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BALLARAT GOLF CLUB
COURSE INSPECTION

1ST SEPTEMBER 2023

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Contents

Introduction
An inspection of the course at Ballarat Golf Club was undertaken on the 1st of September 2023. The focus of the inspection was to assess the current condition of key playing surfaces and identify any issues related to surface performance and overall consistency throughout the year.
A tour of the course was undertaken with Course Superintendent Jeff Powell who was able to provide valuable insight into the course and the current issues affecting surface performance, particularly throughout the cooler months of the year.
Areas inspected included selected greens, surrounds, fairways, bunkers and tees.
AGCSATech have been involved in ongoing water and soil testing at Ballarat golf Club for a number of years as well as past course inspections in 2022 and have previously provided advice on turf species selection in 2021, when perennial rye grass was raised as an option for fairway turf during the winter months. During this period, we have been able to gain a good understanding of the ongoing turf management issues facing Ballarat Golf Club.
The report below will provide an assessment of the current issues facing the club as well as utilising some background information collected from previous visits and test results, to provide recommendations on improvement of agronomic conditions and consistency of the playing surfaces throughout the year.

Executive summary
Turf Quality Concerns:
- Greens are facing problems related to turf quality, particularly during winter, and achieving consistent quality playing surfaces throughout the year.
- Initial intense renovations will be required to remove increased organic matter in the top of the green profile.
- Hollow coring a minimum of twice per year with large diameter tines will be required along with regular monitoring of organic content through loss on ignition testing to ensure the renovations are adequate to maintain organic content within acceptable levels.
- Fairways and green surrounds have also faced issues with consistent turf quality throughout the year.
- Green quality can suffer toward the end of summer with salinity build up due to water quality.
- Addressing the core agronomic issues identified for each surface will assist greatly in returning consistent high quality playing surfaces.

Thatch Buildup:
- There is a significant issue with thatch accumulation, primarily within greens, surrounds and fairways.
- Adequate time has to be provided to the maintenance team to implement the programs required to ensure organic matter accumulation is maintained at acceptable levels.
- This includes the implementation of an intense renovation program to significantly reduce the current levels prior to returning to regular renovation practices.

Water Quality and Salinity Problems:
- Water quality problems, including increased salinity in late summer, are negatively impacting the turf quality in greens.
- This is compounded by the above issues with organic matter accumulation.
- Monitoring water quality and soil salinity, particularly toward the end of the irrigation season will be vital in managing the greens going forward.

Sand Supply and Quality Challenges:
- Obtaining high-quality sand that meets the specifications for greens renovation and dusting is a persistent challenge, affecting the overall maintenance.
- Extensive testing has been undertaken to find a suitable local source, unfortunately this has not been successful and sand from Gippsland has been determined the most suitable material.

Design Issues:
- Design issues are evident across the course, particularly in fairways, where inadequate budgets were available for extensive drainage systems during construction.
- High thatch levels have made existing drains ineffective and require renovation or new drain lines installed in key positions throughout the course.

- Some fairway designs lead to balls being concentrated in specific areas, leading to excessive divoting, making it difficult to maintain turf coverage during the winter or periods of slow growth.

La Niña Impact:
- Over the past three years, the effects of La Niña have shortened the effective growing season of couch grass. This has led to delayed recovery from winter and limited active growth, making it difficult to achieve full recovery.
- This has limited renovation opportunities, and winter preparation.
- Consequently, there has been a progressive decline in fairway turf quality.

Thatch Accumulation:
- Thatch accumulation is a natural process in turf surfaces, particularly when using high-density turf grass species such as couch grass and bent grass.
- The factors that promote the breakdown of organic matter, such as good soil aeration, a healthy microbial population, and favourable soil temperatures, have been constrained in previous years, resulting in increased organic matter accumulation.
- Regular turf renovation, primarily through hollow coring, is essential to reduce organic matter buildup and restore more favourable agronomic conditions for maintaining high-quality, consistent turf playing surfaces.

Greens

An inspection of all greens throughout the course was undertaken including surface composition, thatch levels, moisture content and inspection of the profile.
The following observations were made:

- Surfaces consisted of a mix of creeping bent grass (*Agrostis stolonifera*) and winter grass (*Poa annua*) the percentages of each varying between greens.
- The surfaces were presented to a good standard.
- Thatch levels on most greens were considered above desirable levels.
- Greens were showing signs of holding excessive moisture within the surface
- Greens were generally soft under foot with signs of ball marking on several greens.

Photographs 1 and 2: Showing typical surface composition of greens and ball marking, indicating excessive moisture and thatch within the surface of the green.

Surface composition

The surfaces of greens consist predominantly of Penn G2 and 007 creeping bent grass (*Agrostis stolonifera*) varieties with varying amounts of winter grass (*Poa annua*) ranging between 10-30% within the surface of each green. The greens were generally in good condition in terms of turf coverage. Moss was present within the surface of several greens indicating elevated levels of moisture and periods of turf stress, where moss has been able to establish. issues with excessive moisture within the surface dominate the ability to produce consistent high-quality putting surfaces.

Greens Profile

Examining the greens profile can offer valuable insights into the maintenance history, frequency of renovations, types of sand used, and the periods when thatch has accumulated. When observing the profiles of most greens, you can determine a history of renovations through the presence of sand layers and organic matter strata. In a general overview, the profiles tend to display a consistent accumulation without the distinct layering that is often found in greens where renovations are infrequent. The absence of well-defined layers can also be attributed to regular sand dusting applications during the growing seasons, which aids in diluting the buildup of organic matter. Sand particles are clearly visible throughout the profile, along with sand-filled core holes, indicating effective past renovation practices.
In the top 10mm of most greens, there appears to be a change in the profile with an increase in organic matter density, with less visible sand in the profile. This indicates a decrease in renovations over the past 3-5 years, possibly compounded by a change in sand suppliers, which has contributed to the current challenges faced by the greens.

Additional hollow coring should assist with removing this layer and back filling core holes with a suitable sand to provide vertical channels of sand which will allow free movement of water and oxygen into the profile.

Photograph 3: showing typical green profile. There is a good mix of sand and organic matter above the original gold sand and a greater density of organic accumulation within the upper 10-15mm of the surface which needs to be removed.

