient irrigation is simple – apply water at the right time and at the right place, and no more than necessary, but how can this be achieved in practice? For racecourses, the "pathway to efficiency" outlined in previous Cranfield University research seems a sensible way forward[5]. (Figure 3).

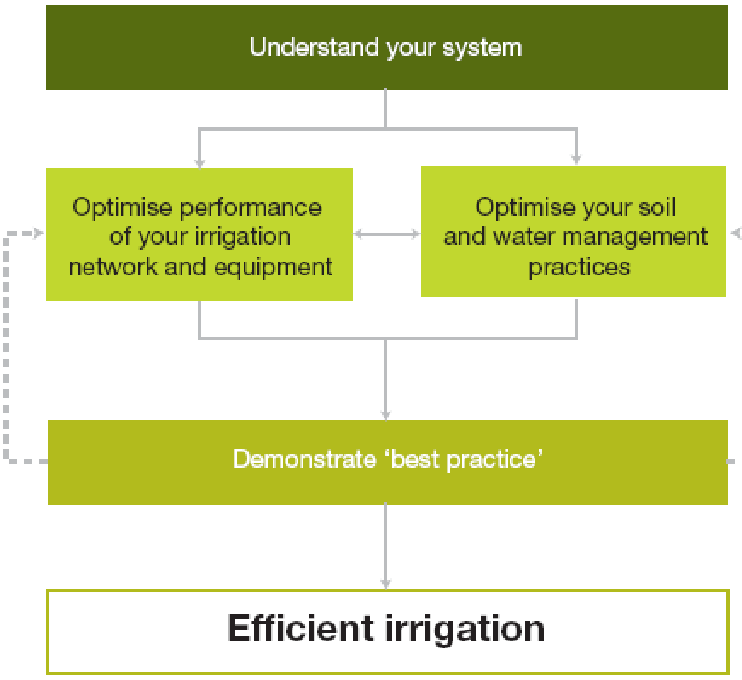

Figure 3 'The Pathway to Efficiency' (from [5])

2.2.1 Understand your system

This is the critical starting point on the pathway and is the key to getting the best out of your irrigation equipment and your soil and water management practices. Try the 5-minute Irrigation Performance Assessment in Appendix 8.2 to see how well you really understand your system.

2.2.2 Optimising your irrigation network and equipment

This means focusing on three key areas – pressure, water use and uniformity. The most widespread problem is low pressure, often the result of extending irrigation schemes without paying sufficient attention to the impacts of increased demand on pump capacity, the distribution network and equipment performance. The result is poor application uniformity with knock-on effects on turf quality

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[5] Knox, J; Kay M (2007). Save water and money – irrigate efficiently. A publication of the Natural England Regional Farm Advice Programme. Available from Natural England, Cranfield University and the UK Irrigation Association website.

and going conditions. Regular checks are needed on pressure and volumes of water delivered to different sections of the track for comparison with manufacturer's guidelines for pumps and on-course equipment. On-course tests using catch-cans can be used to check that correct equipment settings (e.g. sector angle, sprinkler spacing etc), water pressures and flow rates are being translated into a uniform application of water across the course (see Appendix 8.3) .

2.2.3 Optimising your soil and water management practices

This hinges on ensuring that water applications are managed (scheduled) according to turf and soil going requirements without unnecessary waste, avoiding over-irrigation and/or surface run-off. Most irrigation still relies on gut feeling to determine when it is right to irrigate, usually by walking the course and taking going measurements, combined with visual turf assessment. However, pressures from public expectation combined with the requirement to demonstrate 'reasonable need' at abstraction licence renewal will inevitably force ground staff to adopt a mix of both subjective and more scientific scheduling techniques.

2.2.4 Demonstrating best practice

The final step on the pathway is to demonstrate 'best practice.' Some of the best practices that have proved over time to lead to more efficient irrigation are listed below:

- Rate irrigation highly within your management system
- Know your soils – from an irrigation perspective (see Section 3)
- Design and maintain irrigation systems correctly, select appropriate systems and introduce scheduled servicing and regular maintenance
- Monitor all aspects of each irrigation event
- Use objective monitoring tools to schedule irrigation
- Irrigate to minimise ET by avoiding peak temperatures during the day
- Use more than one method to schedule irrigation
- Retain control of irrigation scheduling
- Remain open to new information

Water consumption can be reduced by monitoring water losses from the racecourse and replacing the water lost with controlled water applications (irrigation). This keeps wastage to a minimum and provides records of water use for any future abstraction licence application. The Environment Agency also requires you to protect water resources from pollution – both runoff and leaching through drainage can pollute water courses, with fertilizer or pesticides for example. By optimizing irrigation, the risk of pollution from runoff and leaching is reduced.

In practice, this might mean a change in your current practice but there are a number of relatively simple steps that can help to monitor water loss and achieve effective irrigation.

2.2.5 Measuring accuracy and uniformity

Manufacturers' guidelines for sprinkler output (based on nozzle size and pumping pressure) are not necessarily the same as the amount of water that reaches the intended target area. This can be due to drift (in windy conditions), worn nozzles, poorly aligned sprinkler heads, variable water pressure, and obstructions such as running rails, etc.

Direct measurement of the amount of irrigation water that reaches the target area is the best method to determine how much water has been applied. This is achieved by placing catch-cans on the turf. 5 litre buckets will do, preferably white in colour to reflect direct sunlight that would cause the water caught to evaporate. An example calculation is provided in Appendix 8.3. Compare these values to the target values you were expecting – is your system accurate?

Figure 4 Variability in spray pattern due to interference from the running rail

Having an array of catch-cans allows you to check uniformity as well. Note it is essential to use a large number of identical cans fir this, or the results can be seriously misleading –typically use 50 to 100 cans per test.

- If you are using a boom system then a few lines of catch-cans spread evenly across the track should be placed in the path of the boom and the boom travelling speed recorded.
- If you are using sprinklers or rain guns then a grid of catch-cans should be placed to cover the area between sprinklers and the time of irrigation recorded.

2.2.6 Improved scheduling using weather stations and soil moisture content sensors

When irrigating, it is vital to take into account the additional water 'applied' through rainfall and water lost – principally through ET (as shown in Figure 9), but also from runoff and drainage. Without this consideration, water will either be over- or under-applied. The ‘daily change’ in soil moisture can be calculated using the following equation (on a daily basis),

$$\text{Daily change (mm)} = \text{rainfall} + \text{irrigation} - \text{ET} - \text{runoff} - \text{drainage}$$

Where rainfall, irrigation, ET, runoff and drainage are all measured in mm.

To perform this calculation it is necessary to know the depth of rainfall, and ET. Small self-contained weather stations have been installed on some racecourses (Figure 5). These allow the manager to determine *when* rain falls and *how much* falls, and other useful information such as solar radiation, wind speed and relative humidity. These measurements, in conjunction with computer software allow calculation of the evapotranspiration and the determination of a 'daily change' soil water balance.

