CASE STUDY

Assessment of Irrigation at Kingsway Reserve

City of Wanneroo

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Summary

Perth NRM worked with the City of Wanneroo over the 2019/20 irrigation season to improve the efficiency of irrigation on the football oval at the Kingsway Sporting Complex.

The uniformity of the sprinkler irrigation at two sites on the oval was measured by using a grid of catch cans. The distribution uniformity of the irrigation pattern was below acceptable standards even under low wind conditions.

Six sets of soil moisture sensors were installed below the turf to determine the accuracy of the sensors and to assess the usefulness of the equipment in assisting with scheduling of irrigation events. The equipment accurately measured soil moisture.

The biggest limitation to using soil moisture sensors to assist with irrigation scheduling was the poor application uniformity of the irrigation.

The sensors showed that the soil moisture below much of the sprinkler wetting pattern was above the critical moisture content indicating that the irrigation could have been reduced. However, within 10 metres of the sensors, in the locations where the sprinkler application rate was lower, the soil was dry, and the condition of the turf was poor.

In an attempt to improve the sprinkler uniformity, the sprinkler nozzles and operating pressure were altered, and the uniformity was re-tested. These changes made only slight improvements to the uniformity of the irrigation.

It is estimated that over 50% of sports turf in the Perth Metropolitan area show dry patches in the summer months as a result of poor irrigation uniformity. This poor uniformity is exacerbated under windy conditions that are common on the Swan Coastal Plain. To significantly improve irrigation uniformity, it is likely that on many areas, sprinklers and laterals will need to be installed at closer spacings than what are currently used.

Guidelines for the design of turf irrigation systems that have an acceptable distribution uniformity in the windy conditions should be developed and this information needs to be extended to industry.

To schedule irrigations more accurately irrigation managers should use evapotranspiration data from the nearest weather station. Soil moisture sensors can be used to monitor the effectiveness of this weather-based approach.

Background

Climate change and falling water tables have resulted in the Department of Water and Environmental Regulation planning to reduce water allocations to irrigators in the north Wanneroo area by 10% in 2028. This reduction in water allocations will require irrigators to either irrigate more efficiently or reduce the area of land that they irrigate.

The low cost of water, poor irrigation application uniformity and a lack of understanding of evaporation replacement methodologies and soil moisture monitoring has often resulted in poor irrigation efficiency on sports turf areas.

The City of Wanneroo manage large areas of sports turf. Perth NRM, with assistance from Forrest and Forrest Horticultural Consultancy Services, worked with City of Wanneroo staff over the 2019/20 irrigation season to assess methods to improve irrigation efficiency on a site at the Kingsway Sporting Complex. The uniformity of the irrigation system was measured, and soil moisture monitoring was used to assess the City's evaporation replacement approach to scheduling irrigation.

Hunter I25 sprinklers with brown jets are used to irrigate the Kingsway football oval. They are spaced in a triangular pattern at a distance of 16.5 m x 16.5 m and have an operating pressure at the sprinkler head of 500 kPa. The soil type is a Yellow Karrakatta sand which contains less than 2% clay.

The City of Wanneroo use evapotranspiration (ETo) data from a weather station at the Kingsway Sporting Complex. The irrigation controller is programmed to replace a percentage of the ETo and this amount is applied automatically as irrigation.

The work on the Kingsway site can be as a case study for directing future work with sports turf irrigators.

Results and discussion

Irrigation uniformity

The overlapping circular patterns of sprinkler irrigation systems do not apply water uniformly. The Distribution Uniformity (DU) is a statistical measure of the uniformity of an irrigation system. The internationally accepted minimum standard for the DU of a sprinkler irrigation system is 75%. To obtain even grass growth irrigators need to ensure that the areas with the lowest application rate receive sufficient water, consequently areas that have a higher application rate receive excess water. The scheduling coefficient (SC) is a measure of the additional amount of water that needs to be applied to ensure that the driest areas receive sufficient water.

Sprinkler uniformity testing at the Kingsway football oval

Thirty catch cans were placed at an even spacing within the sprinkler wetting pattern at two locations (north and south test areas). Irrigation was applied, the water in each can was measured and the distribution uniformity of the irrigation was calculated. Figure 1 shows the application rate (mm/hour) in the north test area. The black cylinders indicate the location of the sprinklers. The testing was conducted during light south westerly winds.