Thatch

Thatch accumulation within the green profile is the primary factor affecting putting green performance. The accumulation of thatch or organic matter is a natural part of maintaining a high-quality turf surface. Thatch is made up of living and non-living stems roots and shoots that accumulate between the zone of green vegetation and the soil surface. Turf grass species with a high shoot density, under intense maintenance, such as couch grass and bent grass, have the potential to develop thatch layers quite quickly, particularly on sand-based profiles where there is limited microbial activity. This is a natural process which requires regular physical removal of organic matter in order to maintain ideal growing conditions to support a consistent high quality playing surface.

When assessed, the thatch depth on greens was generally between 80-90 mm with the highest concentration of organic matter within the top 10 mm of the profile. Focus should be on removing this layer including the organic matter below, down to the original sand profile.

Implementing more rigorous renovation program involving larger diameter tines at closer intervals will aid in reducing the level of organic matter within the green surfaces within the current program of aerating twice per year. The table below outlines the surface area affected using various tine sizes and spacing calculations. It is recommended that a minimum of 5/8 (15mm) tines be used at close spacing (25 x 50 mm) each time the surface is hollow cored. This process must be checked to ensure a core is removed through to the clean sand below the organic layer. These holes are then backfilled with approved fresh sand to create a vertical column of sand allowing free movement of water and air into the profile. These columns will also encourage root growth into the fresh sand.
A minimum of 30 percent of the surface should be removed annually until organic matter levels are below 4% organic content in the top 20mm of the profile. The spacing can then be increased to remove 20% of the surface annually to adequately manage the ongoing accumulation of organic matter.

Tine Size	Spacing	Area of surface impacted
1/2 inch (13mm)	**1 x 1 (25 x25mm)**	**19.63%**
1/2 inch (13mm)	**1 x 2 (25 x50mm)**	**9.82%**
1/2 inch (13mm)	**2 x 2 (50 x50mm)**	**4.91%**
5/8 inch (15mm)	**1 x 1 (25 x25mm)**	**30.68%**
5/8 inch (15mm)	**1 x 2 (25 x50mm)**	**15.34%**
5/8 inch (15mm)	**2 x 2 (50 x50mm)**	**7.67%**

Taken from Hartwiger and Obrien USGA Green section record July 2001.

Table 1: Showing percentage of surface removed with various tine sizes and spacing.

Issues associated with excessive thatch include;

- Excessive moisture held in the upper surface
- Soft, slow putting surfaces prone to ball marking
- Poor drainage
- Poor aeration
- Reduced root development
- Soft wet surfaces during winter
- Reduced drought tolerance during summer
- Reduced efficiency of fertiliser and pesticides
- Increased incidence of black layer
- Wedd development

Maintaining an adequate renovation program will ensure green performance will remain consistent throughout the year and overall costs for maintenance will be reduced.
Testing undertaken previously (March 2022) showed the organic content of the top 20mm above desirable levels as shown below.

The two samples submitted for a loss on ignition (LOI) test to determine the level of organic matter within the profile from the 7th green at Ballarat Golf Club, have been completed and the results are presented in the following table;

Table 2.

Sample	Moisture content*	% Organic Matter#
Green 7 (0-20mm)	37.1	5.6
Green 7 (20-40mm)	19.6	3.3
Ideal Range	15-25%	<4 %

***Moisture content determined by AS1289.2.1.1 oven dried to a constant mass 105-110^{0}C**
#LOI determined on 105^{0}C oven dried sample, Percentage organic matter is assumed to approximate %LOI 550^{0}C

The test results above confirm previous maintenance has been adequate with an organic content below 4%, with the top 20mm above the desirable levels and contributing to the most recent issues with surface performance.

The challenge confronting many golf clubs lies in striking a balance between conducting sufficient turf renovations to keep organic matter levels within acceptable limits and ensuring a steady cash flow from regular members and guests who use the golf course. This delicate balance often results in clubs scaling back turf renovations, which may see some benefits in the short term. However, over time, this approach can profoundly impact playing surface conditions, giving rise to issues in both winter and summer. Such problems include waterlogged surfaces in winter and diminished root depth, drought-induced stress, and increased labor requirements in summer to maintain turf coverage.

Black layer

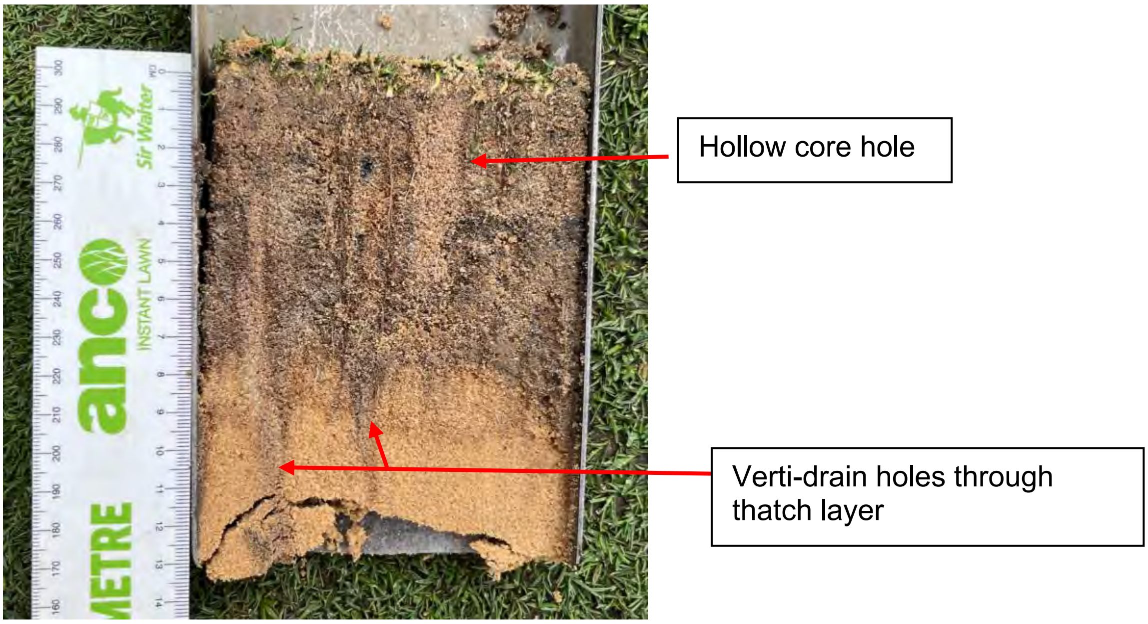
Black layer is primarily a result of anerobic conditions or a lack of oxygen present within the soil profile. Sand based profiles with thatch accumulation in the upper portion of the profile are prone to becoming waterlogged, preventing gaseous exchange between the profile and atmosphere. High levels of organic matter can hold up to 50%/V of water within the profile effectively filling all pore spaces preventing oxygen movement into the soil profile and the exit of other gasses produced through decomposition and microbial activity. Microorganisms within the soil which rely on oxygen are depleted and anerobic bacteria thrive, producing hydrogen sulphide gas which is toxic to plant roots. The results are the formation of a black slime within the profile which clogs pores within the soil and further compounds problems.
Symptoms on the surface include thinning turf, a bronzing or yellowing of turf leaves, reduced root growth, and eventually loss of turf. Weeds and algae form within the areas of thin turf coverage further reducing the overall quality of the surface and limiting recovery potential.
Black layer was also observed within the surrounds of greens and should be treated in the same manner as greens moving forward.