A minimum requirement is for a monitoring system that can record daily rainfall and ET.

Figure 5 An on-course weather station (left) and theta probe inserted next to GoingStick (right)

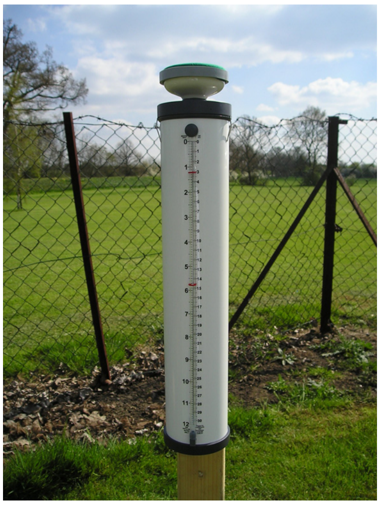

Figure 6 An atmometer (ETgage) used for measuring reference evapotranspiration (ET)

These include the use of direct measurement apparatus such as rain gauges (to measure rainfall) and 'Class-A pan' or porous ceramic 'atmometer' to obtain a direct measurement of reference evapotranspiration (evaporation and transpiration combined, or ET). In the UK, an increasing number of golf courses are now using the ETgage to estimate daily evapotranspiration on the course (**Error! Reference source not found.**). These basic devices are much cheaper (£300) than a weather station and can be placed at a representative point adjacent to the racecourse. Recent studies using ETgages for agricultural irrigation management have shown them to provide a high degree of accuracy for estimating ET (see Appendix 8.1).

In contrast, a full specification weather station typically costs in the order of £2500-£3000 at current prices. A full specification system offers automatic, computer-based logging of temperature, rainfall, solar radiation and sunshine hours, with detailed calculations of. As an alternative, some companies market schemes whereby you can rent a weather station and they provide calculations of soil moisture deficits, irrigation depths etc. Such services cost in the region of £1000 per annum.

Soil water measurement methods such as tensiometers, time domain reflectometry (TDR) and capacitance sensors allow direct measurements of the soils water status, enabling the manager to make informed decisions on whether to irrigate or not. Unfortunately, due to the high contact forces that horses have with the ground on a racecourse, and the depth of their hooves, it is not possible to permanently install soil water sensors within the top 150 mm of the soil profile on the running line. Installation would result in either damage to the sensor, or worse still, injury to the horse and its rider. Some racecourses do install water sensors under the running rail, off the racing line. However hand-held soil water sensors, such as a Theta Probe (available from Delta-T Devices, Cambridge, UK) , can still be used to good effect (Figure 5).

2.2.7 The importance of record keeping

Good record keeping of all irrigation applications is essential, particularly in the context of abstraction licence renewal – racecourse management staff need to record *what*, *when*, *where* and *why*.

What **was** ***(the amount)*** **of water applied?**
When **the water was applied?**
Where **the water was applied?**
Why **(the reason) was the water applied?**

By keeping good daily records you can both measure and demonstrate to the public, sponsors and the regulator, good effective irrigation water use. It is also essential as a management tool; without it you can not measure the improvement in response to improvements in scheduling, equipment etc.

3 Achieving Consistent Going: Causes and Management of Variation

3.1 *Why is consistent going important?*

The target 'ideal going' for racing, as stated in BHA General Instruction 3.2 ('Orders and Rules of Racing'[6]) is '*National Hunt courses* (jump courses) *should aim to produce good ground (and no firmer than Good to Firm),*' and '*Flat courses should aim to provide good to firm ground*', although good is acceptable in some cases.

The potential for the risk of injury to horses is greater when the surface rating goes from relatively firm to significantly softer over a short distance[7].

Track variability is very much part and parcel of UK racing as the racecourses have historically been developed on primarily poor agricultural land of varying soil type (soil types in the UK tend to vary over short distances due to our complex geology). In countries such as the US and those in the Far East, courses tend to have more consistent going because the tracks are purpose built and constructed from one material type. In the UK we are challenged with developing consistent going around a track, reducing the need for a horse to adapt to changing surface conditions during a race, and therefore reducing the potential for serious injuries to occur. To do this we need to map the causes and effects of variation around the racecourse and manage accordingly.

3.2 *How can I achieve consistent going?*

To achieve consistent going it is crucial that you manage your course in sections defined by the causes of variation (soil type, shade, topography etc). The most common example of this would be targeting different amounts of water to different soils on the track using strategic irrigation applications.

A good knowledge of the conditions found on and around the racecourse is necessary to be able to identify distinct sections of the racecourse that will require specific management. The starting point and the most useful information is a soil map of the racecourse. This will indicate the soil types present and where changes in soil type occur on the racecourse.

Each soil type will have its own unique characteristics in terms of texture, strength, infiltration (of water) and drainage. These factors all influence the amount of water required to alter a firmer level of going to a preferred softer level of going around the track generally.

Going can change around a racecourse due to variations in many factors, including the soil type, soil water content, compaction (particularly on the racing line), grass cover, drainage, topography, orientation, shading and poorly adjusted irrigation sprinklers or leaking irrigation pipes, and the presence of crossings. These factors can lead to a non-uniform surface rating (inconsistent going) around the length and across the width of the racecourse.

3.3 *How do I identify the soil types present on my racecourse?*

This is an extremely important exercise as it provides a very useful management tool. Once a soil map has been created it is unlikely to change so it is a sound one-off investment. Three options are presented here and they vary both in the time taken, the quality and the cost of the soil type identification. The identification can be carried out by either a qualified advisory service, such as that offered by an agronomist, or it can be carried out by a member of the maintenance staff. Some of the options available include:

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[6] BHA. (2005) The Horseracing Regulatory Authority General Instructions. Horseracing Regulatory Authority, London.

[7] Chivers, I.H. (1999) 'Prescription Surface Development: Racetrack Management', in D.E. Aldous (ed.), *International Turf Management Handbook*. London: CRC Press, 299-310.

3.3.1 In-field hand soil texture test method

A good indication of the soil types present on the racecourse can be achieved using the hand soil texture test. This is an inexpensive method, but can be time consuming. Soil samples are collected and moulded in the hand following step by step 'yes-no' answers to questions given in a key to their identification, such as 'Does the soil feel gritty?' or 'Does the soil stain your fingers?' The test can be carried out in situ and experienced practitioners can achieve a good degree of accuracy in identifying the soil type. *A key to carry out the hand soil texture test is provided in Appendix 8.4.*

You can do this using a 'survey grid', with a map of the course in hand, simply walk the course and, at regular intervals of a quarter-furlong, sample the soil and work out the texture using the key, then make a note of the soil in that location and move on to the next sampling point.