The distribution uniformity (DU) of this test was 72% which is below the minimum acceptable DU for sprinkler irrigation (75%). It can be seen in Figure 1 that at 72 % DU some areas are receiving two and a half times as much water as other areas. The scheduling coefficient for this test was 1.6. This means that an additional 60% of water needs to be applied in order for the driest 5% of the wetting pattern to receive sufficient water.

Figure 2 is an aerial photograph of a portion of Kingsway Reserve that was taken in January 2020. The football oval and rugby pitch are shown within the red lines. A regular pattern of brown patches can be seen on both areas and these patches relate to dry areas within the sprinkler wetting pattern. Figure 3 is a photograph of the oval which was taken in December 13 following a week of hot, dry and windy weather. The dry patches can also be seen. These patches occur midway between the irrigation laterals.

Figure 1. Diagram showing the variable rate of irrigation that was applied during the test in the north area.

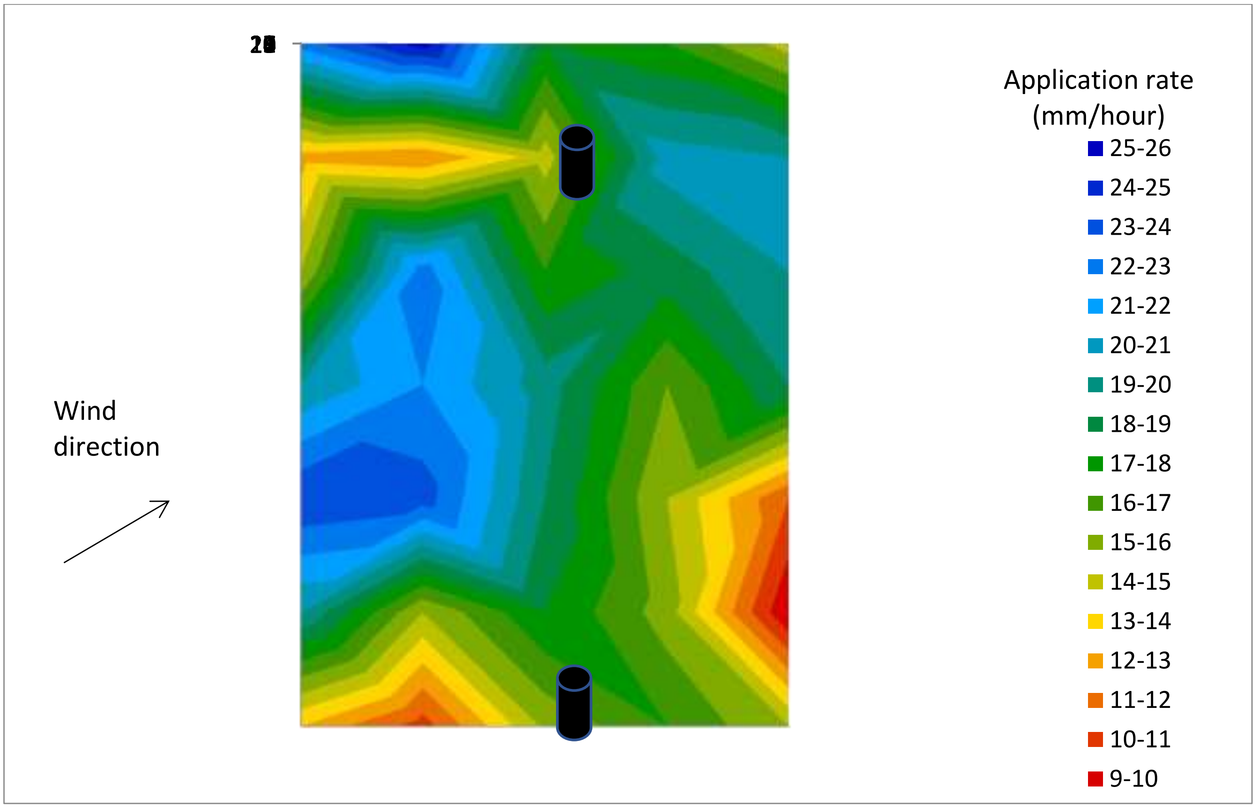


Figure 2. Aerial photograph showing the dry patches in the wetting pattern

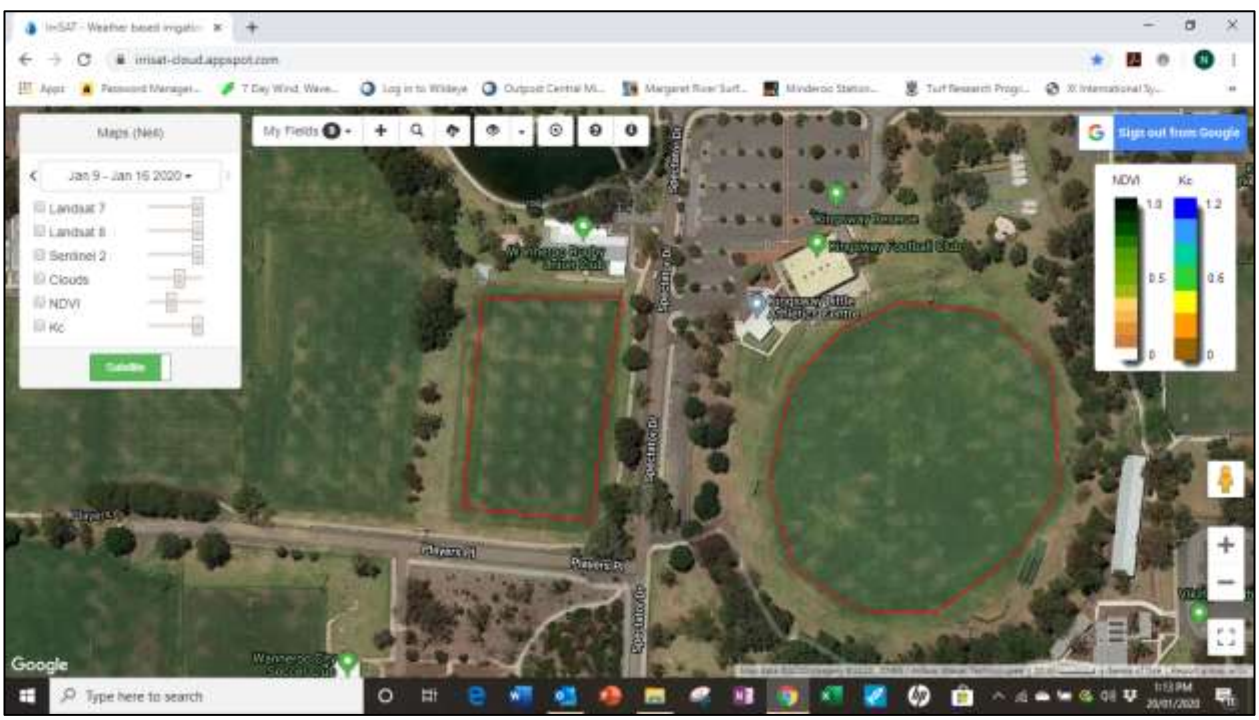


Figure 3. Dry patches on the Kingsway football oval on December 13, 2019

The irrigation uniformity testing, which was conducted when a light south westerly wind was blowing, showed that the uniformity of the irrigation was poor (DU = 72 % north area and DU = 65 % south area). Further uniformity testing should be conducted to get a better understanding of the irrigation uniformity over a range of typical wind speeds and directions.