Recommended Control Measures:

- Hollow coring during renovations is the most effective method of thatch removal and should be undertaken as previously recommended as the primary thatch control measure.
- Regular aeration is crucial for managing black layer. The use of solid needle tines can be undertaken regularly with minimal disturbance of the surface or to golf.
- Needle tining creates channels for air and water movement helps alleviate compaction and encourage oxygen penetration into the soil. This process should be undertaken regularly to assist in reducing the conditions that favour black layer development.
- Regular sand dusting helps dilute organic matter and improve the overall soil structure. It also enhances surface smoothness, which is important for maintaining high quality putting greens.

Photograph 4: showing black layer within the profile of the putting green and a distinct layer sealing the surface of the profile.

Photograph 5: Showing black layer within the profile of a green with typical symptoms of yellow to bronze coloured leaves within the surface.



Photograph 6: Showing previous renovation results. Verti drain marks on the left which go through the thatch layer into the clean sand below, Fresh hollow core hole on right which does not penetrate entirely through the thatch layer.

Hydraulic conductivity

Saturated hydraulic conductivity measures the capacity of water to flow through a fully saturated soil profile, where all the pore spaces in the soil are filled with water, providing an accurate assessment of the profile's water movement abilities. In a dry profile, water can permeate more rapidly until all the air is displaced from the soil, and all the pores are saturated with water.

The presence of organic matter significantly affects the profile's hydraulic conductivity, often leading to a noticeable reduction in water infiltration capacity. In cases where this is a concern, tests are conducted both with and without the thatch layer to assess and highlight the impact of organic or thatch layers on hydraulic conductivity.

An evaluation of the 13th green was carried out to determine how the thatch layer was influencing the green's performance. Volumetric Water Content (VWC%) was assessed using a Field Scout TDR moisture probe and a simplified test for saturated hydraulic conductivity to emphasise the effect of the thatch layer. The results are presented in the table below.

Hydraulic conductivity was significantly reduced due to the effects of the thatch layer present. The results showed a hydraulic conductivity of less than 5 mm per hour, however, once the thatch layer was removed the hydraulic conductivity significantly increased to approximately 300mm per hour. This is promising in the fact that the base and structure of the greens is still viable and the primary influence on performance is the thatch layer in the upper 20mm of the surface.

While the hydraulic conductivity rate may marginally improve during the summer months, the consequence is that irrigation applied typically exceeding 10mm per hour would lead to runoff, as the surface would be unable to absorb a greater volume of water. This would result in wet and dry areas during summer, and in winter, runoff would occur during heavy rainfall, causing saturated surfaces with surface water present. This is likely to occur throughout the course where these conditions of excessive thatch are experienced.

Table 3.

13th green assessment	Surface including thatch	Sand profile below thatch
Moisture content (VWC%) 70mm probes	**48.9%**	**13.9%**
Saturated hydraulic conductivity (mm per hour)	**<5mm per hr**	**300mm per hr**

Table 3. Showing the effect of thatch layer present on the surface of the 13th green.

Photographs 7 and 8: Showing the influence of thatch on moisture retention in the top 70mm of the profile and immediately below the thatch where moisture content is ideal.

Winter grass management

The level of poa annua present within the green surfaces varies, this can also be an indicator of underlying issues with high levels present in those greens with elevated organic matter, moisture retention and wear concentrated into isolated areas due to the design of the green.
In the past there have been several programs to manage poa within the surfaces including a period where a direction from the board was to allow poa to establish as a mixed species surface.
Winter grass (*Poa annua*) is one of the most highly adaptable plants on earth.
A common and problematic weed in golf course turf management. It can be particularly challenging to control due to its ability to adapt and thrive under a wide range of conditions. Problems associated with Poa annua on golf courses include:

- Competition with desirable species: Poa annua competes with the desirable grass species on golf courses, such as bent grass and couch grass. It will often outcompete these grasses for resources like water, nutrients, and light, leading to a decline in turf quality and playability.
- Different Growth Habits: Poa annua has different growth habit compared to bent grass, it tends to grow in clumps, leading to an uneven playing surface and poor ball roll consistency.
- Seed Production: Poa annua is prolific in seed production. A single plant can produce thousands of seeds, which can remain viable in the soil for several years. This makes it challenging to prevent its reestablishment even after successful control efforts.
- Environmental Tolerance: Poa annua is adaptable to a wide range of environmental conditions, making it difficult to manage. It can thrive in both cool and warm-season grasses, and it's often more tolerant of shade and disease than other grass species.
- Rapid Germination: Poa annua can germinate quickly when environmental conditions are favourable. This rapid germination can lead to a high population of this weed in a short amount of time, particularly in areas of thin turf coverage.
- Herbicide Resistance: Over time, Poa annua populations have developed resistance to commonly used herbicides. This makes chemical control less effective and requires a multi-pronged approach to management strategies.
- Colour and Texture Mismatch: Poa annua has a different colour and texture to creeping bent grass. This can result in a noticeable inconsistency in the appearance of the turf, affecting the aesthetic quality of the golf course.
- Ball Roll Issues: The presence of Poa annua can create issues with ball roll, as it often has a different texture and density than the surrounding turf. This can impact the golf course's playability and performance.