3.3.2 Particle size distribution analysis

Soil samples are collected at locations along the length and across the width of the racecourse. Several soil samples per location are required. The samples should be put into separate bags and labelled to identify the location where they came from. The samples should then be sent to a laboratory service provider that can determine the soil textural class for each sample using particle size distribution analysis – if you are unsure of where to find a suitable laboratory ask your agronomist or advisor for a recommendation.

Particle size distribution analysis by the 'Pipette Method' is an accurate method, but the sampling can be time consuming and potentially expensive, depending on the number of samples to be tested. The laboratory analysis takes approximately one week to complete. An alternative, faster and lower cost method laboratory method is analysis by 'Laser Particle Sizing', the results are less accurate than the pipette method but are probably better than the hand texturing method – so might be useful for mapping the soils around your racecourse.

3.3.3 EMI soil mapping

Developments in remote sensing for precision farming has led to more efficient, economic and effective management practices, and has driven advances in soil mapping techniques, including non-intrusive rapid scanning sensors that can measure soil apparent electrical conductivity (ECa) by electromagnetic induction (EMI). Research has shown that EMI soil scanning can quickly identify general soil characteristics, and highlight areas that require further study using traditional soil analysis techniques[8,9].

Maps generated by EMI scanning do not produce soil maps directly but can indicate where soil characteristics change, due to the ability of the soil to conduct an electrical current. Sand has a low conductivity (usually indicated by a lighter area on a map), silt has a medium conductivity, and clay has a high conductivity (usually indicated by a darker area). The maps generated enable the racecourse manager to identify variation across the course and adjust their maintenance practices accordingly for that area. By targeting soil sampling to areas of different conductivity on the racecourse a soil map might be produced at lower cost than using the above 'survey grid' methods.

A commercially available service that combines EMI scanning, on-site soil surveying and laboratory analysis costs in the region of £3800, but the benefit is that a detailed map of variability is produced that can identify not only soil-type features but also soil moisture content distribution and in some cases buried features such as services, collapsed drains *etc.* that can contribute to racecourse variability – depending on site conditions and soil moisture status at the time of the survey.

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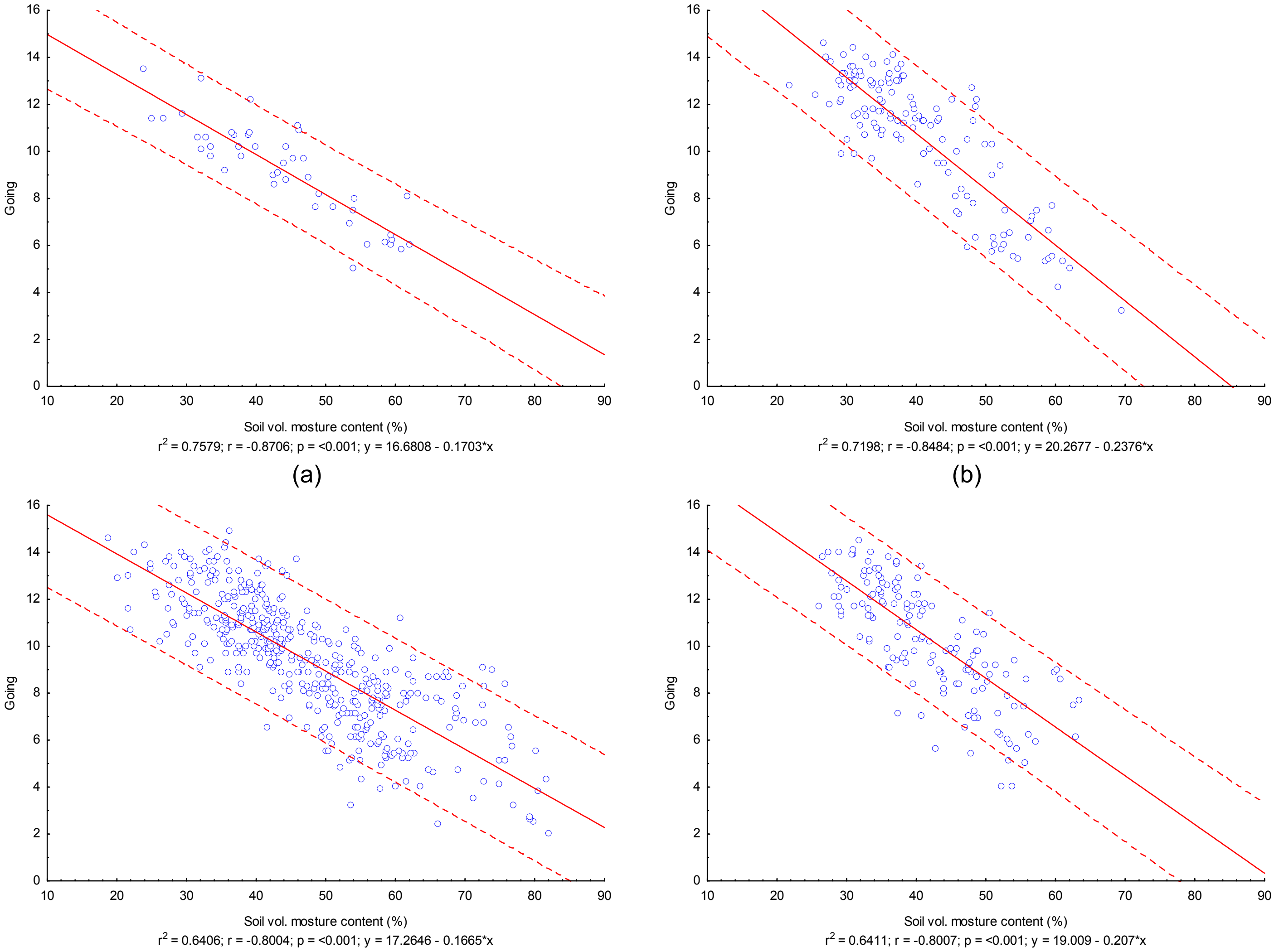
[8] James I T; Waine T W; Bradley R I; Taylor J C; Godwin R J (2003). Determination of soil type boundaries using electromagnetic induction scanning techniques. *Biosystems Engineering*, **86**(4): 421-430

[9] Gale, L.W. (2003) *A Preliminary Investigation into the Relationship between Electromagnetic Induction Data and Soil Chemical and Physical Properties of a Low Maintenance Natural Turf Football Pitch*. MSc thesis. Cranfield University, UK

3.4 *Irrigating to manage going*

The general principle is that by adding water, going will reduce in firmness. Research has shown that the relationship between the quantity applied and the exact change in going is complex and dependent upon a number of factors including variation in soil texture and structure and seasonal variation in turf rooting [1].