In summer, the football oval at Kingsway sporting complex is typically irrigated once per day at about 10:30 pm. At this time of day during the summer months the wind is typically light to moderate and from the east to south east direction. However, during hot periods the wind is typically stronger, and this may influence uniformity.

Altering the nozzle size and operating pressure to improve uniformity

Unless the existing irrigation system applies water with a very poor uniformity it is unlikely that a local government authority would install a new irrigation system with closer sprinkler spacings. This would involve installing new laterals pipes, and additional valves and sprinklers to the area.

The application uniformity of the existing system may be able to be improved by making minor changes, such as changing the sprinkler type or nozzle size, or increasing the water pressure at the sprinkler head.

To test if changes to the nozzle size and pressure could improve the distribution uniformity further sprinkler uniformity testing was conducted on February 3, 2020. Testing was conducted on a day with moderate easterly winds which had an average wind speed of 11 km/hour over the testing. This wind speed and direction is common in summer when hot conditions occur, and the dry patches appear in the turf.

The sprinkler uniformity of the existing system (Hunter I25 sprinkler with brown nozzles and with a pressure of 500 kPa at the sprinkler nozzle) was assessed. Then the nozzle size was increased to the blue nozzle and operated with a system pressure of 400 kPa to see if this would result in an improvement in the application uniformity. The larger nozzle and lower pressure will produce a larger droplet size that might perform better in windy conditions.