To manage Poa annua effectively a combination of cultural practices, chemical control, and integrated pest management strategies will be required. is often necessary just to manage the level of poa annua present within the surface. Total control can be very difficult if not impossible is there is a high percentage of poa annua present within greens and surrounding surfaces.

Poa Cure (Methiozolin) is a relatively new herbicide designed to specifically target Poa annua in creeping bent grass putting greens. This herbicide has been trialled in one section of a green at Ballarat golf Club with good results initially. There is an option to utilise this herbicide as part of an overall program to reduce the level of poa annua within green surfaces.

Recommendations

The overriding issue with greens is the elevated levels of organic matter within the surface of each green. This is also contributing to the persistence of poa annua within the surface. Managing the winter grass with the use of a combination of herbicides and growth retardants can produce an acceptable surface.

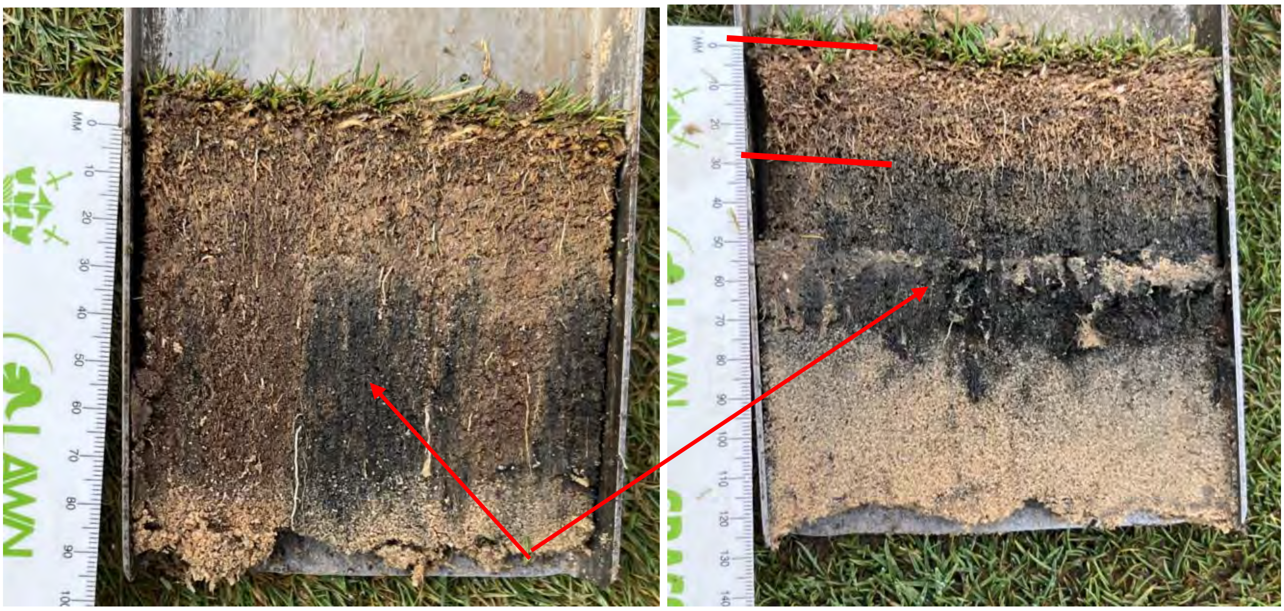
Undertake loss on ignition testing on several greens to determine the current levels of organic matter present within the surface at two depths. Take 50mm plugs from three greens (worst, middle and best) submit to AGCSATech for testing for loss on ignition to determine the organic matter content within the 0-20, 20-40 depth. This data can then be used to monitor the progress on renovation practices and ensure programs are achieving desired results.

Investigate the use of poa cure on greens with high levels of poa annua
Consider the combination usage of Primo maxx and Ethephon to reduce the influence of poa annua on the quality of the surface during key periods. A combination of ethephon, paclobutrazol and Methiozolin can be used at various times of the year. Care must be taken in using these chemicals and it is recommended to seek advice from the supplier of Methiozolin to develop a suitable program.

Hollow core greens with large diameter tines at close spacing to remove as much organic matter as possible from the surface.
Top dress with approved sand to back fill holes
Continue dusting program during peak periods of growth to assist in maintaining good balance between mineral and organic components of greens.

Surrounds

The surrounds throughout the course consist of approximately 250-300 mm sand capping layer over the existing native soils. The surface of surrounds comprises primarily of bent grass with some winter grass throughout. The turf coverage varies from hole to hole depending on design and level of traffic.
Many of the surrounds inspected had a significant thatch layer present. The dense thatch was preventing water moving into the profile as well as retaining excessive moisture. In some areas the sand profile below was saturated with the sand losing mechanical stability. As a result, the ground would move under foot.
Although sand profiles are susceptible to increased thatch buildup due to lower levels of microbial activity, there is no evidence to suggest that increasing microbial populations will have any impact on the rate of organic matter accumulation. The most effective approach for managing thatch in fine turf is physical removal through hollow coring. This involves the physical removal of material to the full depth of the layer, as it is the most efficient method without causing significant disruption to the surface. While other methods, like scarification, are options for thatch control, hollow coring is the preferred technique. Applying a sand top dressing to surrounds and fairways can be costly and may not be practical. However, it is strongly recommended to undertake hollow coring and top dressing as soon as practicable to reduce the organic layer and provide entry points for water and oxygen.



Photographs 9 and 10: Showing dense thatch layer in surrounds with black layer present within the profile.

Recommendations for surrounds

Hollow core all surrounds with large diameter tines (minimum 15mm inner diameter) at close spacing (maximum 50mm x 50 mm) to remove as much material as possible.
Ensure coring penetrates through the thatch layer to the sand layer below.
Back fill holes with approved sand, Repeat his process again prior to winter 2024.