The research demonstrated a strong negative linear relationship between going and moisture content on all soil types tested (Figure 7). For example on a sandy loam soil found on two racecourses, a decrease in Going from 10 to 8 using the TurfTrax GoingStick would require an increase in soil volumetric moisture content of 21% (Figure 7d). This change in moisture content can be achieved using irrigation but the depth of water required is dependent upon a number of variables.



(a) (b)

(c) (d)

Figure 7 The relationship between (volumetric) soil moisture content and going on (a) clay (b) clay loam (c) sandy clay loam and (d) sandy loam soils from two racecourses in the UK. The dashed red lines represent the boundary within which there is a 95% probability that the linear relationship modelled by the solid red line is correct. r^2 is the 'goodness of fit' of the linear model and is better the closer the value is to 1. The slope of the model, or the rate of change in going as soil moisture content is changed, is given by the multiplier of x, (*i.e.* 0.1703 for the clay, 0.2376 for the clay loam, 0.1665 for the sandy clay loam and 0.207 for the sandy loam). The importance of these parameters is explained in the text.

The general interpretation of Figure 7 is that a reduction in going can be achieved by an increase in moisture content and that the rate at which this going reduction – moisture content increase relationship takes place is constant, i.e. the same increase in moisture content will always result in the same 'amount' of decrease in going as measured by the GoingStick, whether you go from 20 to 30% or 40 to 50%, for the same soil type. This is indicated by the diagonal solid red lines in Figure 7

The first problem arises because the rate of change is different for different soil types (the slopes of the lines are different) – there is a specific relationship for each soil. The relationship is also site specific and depends on soil management practices used on site. Achieving moisture content change through irrigation is challenging because the even vertical distribution of water is often limited by soil properties such as structure and differences in bulk density (compaction etc.)

With a map of soil variability around the track different amounts could be applied to different soils. There are other factors such as topography and differential compaction that also have to be considered and these cause variability in the data and reduce the value of r^2, or the 'goodness of fit' of the model used. For example note that within the upper 95% confidence band, an addition of 21% could result in no change in going, although this would be unlikely.

In practice many irrigation managers will rely on experience, knowing which areas of the track require more or less water. This is all very well, but when Head Groundstaff / Estate Managers move courses, or leave then a significant knowledge gap can exist. A good estimate of the amount of water required to change a firmer level of going to a preferred softer level can be achieved with the development of a user-friendly '*irrigation ready-reckoner*' table (see Appendix 8.5). Groundstaff can use this to quantify and record their irrigation experience, simply by measuring the change in going in response to known depths of irrigation water. Over time this creates a permanent 'ready reckoner' which can be used by current and future staff. This is necessarily unique to each racecourse as the system is too variable for generic solutions.

It is critical that management decisions are based on time periods that allow water to fully infiltrate through the profile. Understanding differences in water content through the profile greatly improves the management of going – enough time must be allowed for water to move into the soil profile. The change in going is also sensitive to the particular moisture content prior to irrigation – especially on clay soils. It is important to keep note of forecasted rain when adding water as irrigation otherwise ground can become too soft.

3.5 I have clay soils on my course – how does adding water affect my soil structure and going?

Many (but not all) clay soils will shrink when they dry and swell when they get wet. This is what causes cracking as a clay soil dries out. In the natural environment in the UK, the soils would dry in the summer, shrinking and cracking and then wet in the winter – swelling. This cyclic shrink-swell of clay soils helps form structure in the soil which aids drainage, aeration and root growth.

Racecourses that maintain the going at or very close to a level conducive to racing by irrigating between summer race meetings will be keeping the soil wet so that it does not shrink during the summer months.

This potentially leads to excessive water use and, on racecourses that are on these shrink and swell clay soils the swollen soil is prone to compaction in both the summer and winter. If winter racing is held on the same racecourse, and remedial action is not taken to alleviate compaction and structural damage, there will be no development of structure in the soil by shrink swell and drainage problems can occur. Remember that waterlogged surfaces are one of the main causes for cancellations of flat and jump racing[10].

Soil should ideally be allowed to dry, which causes shrinkage that maintains and renews the soils structure through the natural formation of cracks, fissures and soil, aggregates. The benefits of good soil structure include enhanced soil aeration, better turfgrass rooting and improved drainage

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[10] Mumford, C. (2006) *The Optimization of Going Management on UK Racecourses using Controlled Water Applications*. Unpublished EngD Thesis. Cranfield University, UK.

characteristics. This can take 2-3 weeks and of course has to be fitted into the racing calendar without putting fixtures at jeopardy from cancellation due to firm ground – but with planning, many clay-based racecourses will be able to allow for ‘drying-shrinking breaks’ in their summer watering programmes, where racing calendars, and irrigation infrastructure to re-wet the course following the drying period, exists.

Taking this approach also reduces water consumption, complying with the requirements of the Water Act 2003 (as discussed above). However the risk of soils being too dry (and hence too firm) prior to a meeting must be managed. Irrigating with large quantities of water in short time periods prior to racing will lead to all the problems identified in Scenario 1 – 'Applying more water than necessary' – presented above.

3.6 But if I don’t irrigate, cracks appear at the surface – how can I prevent this?

Racecourses that have long periods between race meetings, and/or a high clay content, may experience cracks forming at the surface if irrigation is significantly reduced between race meetings. A common misconception is that large volumes of water are required to close the cracks, when the reality is quite the reverse. Applying large volumes of water to large cracks generally results in the water flowing down the cracks, bypassing the intended soil target area. As a consequence, the cracks remain open and the water applied is lost (wasted) to drainage. However, more frequent applications of smaller amounts of water that do not result in drainage and run-off are more likely to wet the soil *between* the cracks near the surface, which causes it to swell and close the cracks.

4 Enhancing irrigation infrastructure

4.1 Equipment choice

The BHA stipulate that racecourses must be able to apply 6 mm of water to the whole racecourse in 24 hours as an absolute minimum; summer jumping courses should have a greater application rate than this. To achieve applications of water greater than 6 mm per day may require an increase in the capacity of the irrigation system, so that the water flow rate and pressure is sufficient to apply the larger volumes of water to the entire racecourse in a 24 hour period. This may mean increasing the pumping capacity, irrigation pipe diameters and the controlling systems, dependent on the irrigation system currently installed.