Table 1 shows the results of the testing. Changing the nozzle and operating pressure made only a slight improvement to the distribution uniformity (DU) and scheduling coefficient (SC).

Table 1. Sprinkler uniformity test results when nozzle and operating pressure were altered

Sprinkler	Nozzle	Sprinkler spacing	Wind speed	Pressure kPa	DU	SC
Hunter I25	Brown	16.5 m x 16.5 m	11 km/hour easterly	500	68	1.9
Hunter I25	Blue	16.5 m x 16.5 m	11 km/hour easterly	400	70	1.8

Though only two nozzle/operating pressure combinations were trialled it is likely that changes to nozzle size and pressure will not be able to increase the uniformity of the system. To significantly increase the uniformity of application the sprinkler spacing will have to be reduced.

Soil moisture monitoring at Kingsway football oval

Teros 10 capacitance sensors were used to monitor soil moisture below the turf during the summer of 2019/20. Figure 4 shows one set of equipment with three probes and a data logger. The probes were installed at 4, 8 and 12 cm deep as it was believed that these depths corresponded with the top, middle and bottom of the main root zone.

Three sets of soil moisture sensors were installed into the north test area on the oval and three sets of soil moisture sensors were installed into the south test area on the oval. The north side of the oval was classified as a high wear location and the south side of the oval was classified as a low wear location. Three sets of soil moisture sensors were installed at each site so that the accuracy and consistency of the equipment could be assessed.

The sprinkler uniformity testing data was used to locate an area within the north and south areas that received an irrigation application rate that was average for the whole wetting pattern. The sensors were installed in this 'average application rate' area. The loggers and battery packs were placed in valve boxes below the surface of the turf. GPS coordinates of the location of the valve boxes were taken so that they could be found and removed prior to coring the turf.

Wildeye plug and play IoT hardware cloud-based software and data hosting was used for collection, presentation and analysis of sensor data.

Figure 4. Teros 10 capacitance probes connected to a Wildeye logger

Consistency of data

Three sets of sensors (3 sensors at 4 cm deep, 3 sensors at 8 cm deep and 3 sensors at 12 cm deep) were installed within 50 cm of each other at both the north and south sites. This was done so that the accuracy and consistency of the sensors could be evaluated. Variability in measurements can be caused by:

- Poor installation, such as having pockets of air around the sensor
- Not placing the sensor within a representative section of the root system and irrigation pattern
- The accuracy in the equipment itself

The soil moisture graphs showed that the sensors in the north area all gave similar readings and the soil moisture sensors in the south area all gave similar readings. It was concluded that when Teros 10 sensors are properly installed in a representative section of the root zone they can be successfully used to monitor soil moisture under turf.

Differences in soil moisture in the north and south areas

Figures 5 and 6 show the soil moisture graphs for the south and north sites respectively. The line graphs show the volumetric water content of the soil with the percentage indicated on the left vertical axis of the graph. The evapotranspiration for the Wanneroo weather station is shown by the bar graphs and is indicted as mm on the right vertical axis of the graph. The daily irrigations can be seen in the soil moisture data.

The soil moisture levels in the north area were significantly drier than those in the south area (Figures 5 and 6). Whether these differences in soil moisture were related to greater activity and consequent wear of the turf in the north area or whether they were due to different irrigation application rates could not be determined. The initial uniformity test showed that the application rate at the sensors in the north area was 16 mm/hour while in the south area the application rate at the sensors was 20 mm/hour.

Figure 5. Soil moisture data from the south area for a period of time in January 2020