Fairways

The fairways consist of Santa Ana couch grass with winter grass present at varying levels throughout the course. The profile design on fairways consists of a shaped base (which mirrors the finished surface levels) with a sand capping of approximately 250-300mm. During construction a temporary turf cover was established using fine leaf fescue. The fescue was then over planted with Santa Ana couch grass and the fescue transitioned out using selective herbicide. This process allowed thatch that had accumulated during construction and the remaining plant material to become part of the profile, effectively introducing a layer of organic matter to the sand capping. The result over time being a distinct layer has formed on the surface of all fairways. Whilst it varies in depth from location to location, the organic matter present on some areas has a distinct red brown colour, indicating the origin from fescue as opposed to couch grass which tends to have a grey black colour. Irrespective of origin, the accumulation has occurred from construction and is having a major effect on the surface quality throughout the seasons.

Photograph 11: Showing typical organic layer on fairways holding excessive moisture within the surface.

As with greens, the presence of excessive organic matter in the surface prevents the movement of water and oxygen through the profile, holding excessive moisture within the surface, limiting root growth, reduces drought tolerance, reduces the effectiveness of herbicides, insecticides and fungicides.
During construction drainage installation was limited to key areas of each hole and primarily focussed on intercepting surface water via pits installed in low points throughout the course. Whilst this is effective approach for heavy rainfall events, persistent light rain (which is common in Ballart) does not accumulate as surface water, instead soaks into the surface where it is required to pass through the thatch layer before moving into the sand profile below.

Design

The sand capping and undulating topography within the fairways also causes the accumulation of surface water into low laying areas and lateral water movement through the sand, which can be expressed as wet spots within fairways where water is coming to the surface from below.

Photograph 12: Showing water directed to centre of fairway creating wet areas due the build up of organic matter preventing water entering the profile.

The same undulations also direct golf balls to low areas and during periods of slow growth, excessive divoting occurs leaving sections of the fairways with sparse turf coverage.

Photograph 13: Showing wet area and many divots in low laying area of fairway.

Photograph 14 and 15: Showing Fairway profile with thatch layer, saturated profile and black layer within the lower section of profile due to prolonged periods of saturation.

Photograph 16: Showing profile of the 13th fairway with extensive thatch layer within the surface and saturated sand capping layer below indicating inadequate sub surface drainage within the area.

Drainage

As mentioned previously, drainage was installed primarily as interception of surface water during heavy rainfall events in low laying areas with the installation of pits where water can freely enter the drainage network.
Persistent light rainfall on the other hand tends to infiltrate the surface where if falls with minimal lateral or surface movement. This allows the profile to become saturated in areas as the level of rainfall is insufficient to cause run off.

Water entering through the thatch layer and into the sand capping has minimal drainage to assist with quick removal from the profile. The result being the sand capping is becoming saturated and water is building up within the profile removing all oxygen from the sand profile and black layer is forming throughout the wetter months.
The installation of drains in the base of the fairway to assist with water movement from the profile and into the existing drainage network will greatly assist in improving the agronomic conditions within fairways and some surrounds. These drains should be strategically placed to intercept water within the profile and prevent wet spots developing from saturated soil below.
This is a separate issue to the influence of the thatch layer on the surface of fairways preventing water entering the profile. The most effective strategy for this issue is regular thatch removal and sand slitting of the surface to allow water to enter the profile freely.

Photograph 17: Showing typical thatch layer accumulated within fairway profiles. The distinct red/brown thatch is typical of thatch derived from fescue's.
Photograph 18: Showing volumetric water content held within the top 70mm of the fairway surface. 65% VMC is above the storage capacity of the soil indication total saturation of the profile.

Drainage or sand slits will only work effectively while there continues to be a direct link or highly permeable sand trench extending right to the surface, where water can enter freely as it moves across the surface. The movement of soil particles and the accumulation of fine soil and organic matter will over time reduce the efficiency of drain lines as permeability is reduced.
A fine layer, even a few millimeters can be enough to impact a drain from functioning effectively. Once the surface is sealed, the drain will no longer work to remove surface water as it is prevented from entering the trench or sand layer below.
For drainage to remain effective, the link between the sand trench and the surface must be maintained. Regular sand top dressing, dethatching, hollow coring are ideal practices which can be implemented to maintain or renovate drain lines or sand capping, ensuring they continue to work effectively.

Photograph 19: Showing organic matter buildup over drainage lines, effectively preventing water entering into the drain.

There are a range of factors which determine the effective life of a well installed and maintained drainage system, typically after 5 - 10 years organic matter and local fine soils build up and reduce the ability of water to effectively enter the drains.
Drainage can be renovated by stripping off the top of the drain, back to clean sand and then topping up with fresh sand and washed turf. Due to the nature and scale of the sand capping at Ballarat Golf Club stripping the surface would be both time consuming, impractical and potentially prohibitively expensive. It is recommended that large diameter hollow cores would be the most effective process.

Sand supply

The demand for sand has never been greater than in recent years. However, securing high-quality and reliable sources of sand has become increasingly challenging. This is primarily due to the closure of several major quarries, heightened competition for raw materials within the construction industry, and the scarcity of new quarry developments. The specific requirements for sand used in turf construction and, more notably, for golf course applications, make it even more challenging to find suitable sources in Victoria that consistently meet the necessary physical and chemical specifications. The recent closure of Victoria's primary sand supplier for turf construction and topdressing has left many golf courses with the predicament of locating a suitable local sand source.
Considering the rising costs associated with sand extraction and transportation, the preferred solution is to identify a reliable and consistent local supplier. AGCSATech has worked closely with Jeff and several other turf facilities in the region to explore potential suppliers located to the west of Melbourne. Unfortunately, a consistently dependable supply that aligns with Ballarat's ongoing needs has not yet been discovered. The sand employed over the past 12-18 months, sourced locally, is deemed unsuitable for continued use in dusting and topdressing applications.
Currently, a supplier from Gippsland possesses the most suitable sand and is providing the club with sand for topdressing and renovation purposes. The results of recent testing for Ballarat Golf Club are provided as an attachment.