Table 4 A simple comparison between replacement boom and sprinkler systems

System	Travelling Boom	Sprinkler system	Tow-lines
Covers whole track width	✓	✓	✗
Precise and accurate	✓✓	✓	✗
Flexible system	✓		✓
Low labour	✗	✓✓	✗
Sophisticated control		✓	✗
Can be used overnight	✗	✓	✗
Can be used unsupervised (H&S)	✗	✓	✗
Simple infrastructure	✓	✗	✓
Infrastructure accessed easily	✓	✗	✓
Easily maintained	✓✓	✓✗	✓
Susceptible to vandalism	✓	✓	✓
Pricing	Depends on the number of units required		

If you are currently using a static hand moved sprinkler, rain gun systems or tow-lines then you should consider investment in new, more accurate irrigation systems that can offer greater accuracy and control, with potential reductions in labour. You should consider pop-up sprinklers or a travelling boom system. Likewise you might have a pop-up sprinkler system or an older boom system that needs replacing and you might be considering your options for a new purchase. A simple comparison can be made by looking at **Error! Reference source not found.**.

Most racecourses in the UK (both flat and jump) are moving towards mobile hose-reel systems fitted with booms for their irrigation. On a 'typical' racecourse, two machines are being deployed. On some of the larger courses (e.g. Aintree, Ascot and Newbury) 3 machines are in operation. These systems operate with boom typically irrigating a wetted width of 20-24 m across the course and applying 10-12 mm in a single application on jump courses and slightly less on flat courses. The system requirements are usually a 50 kW pumpset and a 160 mm distribution (ring) main. The typical costs for a machine package (excluding underground pipework) are £20-25,000

4.1.1 Travelling boom

Travelling boom irrigators enable the entire width of a racecourse to be irrigated in one pass, achieving more consistent surface conditions (assuming the soil texture does not vary). A study at Cranfield University[1] showed that a boom irrigation system was more uniform than pop-up sprinklers operated from one side of the track. Commercially available systems are capable of negotiating corners and hurdles/jumps. Such systems require greater labour inputs to operate than a conventional pop-up irrigation system. In addition, unless several units are used and assuming the ring main has sufficient pressure, then the time taken to water the whole track can be quite long making it difficult to get enough water onto the track as a whole. Low pressure nozzles can be used to reduce supply pressure demand.

Figure 8 A travelling boom irrigator in use on a racecourse

4.1.2 Fixed sprinkler systems

Modern sprinkler systems can be installed to cover whole track widths (half width from each side). It is important that irrigation rates match infiltration rates – if water is applied too quickly it will pond and be wasted as run-off. If this occurs, use a series of smaller applications. Valve-in-head sprinklers are common in golf applications and are independently controlled, allowing greater control over the area to be watered, and should reduce overall water applications if used correctly. Independent control of sprinklers allows variable application to different soil types or different topographies for example.

A very important application of such sprinkler systems is in the individual irrigation of obstacle take-offs and landings. This allows heavily compacted areas to be kept safe by careful control of soil moisture using targeted, accurate applications of water in localised areas.

Traditionally, servicing of sprinkler systems has been an issue with particular concern over buried pipe work. Modern polyethylene pipe work is more durable than traditional PVC as it is less susceptible to breakage. Contact your irrigation supplier for details – all major brands of pop-sprinklers offer both the valve and pipe technology.

4.1.3 Summary

When choosing a system, you should consider the following:

- Is the system suitable for your operating environment?
- Is the system suitable for your location?
- Seeking good advice from irrigation engineers / consultants
- Getting competitive quotations for all the suitable options

An appropriate solution to a major racecourse in the south east may not be appropriate to a smaller course in the west of the country because the volumes and intensities of water applications will not be the same.

4.2 The importance of regular maintenance

All irrigation systems lose efficiency and effectiveness as they wear. This can be wear of nozzles, adversely affecting spray pattern and droplet size – increasing the risk of drift. Alternatively this can be wear of mechanical parts preventing full movement of sprinkler heads, booms etc. Pump wear and pipe deterioration results in reduced pressures, reducing application rates and sprinkler overlap. Such effects were observed at a number of racecourses in this project.

A programme of regular inspection and servicing is vital and will help prevent the negative effects of non-uniform applications of water. The programme should include regular inspection of nozzles, hoses, seals, couplings and pipe systems and replacement where necessary. Moving components, such as pumps, reel drive systems and pop-up sprinkler heads, should be inspected and maintained by suitably trained personnel. Adopting a routine, preventative approach will result in savings for both water use and equipment costs.

4.3 Enhancing water storage capacity

As was demonstrated in Table 1, not many racecourses are storing water for use in irrigation. This is surprising and quite different from other sectors such as golf and agriculture.

By investing in storage capacity, racecourses can abstract water when water supply is greater. There are other benefits too – the reservoir acts as a storage buffer so that supply of water to the irrigation system is more consistent and flexible (when there is available water in the reservoir).

There is an additional benefit from having water reservoirs because excess rainfall can then be harvested from roofs and/or across the course (whether through surface channel networks or subsurface drainage).

There is a significant capital investment in the construction of reservoirs. The scale of this investment is dependent on a number of aspects including environmental restrictions (SSSIs etc), planning application requirement and the scale of earthworks required. Soil type is also critical – freely draining, light soils will require plastic lining, adding to costs. There is also the cost of the pipework to connect to the water source and the irrigation system, and the cost of double pumping the water (into and out of the reservoir), but a site-specific cost-benefit analysis can be produced by an irrigation engineer/consultant. Costs are site specific and depend on the scale of the project. A recent construction of a reservoir for agricultural irrigation, of 4.7 ha, on a sandy soil and holding 77,280 m^3 or 17 million gallons, cost ca. £150 k. The costs comprised 50% from earth moving, 8.5% from infrastructure and the remainder was the cost of lining the reservoir – obviously this is site and particularly soil dependent.

An additional method of reducing the cost of abstracted/mains water is to recycle water within the racecourse – such systems are increasingly popular in golf, where environmental sustainability is a demand placed on golf providers by players and members. It is conceivable that the same demand could be used as a marketing advantage in horseracing. Again there are capital costs to consider and irrigation water quality should be monitored as salinity can build up, but water can be treated if necessary.

4.4 Water auditing

An irrigation water audit can pay real dividends by helping to demonstrate responsible and efficient water management at licence renewal. It may soon be required by some racecourses irrigating in catchments where the aquatic environment and water resources are considered to be under threat due to an unsustainable abstraction regime. It can also help to:

- Recognise the real costs and benefits of irrigation (£ per m^3 of water) and the value of water to your business. This is invaluable when planning to invest in irrigation, or considering a change in technology, or improving your irrigation efficiency.
- Identify any operational and management issues that can improve your water efficiency.
- Better understand the important links between climate variability, irrigation abstractions, turf water use and equipment performance.

Collecting and using information:

The Environment Agency has yet to define the kind of water audit needed for licence renewal. But it makes good sense not to wait and to start collecting basic information now on how well your irrigation system is working and on your soil and water management practices. Just how much information you collect will depend on your local circumstances and the extent of your system.