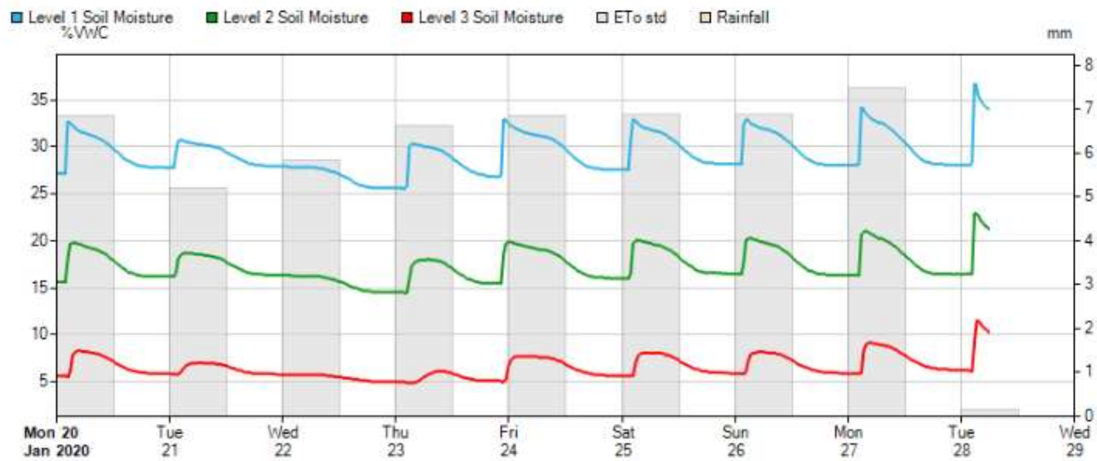
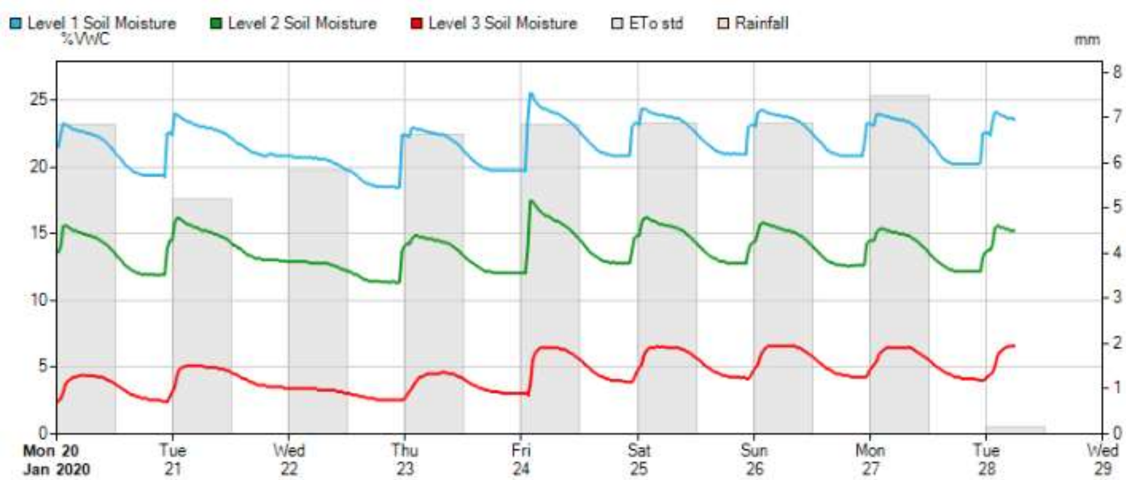


Figure 6. Soil moisture data from the north area for a period of time in January 2020



Soil moisture monitoring research by PNRM with fruit growers on sands at West Gingin determined that soil moisture content in the main root zone should be kept above approximately 8 % in order to prevent crop stress (Lantzke 2020). The critical soil moisture content for turf on the sands of the Swan Coastal Plain requires further examination but the figures for fruit trees can be used as a starting point.

It can be seen from Figures 5 and 6 that the soil moisture content in the top two sensors did not fall below 15% (south area) and 12% (north area). The grass in these areas was dark green, actively growing and did not appeared to be moisture stressed. However, because of the poor irrigation uniformity there were areas within 10 metres of the sensors that contained dry grass. Excavation of the soil in these poor growing areas showed that the soil was dry and this was confirmed with the use of a hand held portable soil moisture monitoring probe (Field Scout TDR 350, Spectrum Technologies).

Irrigation efficiency on sports turf in the Perth area

Distribution uniformity of sprinkler systems

Turf consultant John Forrest estimates that over 50% of the sports turf in the Perth Metropolitan Area shows dry patches in the summer months as a result of poor irrigation uniformity. These areas of weaker grass are the first to become damaged during periods of high use and can become bare and muddy in the winter months.

Irrigation managers who have irrigation systems that apply water with a poor uniformity can take two approaches:

1. Irrigate so that the majority of the sprinkler wetting pattern receives adequate water and accept that areas with a lower application rate will be drier and the grass will grow poorly here.
2. Irrigate so that areas of the sprinkler wetting pattern which receive less water are adequately irrigated and there is no poor growth. This will result in excessive amounts of water being applied to large areas of the wetting pattern.