Alternate species

The conversion of fairway turf species to perennial rye grass (Lolium perenne) or the option to overseed for an alternative winter surface has been the subject of several proposals.
Irrespective of the decision, the underlaying issues of excessive organic matter will continue to dominate the performance of the fairway surfaces, particularly during winter.
Couch grass conversion has been undertaken by most golf clubs throughout the southern states and has shown to be far more sustainable with reduced costs and improved turf quality throughout the year. Whilst Ballarat is a difficult environment to maintain couch grass through the winter months, it has been shown, when optimum agronomic conditions are maintained a year-round quality surface can be presented.
Below is a summary of previously presented information regarding the usage of perennial rye grass vs couch grass in the southern states.

- There are a wide range of couch grass varieties available on the market with particular varieties that perform better in certain environments.
- Santa Ana, which has been around for over 50 years, consistently ranks among the top varieties, especially in Victoria.
- Santa Ana is unquestionably the best choice for the climatic conditions in Victoria, particularly in Ballarat.
- The conversion to couch grass fairways throughout golf courses in Victoria has seen an overall improvement in the quality of turf surfaces and a significant reduction in water requirements, to maintain an adequate turf surface.
- The length of dormancy varies each year with the climatic conditions and geographic location. This has been highlighted in the past years particularly with the influence of La Niña.
- Ballarat in particular is subject to extremely cold conditions and frosts. This tends to place couch grass into a strong dormancy where the turf is devoid of any green colouration whatsoever.
- As a general rule, going into winter with a good coverage of healthy turf, maintaining a dry surface during dormancy, will most likely result in coming out of winter with a healthy flush of new growth in spring.
- Couch grass does not compete well with other grasses at all and any weed or overseeding will cause a loss of couch grass coverage.
- The result of which will be prolonging the period of poor turf coverage in spring through to as late as mid-summer, increased costs for re-turfing, increased disruption to maintenance and members when golf is traditionally at its peak for club tournaments.
- There are currently no golf courses in Australia following an overseeding program. Primarily due to the costs associated outweighing the benefits.
- High wear areas that are susceptible to poor couch grass coverage prior to over seeding are without exception devoid of all turf after winter and require returfing in late spring once rye grass is removed.
- Winter wear tolerance and presentation is greatly influenced by soil type, soil moisture levels and levels of wear.
- Couch grown on a well-draining sand will tolerate far greater levels of wear throughout the winter period when compared to the same grass grown in wet conditions.
- Regardless of the grass species, the primary issues with turf performance on fairways is the design, topography and presence of excessive thatch within the surface of the fairways.
- Traffic management to limit wear and soil aeration will assist in maintaining turf coverage throughout cooler months.
- Green pigments can assist greatly in improving the aesthetic appearance of dormant turf and there is good evidence that applying pigments to the turf prior to the onset of dormancy assists in maintaining colour for a longer period.

Additionally, an important aspect not discussed is the nature of the game of golf itself. Golf is a year-round sport enjoyed through changing seasons, and the approach to golf should adapt to the varying course conditions in each season.
This concept is often overlooked by golfers who has expectations of a consistently level playing field

and flawless lies throughout the year. The seasonal transformations of a golf course and the capacity to adapt to these changes should be welcomed, for this is the genuine essence of golf. Ensuring a well-drained surface during winter can help maintain a healthy couch grass surface, enhancing the enjoyment of members who prefer playing on a drier course. Evaluating the course for improved drainage and water movement through techniques like sand slitting can benefit both couch grass and golfers alike.

Water requirements

AGCSATech has conducted calculations to estimate the annual water requirements needed for course irrigation, and these estimates are provided as attachments. The calculations are based on climatic data sourced from the Bureau of Meteorology specific to Ballarat.
The rainfall data utilised is derived from long-term statistical averages recorded at Ballarat aerodrome. Additionally, the evaporation data is extracted from the same location, with data collected in 2022 during the La Niña weather cycle. These calculations for water requirements take into consideration crop factors relevant to turf to maintain an acceptable turf quality. This entails replacing losses within a range of 40% to 100% based on plant water requirements, consumption and evaporation rates.
In assessing the monthly rainfall figures, an effective utilisation of 50% of the rainfall is considered, accounting for factors like runoff, excessive rainfall, and the time of year. The rates established reflect the monthly per-hectare requirements for both cool and warm season grasses, aimed at maintaining specific standards. The annual totals illustrate a substantial contrast in the volume of water necessary to uphold high-quality cool and warm season grasses.
When calculated across the irrigated surface area, which ranges between 15 to 18 hectares, it becomes evident that maintaining rye grass fairways would necessitate a minimum of 35% increase in water usage.
Based on water quality, perennial rye grass would not be the ideal choice to cope with elevated salinity levels contained within bore water used at the club.

Water quality

In the past years AGCSATech have undertaken water quality testing for irrigation water used throughout the course at BGC. Whilst bore water quality does vary throughout the year, as a general trend the test results show a number of issues related to overall water quality and this has been highlighted in the past, particularly on greens towards the end of the irrigation season where elevated salt levels can build up and turf quality has suffered.

The practice of regularly applying light irrigation to maintain dry and firm playing surfaces during peak golfing periods can exacerbate the development of salinity issues within the soil profile of the greens. This issue becomes more complex when there are elevated levels of organic matter within the profile.
The challenge lies in the impossibility of conducting deep watering across the entire profile due to the adverse effects of softening the surface and slowing down the greens' pace. This predicament is not unique to BGC but is a common problem faced by golf course superintendents across the country, a concern consistently observed by AGCSATech during course assessments. Dealing with an excess of organic matter requires the application of daily light irrigation to sustain firm and fast greens for golf while keeping the turf alive.