Basic information to collect:

Background

- Historical irrigation abstractions on a weekly or monthly basis
- Irrigated area (ha), and total depth of irrigation water applied (mm) in each year
- ‘Other’ agronomic factors that influence turf irrigation practices e.g. race preparation, horse and rider safety
- Irrigation training for course management staff

Irrigation network and equipment

- Pressure at the pump (weekly)
- Metered irrigation water use – volume pumped and the volume supplied to course (each irrigation)
- Water distribution uniformity (annually).
- Soil and water management
- Soil type and soil conditions (going) on the course (weekly)
- Weather data (daily rainfall and ET) (daily).

Use the information to:

- Compare scheduled and metered water use
- Estimate costs of irrigation (£ per m^3 of water)
- Correlate irrigation water use against climate.

5 Recommendations

Based on the above research, predicted water availability issues and the demands of regulators, governing bodies, trainers, jockeys and race-goers, this report makes nine recommendations to the industry and all racecourses to:

1. Raise industry and course awareness of the need to improve water efficiency – improving water use efficiency:
    - reduces water use costs
    - is better for the environment
    - builds a basis for continued use of water for irrigation in the future

2. Encourage racecourses to follow the “Pathway to Efficiency” outlined in this document

3. Map and understand track soil, soil conditions, traffic and wear variability so that managers can:
    - manage variability, for example soil-specific water applications for managing going
    - identify areas of risk to protect and manage accordingly

4. Adopt site specific going management strategies
    - by managing irrigation on a site-specific basis – based on mapped information of soil variation – courses can aim towards safe consistent going for the whole of a track

5. Invest in irrigation equipment and infrastructure to:
    - meet legislative requirements (from the BHA and the Environment Agency)
    - optimise irrigation effectiveness
    - provide flexibility and control to manage going to reduce withdrawal from races and cancellations

6. Invest in weather measurement equipment, such as a weather station so that:
    - precise application rates can be determined that account for recent precipitation, soil moisture deficit and current evapotranspiration
    - best irrigation water use can be demonstrated and recorded for the regulator

7. Schedule irrigation properly
    - peak evapotranspiration is at the warmest times of the day so schedule irrigation outside these periods
    - account for recent precipitation and soil moisture deficit
    - understand soil infiltration rates and how these are affected by compaction and capping in all soils and shrink swell cycles in clay soils

8. Invest more in on-course storage facilities for high-flow (winter) surface abstraction and rainwater harvesting (and even water recycling) to ensure security of supply and ease environmental / financial stresses

9. Invest more in routine calibration, servicing and maintenance of irrigation equipment
    - poorly calibrated, and or maintained equipment, can result in water wastage or under application of water
    - improper servicing/maintenance reduces equipment service life and therefore equipment cost

10. Invest more in training of individuals to ensure best practice
    - Trained staff are more motivated, will perform better and will be less likely to cause mistakes
    - Training on the principles and applications of the "Pathway to Efficiency" is essential for improving water use efficiency and reducing costs

11. Be aware of the importance of the Health and Safety in terms of justifying water use in both renewal of licences and periods of severe water restriction. This is in terms of jockey safety as well as horse safety.

6 About Cranfield Centre for Sports Surfaces

Cranfield University's Centre for Sports Surfaces is one of the world's leading centres for research, postgraduate education and consultancy in sports surface technology and engineering.

CCSS works with industry, sports governing bodies and research partners to provide safe, durable and sustainable sports surfaces – essential for improving access to sports facilities and participation. The Centre offers a unique blend of expertise encompassing scientific, analytical and technical skills in soil and water engineering, soil science, agronomy, irrigation and mechanisation, state-of-art facilities and high-level teaching and research. Our strength is our ability to apply inter-disciplinary science and technology to practical, cost-effective and functional solutions to the development of any natural or artificial sports surface.

7 Contact details

If you have any queries concerning this report, please do not hesitate to contact:

Dr Iain James, Lecturer in Sports Surface Engineering
Cranfield Centre for Sports Surfaces
School of Applied Sciences (Building 42a), Cranfield University, Cranfield, Bedfordshire MK43 0AL, UK t: 01234 750111 x2736 e: i.t.james@cranfield.ac.uk

8 Appendix

8.1 *Mapping and measuring variation in ET*

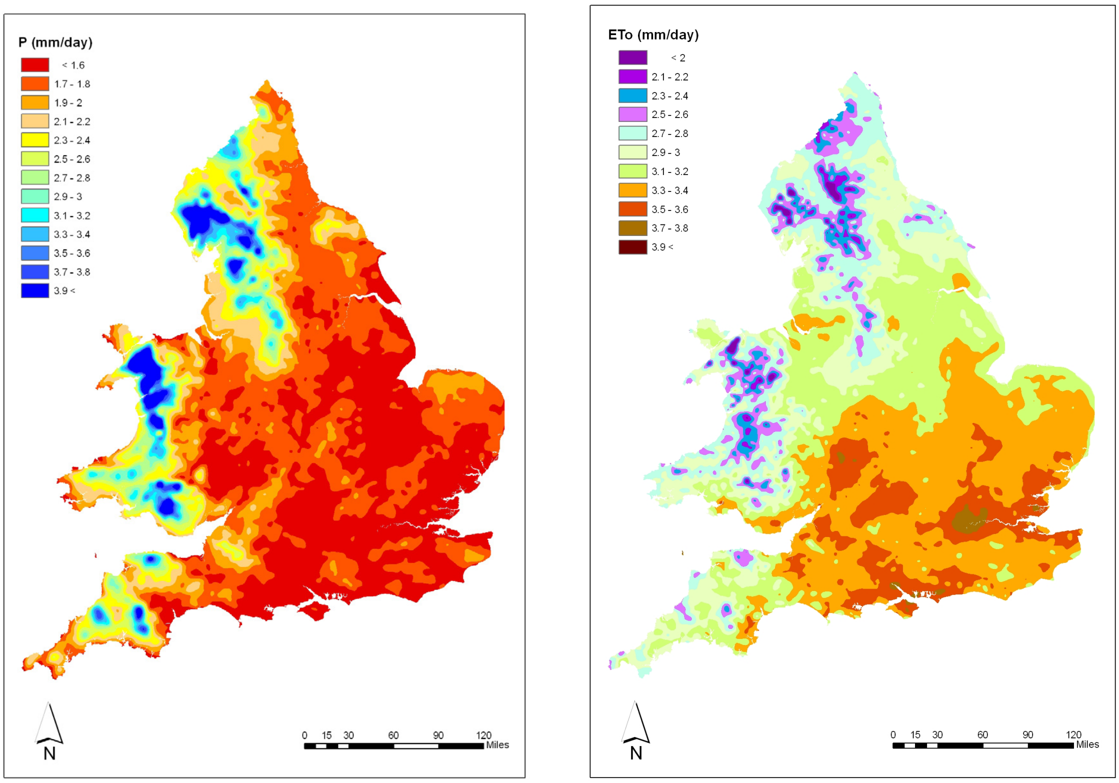


Figure 9 Spatial variation in rainfall (P) and reference evapotranspiration (ETo) in July across England and Wales, based on a 30 year mean monthly gridded climate dataset (Source: Knox et al., 2007a).