Sprinkler manufacturers provide performance specifications (operating pressure, discharge and radius of throw) of their sprinklers. Information on appropriate sprinkler spacings is also often given, however these guidelines are generally based on indoor testing under windless conditions. Many sprinkler irrigation systems are not adequately designed to account for the strong winds experienced on the Swan Coastal Plain and have a poor distribution uniformity on windy days.

As wind speed increases the uniformity of sprinkler irrigation typically decreases. Figure 7 presents data from a Department of Primary Industries and Regional Development (DPIRD) sprinkler testing program (Lantzke et. al., 2003) that shows how the uniformity of sprinkler irrigation decreases as wind speed increases and as the distance between the sprinklers is increased. This data is for an impact sprinkler that is typically used on vegetable properties, but the same relationships occur with turf sprinklers. It can be seen that when spaced at 16 m x 16 m this sprinkler performs satisfactorily at low wind speeds but once the wind speed increases above about 12 km/hour the DU drops below the acceptable level of 75%. However, when spaced at 12 m x 12 m, the sprinkler performs well at all the windspeeds shown.

Figure 7 also shows the scheduling coefficient (SC). The SC is a figure that indicates the additional length of time that a sprinkler system should be run to account for the sprinkler uniformity in the driest 5 % of the area. For example, a system operating at 100 per cent uniformity has a SC of 1.0. If the SC is 1.5 then that irrigation system has to be run for an extra 50 per cent to achieve the same precipitation in the driest area as in the average of the entire wetted area.

Figure 7 shows that when this sprinkler is spaced at a 16 m x 16 m and at wind speeds above 16 km/hour the SC is 1.6 which means that the irrigation needs to be run for an extra 60% of time to ensure the driest areas receive sufficient water.

At a 12 m x 12 m spacing the irrigation system has a SC of 1.3 which means that it needs to be run for an extra 30% of time to ensure the driest areas receive sufficient water. Therefore, on days with high wind speeds a 30% saving in water can be made by using the closer sprinkler spacing.

Figure 7. The effect of wind speed and sprinkler spacing on the distribution uniformity (DU) and scheduling coefficient (SC).

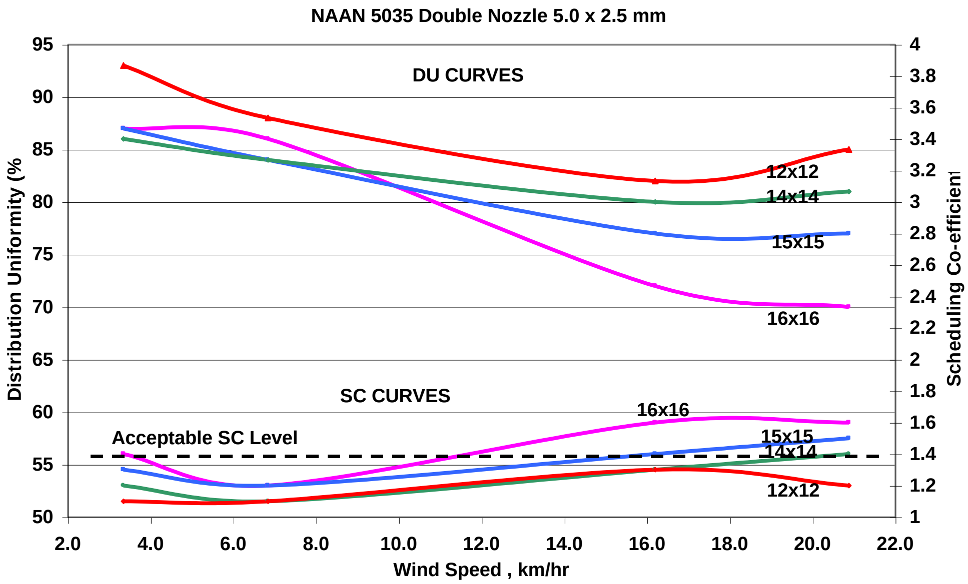
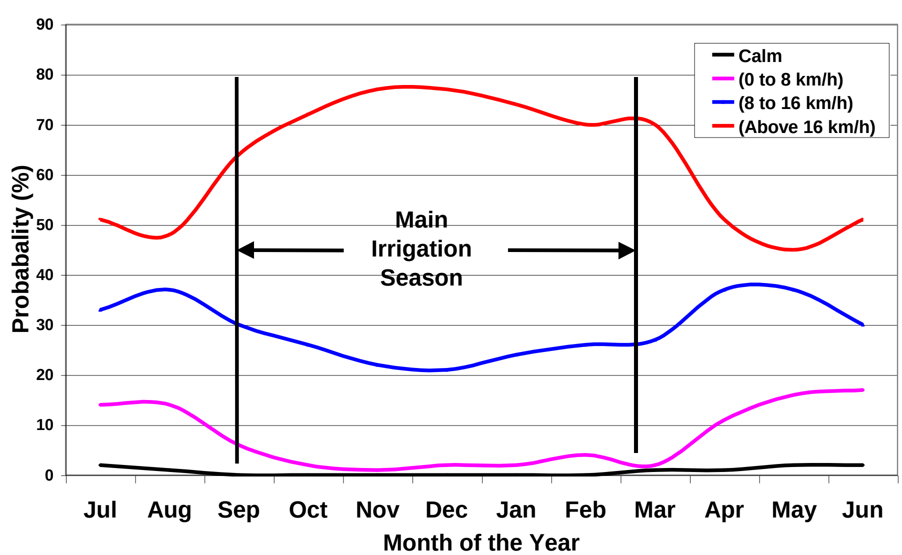