As a result, high levels of evaporation occur on the surface leaving salts behind to build up in the organic layer on the surface. By the end of summer, salinity levels build up to where they are detrimental to plant health, even though salinity within the irrigation supply is moderate.
Deep watering assists in carrying these salts down through the sand profile and below the depth of the roots. Superintendents rely on leaching of these salts with good winter rains each year to return salinity levels to acceptable levels before the commencement of the next irrigation season.
Regular testing at other golf clubs with saline irrigation water has seen this cycle occur annually, with the added benefit of low organic matter allowing for deep watering once er week to assist with flushing salts through the greens profile.
Irrigation best practice relies on maintaining minimal thatch levels and implementing long, deep irrigation cycles on a weekly basis to thoroughly wet the entire sand profile to field capacity. This approach encourages the development of a deep and extensive root system while assisting in the

flushing of salts through the profile. Following this process, the greens can be allowed to dry out and will only require light supplementary watering to maintain appropriate surface moisture and cool the turf canopy during hot days.
Balancing ideal agronomic conditions with conditions suitable for high-level golf is one of the greatest challenges facing golf course superintendents. Achieving this balance requires minimising the presence of organic matter on the surface, enabling the implementation of deep watering without resulting in soft, slow greens.
Couch grass and Santa Ana in particular has a far greater tolerance to salinity and these issues are not experienced to such an extent on tees and fairways where a couch grass surface is maintained.

Water samples were taken from the bore previously (10/3/22) for analysis, with the results available in the documents attached to this report.
A brief summary of the findings is as follows:

- Salinity levels are at a medium hazard level, and it is anticipated that they may rise during the summer irrigation months.
- The Sodium Adsorption Ratio (SAR) is low, indicating a favourable potential for leaching salts with fresh water.
- The Residual Sodium Carbonate (RSC) is low, with no bicarbonate formation.
- Sodium and Chloride levels are high.

The bore water is deemed suitable for irrigation; however, as the irrigation season progresses, sodium and chloride levels will accumulate within the surface of the soil profile to a point where they can impede the growth of susceptible species, such as Poa annua and bent grass.
As bore water is the primary source of irrigation utilised throughout the season, focus must be on improving agronomic conditions to provide good hydraulic conductivity and promote a deep root system. water that is currently applied is consumed through plant water use and evaporation, leaving behind accumulated salts in the profile. Towards the end of each irrigation season, salt levels can become problematic if regular leaching with rainwater or fresh water does not take place. Ensuring effective infiltration during the winter period will aid in flushing salts out of the profile. Additionally, the use of soil conditioners like gypsum will assist this process.

Weather patterns

The Past three years has seen Australia under the influence of La Niña weather patterns which has resulted in overall cooler daytime temperatures, particularly in spring and summer. La Niña also has an influence on rainfall with increased rainfall over the summer months. The has resulted in soil temperatures not reaching the required levels until well into November or early December and the peak growth period being shortened by up to two months each year. This has had a profound effect on warm season turf growth throughout the southern states of Australia with a progressive decline of turf quality observed over the past three years.
At Ballarat Golf Club a shorter growing season has resulted in less vigorous growth and recovery after winter with fairways only fully recovered mid to late summer with a flow on effect of reduced production of vital carbohydrates, which assist with over wintering and good spring growth and recovery from wear and damage. Each year has seen a progressive reduction in good spring growth and turf quality throughout this period. A lack of spring growth has also seen an opportunity for increased weed development in areas of thin turf coverage.
With a variable climate now a reality, it is imperative that optimum growing conditions are maintained in order to provide turf surfaces with the best opportunity to adapt and cope with a changing environment. This includes maintaining low levels of organic matter accumulation and good drainage and encouraging a deep healthy root system.
The return of El Niño weather patterns should see an increase in temperatures and turf growth in the seasons ahead.

Current Maintenance Programs

Having a good understanding of the challenges facing Ballarat Golf Club, along with the current maintenance programs in place for weed control, fertilisation, and fungicide applications, there is no immediate need for significant alterations to the ongoing maintenance programs.
However, the overarching issue that significantly affects all critical playing surfaces is the accumulation of excessive organic matter. This issue is further compounded by factors such as poor water quality, recent weather patterns, inadequate drainage and the difficulty of undertaking

essential renovations during peak growth periods in previous years. These interconnected factors all contribute to current concern related to the club's playing surfaces.

Machinery

Discussions with the course superintendent and staff indicated that current maintenance equipment is generally adequate to continue to maintain and present the course to a high standard. However, there is significant renovations required outside of the twice annual green renovation. This will place greater demand on availability of equipment for both regular maintenance and additional renovations required. The course superintendent is best suited to determine the additional requirements to the fleet for maintenance and the additional project work.
The purchase of a toro 648 hollow coring unit has been arranged which will be a highly positive addition to the course and allow renovation and maintenance to be undertaken when it suits the club as opposed to waiting on the availability of contractors.

Given the large extent of renovation work required, it is essential that an additional dual-purpose unit be purchased for renovation of greens, tees, surrounds and fairways. A Verti-Drain unit from the “15 series” has been specifically developed for high-speed operation similar to a coring machine, with the additional option of implementing a pitchfork action when using solid tines to heave compacted soils. The unit is tractor mounted and designed for both broad acre and greens, with an effective coring depth of 150 mm (beyond that of traditional coring machines). The unit has options to hollow core or solid tine and would be considered an essential component used to effectively manage all golf course surfaces.

Here are the key advantages of using a Verti-Drain unit:

1. **Soil Decompaction:** A Verti-Drain unit reduces soil compaction by utilising a pitchfork action, which can be adjusted in aggressiveness to suit, depending on the surface
2. **Reduced interference with play:** greens can be aerated quickly and regularly with needle tines (6-10mm) with minimal disturbance to the surface, allowing play to continue immediately after treatment.
3. **Increased depth of aeration:** the various tines available and the action of the machine allow for deep aeration with either hollow or solid tines beyond the depth of a standard hollow corer.
4. **Thatch Reduction:** The Verti-Drain unit offers large diameter hollow core options beyond that of a traditional coring unit. A tractor mounted unit allows a closer spacing between holes as there is greater control on ground speed.

A Verti-Drain unit ability to address soil compaction, deep tine aeration, thatch removal, and promote root growth, across all surfaces makes it an essential tool for effective golf course surface management.

Photograph 20: The Verti-drain 1517 series suitable for greens coring, fairway aeration and compaction relief.

Staffing

The extensive renovations required will exert additional pressure on the current limited staffing levels. It is imperative to allocate additional staff to undertake the renovation work on fairways and surrounds effectively and manage the cleanup process, with minimal disruption to members and the existing maintenance program. Ideally, a minimum of two additional staff members should be enlisted for this purpose.