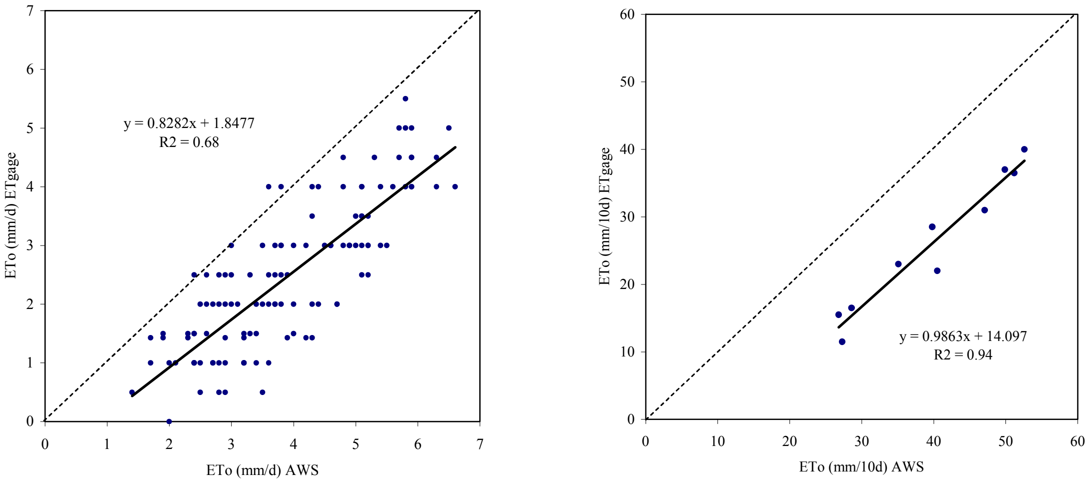


Figure 10 Daily (a) and 10-day (b) comparison of reference ET derived from the ETgage with an automatic weather station (AWS) between May and August 2006 (Source: Knox et al., 2007b).

8.2 5-minute irrigation performance assessment

Q1. Do you have enough water in a season to meet your total course irrigation demand?

1 Don't know
2 Inadequate volume
3 Adequate in an average year
4 Adequate in all years

Q2. Can you abstract enough water to meet your course water requirements in a peak month?

1 Don't know
2 Inadequate volume
3 Adequate in average year
4 Adequate in all years

Q3. Do you have a strategy for managing periods of limited water availability/restriction?

1 No plan
2 Limited consideration
3 Some consideration
4 Detailed strategy

Q4. How efficient is your on-course storage and distribution system?

1 Don't know
2 OK
3 Good
4 Excellent

Q5. Does your irrigation system (e.g. gun, boom) operate at its design pressure in each section of the track?

1 Don't know
2 No
3 Yes, in most sections
4 Yes, in all sections

Q6. How uniformly does your system apply irrigation water within different areas of the course?

1 Don't know
2 Large variations
3 Some variation
4 Only minor variations

Q7. Do you know the rate of water applied (e.g. m_3/ hr) by your system?

1 Don't know
2 Based on manufacturer's information only
3 Measured some time ago
4 Measured routinely

Q8. What is the current physical condition of your pumping, distribution and application system?

1 Don't know
2 Major repairs required
3 Minor repairs required
4 No repairs required

Q9. Do you compare your surface quality and going against the volume of water applied?

1 Not measured
2 At whole-course level only
3 Sometimes at section level
4 Routinely at section level

Q10. Do you use a scientific tool (e.g. theta probe, computer model etc) to schedule your irrigation applications?

1 No, visual inspection only
2 Scientific tool in some sections
3 Scientific tool on all sections

Q11. Do you modify your irrigation applications in response to forecast weather conditions?

1 No
2 Sometimes
3 Usually
4 Always

Q12. What is the quality of the water you use for irrigation?

1 Don't know
2 Marginal
3 Satisfactory
4 Good

Q13. Do you think you would save water by becoming more efficient?

1 Yes, definitely
2 Maybe
3 Don't know
4 No

Now add up your score to assess your opportunity to improve irrigation efficiency:

Score:
0 – 17 Major
18 – 34 Moderate
35 – 51 Minor

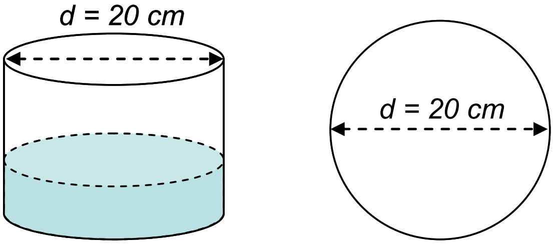
If your score is low then revisit the questions to see where you can best make improvements to your irrigation system and management practices.

8.3 Calculating irrigation depth using catch-cans

You can use the following calculation to determine the amount of water applied (depth in mm):

$$\text{Irrigation (mm)} = \frac{\text{Volume of water in the catch-can (litres)}}{\text{Surface area of the catch-can (m}^2\text{)}}$$

For example consider the catch-can below which contains 350 ml (or 0.35 litres) of water



We measured the volume of water (using a measuring cylinder or jug) to be 0.35 litres, but we need to calculate the surface area of the catch-can of diameter d of 20 cm…