Figure 8 shows the probability of different average wind speeds at Perth during each month of the year. It can be seen that in the main irrigation season the wind speed is often above 16 km/hour.

Figure 8. Probability of a different average wind speeds at Perth during the months of the year



Poor irrigation uniformity is probably the biggest constraint to increasing water use efficiency in sports turf in the Perth region. Irrigation managers need to apply considerable quantities of extra water to ensure sufficient water is applied to those parts of the wetting pattern that receive less water. To significantly improve irrigation uniformity, it is likely that on many areas, that the sprinklers and laterals will need to be installed at closer spacings than what are currently used.

The other major factor that results in inefficient irrigation practices is poor irrigation scheduling. Not using predicted or actual evapotranspiration (ETo) to accurately schedule irrigation amounts also decreases water use efficiency but it is difficult to schedule irrigations using ETo data when the irrigation system does not apply water at a reasonable uniformity (see the section on 'Using evapotranspiration data to assist with scheduling irrigation').

Information that clearly demonstrates that closer spacings will increase the DU, particularly under windy conditions, is required to convince local government authorities and other managers of sports turf that many of the existing designs are not appropriate.

Sprinkler uniformity tests conducted in the past should be collated from all available sources to better understand the performance of existing sports turf irrigation systems.

If required, more sprinkler testing on sports turf areas should be conducted under a range of wind conditions to understand how wind effects application uniformity. The DPIRD sprinkler testing facility could be re-established to allow testing of sprinklers at various spacings and pressures over a range of wind speeds. This facility measured the uniformity from one sprinkler only and used a computer program (Space Pro) to allow the user to overlap wetting patterns at different spacings and orientations. This approach greatly reduces the amount of field work that is required.

An economic assessment should be conducted comparing the total capital and operating cost of installing a more uniform irrigation system and with examples of typical existing irrigation designs. The capital cost of installing a more uniform system will be higher (more laterals, sprinklers and valves per hectare) however more even turf growth can be achieved with less water which is important with a planned reduction in water allocations. Alternatively, the higher capital cost can be compared with other approaches to dealing with a reduction in water allocations such as reducing the area that is irrigated or buying additional water allocations.

Existing irrigation systems have been designed assuming plentiful water supplies and a cheap cost of water (pumping costs only). Now that water allocations are being reduced it is likely that the economic assessment will show that irrigation systems with a better DU are the best option for any new irrigation systems, and possibly for replacing existing systems that have a very poor application uniformity. If the climate continues to dry further, reductions in water allocations may be necessary or temporary water restrictions may be applied following a number of consecutive low rainfall years.

An additional benefit of having an irrigation system with an acceptable DU is that, because of the reduced variability, fewer soil moisture sensors are required to understand soil moisture over an area of sports turf.

Further increases in water use efficiency could be made by having different irrigation shifts to account for the different water demands of different areas. In the case of Kingsway Reserve, the football oval and the surrounding open space were irrigated on the same shift. The water requirements of the open space are less than the oval, so these areas are receiving excessive amount of water.