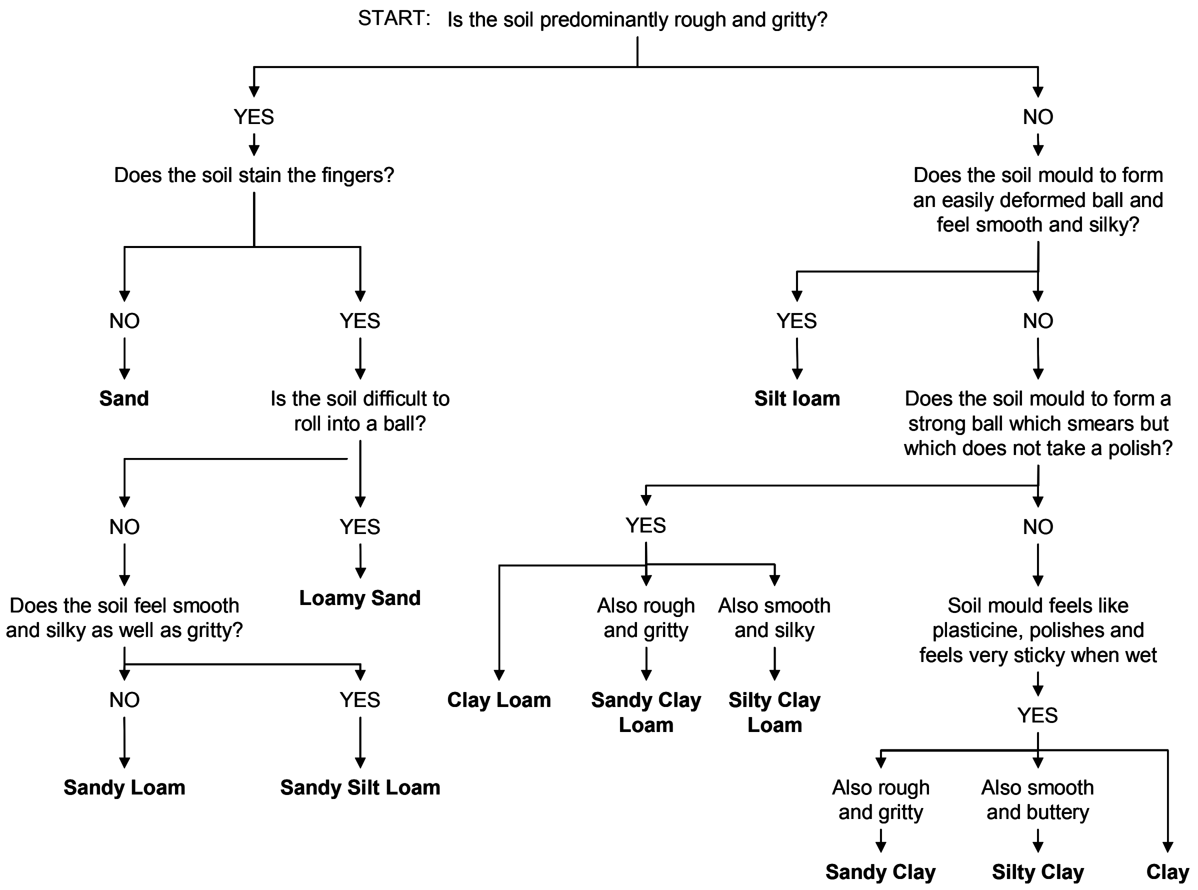
$$\text{Surface area of the catch-can (m}^2\text{)} = \pi \times \frac{d^2}{4} = 3.142 \times \frac{0.2 \times 0.2}{4} = 0.0314 \text{ m}^2$$

Therefore the depth of irrigation is:

$$\text{Irrigation (mm)} = \frac{0.35}{0.0314} = 11 \text{ mm}$$

If this 11 mm was collected in 10 minutes then the irrigation equipment is applying 1.1 mm/min. For boom systems you will need to know the boom travel speed.

8.4 A key for hand soil texture determination method



General method:

1. Take about a dessert spoonful of soil.
2. If dry, wet up gradually, kneading thoroughly between finger and thumb until soil crumbs are broken down. Enough moisture is needed to hold the soil together and to show its maximum stickiness.
3. When handling the soil, pebbles, grit, roots, etc., should be discarded. Make sure such materials are not being mistaken for coarse sand.
4. Do not over wet the soil - if the sample is very moist, clays have a soft smooth feel which may be mistaken for silt.
5. Follow the paths in the soil identification key (above) to determine the soil texture class.
6. Dark coloured soils may be full of organic matter which gives the soil a silky feel similar to, and often mistaken for high silt content.

8.5 How can I determine how much water to apply to reduce the going to the level required?

To produce the *ready-reckoner*, you will need:

1. Knowledge of the soil types found on the racecourse (ideally a soil map),
   note: if large variations in the soil types exist, for example clay and sand, then a table will need to be established for each soil type.

2. A measurement of going (descriptive or numerical).
   either by your own assessment or using a GoingStick

3. A measurement of the amount of *net irrigation* applied (mm)
   using the calculation below (similar to the Daily Change balance above)

4. A measurement of daily ET and rainfall (mm)
   e.g. from a weather station or a weather service provider.

8.5.1 What does the ready-reckoner table look like?

The table shows the depth of effective irrigation in mm needed to change the initial going to a target value of going. So for example if you wanted to change the going from 10.7 to 9.4 (as measured by the Going Stick) at the example racecourse below, you would need 9 mm of net irrigation (accounting for irrigation/rainfall lost as ET) – see the value highlighted by the arrows where the horizontal and vertical light blue sections converge.

Ready-Reckoner Table

Initial going	Net Irrigation (mm)						
10.7	15	15	13	10	►9◄	8	
10.6	13			9	7	7	
10.5	12	12	9			6	
10.4	11		8				
10.3	9						
10.2	7						
Preferred going	**9.0**	**9.1**	**9.2**	**9.3**	**9.4**	**9.5**	

Note that the table is specific to the racecourse – in particular the soil type at that racecourse, the soil structure and the irrigation system. You will need to build up a table like this of your own but the process is simple and it will allow you and your staff easy access to the information needed to change going as required. The table shown is incomplete; this is because it needs to be constructed over time.

8.5.2 How do I construct the ready-reckoner table?

The ready-reckoner table is easy to develop using the six-step process below.

Step 1: We need to know what the initial going is, so measure going for a known soil type on the racecourse, *e.g.*

Going = **10.7** (as measured with the Going Stick)

Step 2: Carry out irrigation in the manner normally practised, making sure you use catch-cans to measure the depth of irrigation applied!

Applied irrigation = **7 mm** (measured using catch-cans)

Step 3: To find out the effect of the irrigation, re-measure and record going at the same location 24 hours later

Going = **9.4**

Step 4: In these calculations we need to calculate the net irrigation so we will need to allow for the water lost as ET and added as rainfall during those 24 hours.

ET = **3 mm**
Rainfall = **1 mm**
Net irrigation = (rainfall + applied irrigation) – ET
= (1 + 7) – 3
= **5 mm**

Step 5: In this case going changed from 10.7 to 9.4 with 5 mm of net irrigation, so simply plot the value 5 in the right place in the table, for example:

Ready-Reckoner Table

Initial going	Net Irrigation (mm)						
10.7					5		
10.6							
10.5							
10.4							
10.3							
10.2							
Preferred going	9.0	9.1	9.2	9.3	9.4	9.5	

The process (steps 1 to 5) should be repeated for different initial going and preferred going values for each soil type as you water the course over time, until comprehensive tables for each soil type are developed. Continued measurements will enable the refinement of the net irrigation value until a reliable average value is achieved. Note you may need to ignore some spurious results; the final table should show numbers that decrease from left to right and from top to bottom.

This will take time to develop but once developed will be an excellent aid for course watering for a long time. It will also be an ideal tool for demonstrating to the Environment Agency that you are applying water as needed.