Using evapotranspiration data to assist with scheduling irrigation

Irrigation managers use a range of approaches to determine how much irrigation to apply to turf. Some irrigation managers use past experience or the visual appearance of the turf to determine how much water to apply. Monitoring of soil moisture with irrigators has shown that this approach often results in over or under irrigation.

Crop water use is closely related to the rate of evaporation or the rate of evapotranspiration (ETo) as measured from a weather station. Using actual or predicted ETo is the best method to accurately determine how much irrigation is required. The predicted ETo for the coming days is available by email or text message from a number of sources and this information can be used to reduce or increase the amount of water that is applied.

Different areas of turf may have different irrigation needs. The percentage of the ETo that is applied as irrigation (crop coefficient) can be varied to account for the irrigation needs of different areas of turf.

The uniformity of the irrigation system needs to be taken into account when using the ETo and crop coefficient approach. On areas of turf that have a poor irrigation uniformity, additional water will need to be applied to ensure the areas with a lower application rate receive sufficient water. The amount of additional watering that is required is defined by the scheduling coefficient.

In practice, irrigation controller and system design constraints often limit the capacity to adjust the rate of irrigation, especially where there are large numbers of active playing surfaces.

Comments on the usefulness of soil moisture monitoring in sports turf

Soil moisture monitoring provides useful feedback to the irrigator on the effectiveness of their current irrigation program. The sensors show the irrigation manager what depths irrigations have reached and critical soil moisture levels or 'refill points' for turf on the sands of the Swan Coastal Plain can be determined. Soil moisture sensors can be used to help determine what percentage of evaporation should be replaced by daily irrigations.

The biggest limitation to using soil moisture sensors to assist with irrigation scheduling is the poor application uniformity of the irrigation at some sites. In this study the sensors were installed into an area of the wetting pattern which had an average application rate. The sensors showed that the soil moisture at this location remained moist and that the soil could have been allowed to dry out further without affecting turf growth. However, within 10 metres of the sensors, in the locations where the sprinkler application rate was lower, the soil was dry and the grass was brown. Consequently, the City of Wanneroo Staff could not reduce the irrigation run time for that irrigation shift.

If the aim of the irrigator is to ensure all parts of the wetting pattern receive sufficient water, then the soil moisture sensors should be installed in the driest part of the wetting pattern. The soil moisture content in this area should be then kept above the critical level at which moisture stress occurs. The remainder of the wetting pattern will receive excessive amounts of water.

If the irrigation system has an acceptable distribution uniformity, and some level of minor stress is allowable in the areas with a lower application rate then it is probably best to install the sensors in an area of the wetting pattern that has an 'average' application rate.

Further examination of the turf root zone at Kingsway showed that locating the sensors at 5 cm, 10 cm and 15 cm deep was appropriate to measure soil water at the top, middle and base of the main root zone.

The sensors will need to be removed prior to activities that might damage the equipment such as coring and verti mowing. Removing and reinstalling soil moisture sensors prior to these activities is a major limitation to their use. Alternatively, the area where the soil moisture equipment is located could be marked off and not cored or verti mowed. This however may result in different thatch properties on the untreated area which could affect its water characteristics and make soil moisture readings unrepresentative.

Recommendations

1. Collate past sprinkler uniformity tests from all available sources to better understand the performance of existing sports turf irrigation systems.
2. If required, conduct more sprinkler testing on sports turf areas under a range of wind conditions to understand how wind affects application uniformity. The DPIRD sprinkler testing facility could be re-established to allow testing of sprinklers at various spacings and pressures over a range of wind speeds.
3. Conduct an economic assessment on the cost of installing a more uniform irrigation system and compare this with the current irrigation designs.
4. Develop guidelines for the design of turf sprinklers under windy conditions. It is critical that developers of new sports turf areas use sprinkler spacings that are appropriate for windy conditions. Otherwise it will not be possible for them to irrigate efficiently.
5. Develop critical soil moisture contents or 'refill points' for turf production on the major soil types found on the Swan Coastal Plain. Investigate the usefulness of portable hand help capacitance probes as a research and extension tool.
6. Extend this information to:
   - Local Government and other turf irrigators.
   - The Irrigation Association, irrigation companies and installers.
   - Training organisations such as TAFE.

References

1. Lantzke, N.C. (2003). Best practices for irrigation and fertiliser management on sandy soils. Department of Agriculture, Western Australia. Horticulture Australia Project VG98013.
2. Lantzke, N.C. (2020). Using soil water sensors to schedule irrigation of fruit trees on sandy soils. Perth NRM publication.