Furthermore, the grounds staff is concurrently engaged in various projects beyond their routine maintenance duties, which include projects like bunker renovations, tee modifications, and drainage projects. Undertaking these projects in-house not only provides an opportunity for staff development and increased morale, but also translates into substantial cost savings for the club. However, these projects, when in progress, can make it challenging to sustain regular course maintenance, particularly during periods of peak turf growth. Given the extensive renovations required, additional staff is imperative. For instance, renovating the fairways and surrounds alone will require the full-time dedication of at least two individuals to achieve the desired reduction in organic content and appropriate clean up to minimise interference with golf. Additionally, a range of specialised equipment is required, which includes the purchase of the verti drain unit and the availability of key pieces of equipment currently within the machinery fleet.

The following equipment will be regularly required for renovation works on fairways and surrounds.

- Compact tractor
- Verti-drain 1513 or 1517 unit
- Multiple sets of hollow tines to suit unit.
- Bunker rake with front blade attachment
- Course utility vehicle
- Steel drag mat
- Large blower
- Additional utility vehicles and staff for manual pick up of cores from surrounds.

Summary of Recommendations

Below is a summary of the key factors and recommendations to address the primary issues on each of the playing surfaces at Ballarat GC.

Greens

Key Issues for Greens:

- Accumulation of excessive organic matter within the top 20mm of the green profiles.
- Excessive moisture retention in the greens.
- Soft and prone-to-ball-marking greens.
- Black layer development due to anerobic conditions and poor oxygen exchange.
- Mixed composition of creeping bent grass and winter grass on greens.

Recommendations for Greens:

- Conduct Loss on Ignition (LOI) testing to monitor organic matter levels in the top 20mm of the profile on multiple greens.
- Implement hollow coring program twice per year with large diameter tines at close spacing to remove a minimum of 30% of surface area per year.
- Alternate between Toro 648 unit and Verti-drain unit to provide maximum depth to hollow coring on greens.
- Utilise Verti-drain unit to remove cores to a maximum depth of 150mm
- Utilise approved sand from Sand belt Industries for top dressing to backfill holes created during hollow coring.
- Maintain a consistent dusting program during peak growth periods to balance mineral and organic components.
- Explore the use of Poa Cure (Methiozolin) for managing Poa annua in greens with high Poa annua presence.
- Consider a combination of growth retardants like Primo Maxx and Ethephon to manage Poa annua seed head production and ensure a high-quality surface.
- Focus on improving hydraulic conductivity through regular aeration with solid needle tines to aid water movement and oxygen penetration into the soil.

Surrounds

Key Issues for Surrounds:

- Approximately 250-300 mm sand capping layer over native soils in the surrounds.
- Varied turf coverage across holes due to design and traffic.
- Significant thatch layer obstructing water movement and retaining excessive moisture.
- Saturated sand profiles in some areas, leading to unstable ground conditions.
- Lack of sub surface drainage to remove excess moisture from sand profile of surrounds.
- Sand profiles susceptible to thatch buildup with lower microbial activity.
- Hollow coring is the most effective method for thatch removal.

Recommendations for Surrounds:

- Conduct hollow coring on all surrounds using large-diameter tines as per greens with additional hollow coring of surrounds completed when possible.
- Ensure that coring penetrates through the thatch layer to the sand layer below.
- Backfill holes with approved sand and repeat this process before winter 2024
- Install sub surface drains in key wet areas to aid removal of excess water from profile.

Additional Notes:

- Hollow coring is the preferred technique for efficient thatch control and minimizes surface disruption.
- Scarifying is not considered an effective method of thatch control
- The key focus is on removing the thatch layer and enhancing water and oxygen entry points into the soil profile.

Fairways

Key Issues for Fairways:

- Organic matter accumulation in the profile, originating from construction and plant material.
- Excessive organic matter obstructs water and oxygen movement, leading to moisture retention, reduced root growth, decreased drought tolerance, and hindered pesticide effectiveness.
- Limited sub surface drainage installation during construction with a focus on surface water interception.
- Undulating topography and sand capping causing water accumulation in low areas and lateral water movement.
- Wet spots, concentrated divoting divots, and sparse turf coverage in low-lying areas.
- Challenges in maintaining couch grass through winter in Ballarat's cold conditions.
- Santa Ana the most suitable turf variety for fairways in Ballarat.
- Overseeding is costly, and no golf courses in Australia follow this program.
- The primary issue with fairway turf performance is design, topography, and excessive thatch.
- Traffic management and soil aeration help maintain turf coverage during cooler months.

Recommendations for Fairways:

- Install drains in the base of fairways in key locations to assist with water movement from the profile into the existing drainage network.
- During peak growing season, regularly remove thatch through hollow coring with large diameter tines on all fairways.
- Verti- drain with hollow tines should run full time over summer months to remove thatch from fairways and surrounds.
- This will require a minimum of one additional staff member to operate verti-drain and clean up.
- It is recommended to allow cores to dry in fairway surface, break up with drag mat and blow debris into rough areas rather than pick up, creating large volumes of waste material.
- Perform sand slitting to facilitate water penetration into the profile in key wet areas.
- Evaluate the course for improved drainage and water movement, such as sand slitting, to benefit couch grass and golfers.
- Maintain a well-drained surface during winter to assist in couch grass survival.
- Investigate the use of turf pigments prior to the onset of dormancy to assist with turf colour throughout winter.

Additional Notes:

- Perennial rye grass would not be suited to fairways at Ballarat GC and would require significant increases in budget.
- Thatch accumulation would still remain the primary issue facing fairways regardless of turf species.
- Adaptation to seasonal transformations on a golf course should be welcomed, and course conditions may change with the seasons, which is inherent to the game of golf.

Bunkers

- Currently there is a program of bunker renovation being undertaken by staff.
- The results are showing big improvements in the presentation and playability of the bunkers
- This program should continue as budget and available labour allows.

Tees

- Tees were not reviewed in great detail
- All surfaces would benefit from increased hollow core aeration during summer.

Conclusion

The course has matured in the past years and issues which are common on the vast majority of courses AGCSATech inspect. The accumulation of organic matter on fine cut turf is a natural process and requires regular renovation to maintain an adequate balance.
There is no doubt maintaining couch grass fairways in Ballarat provides it own unique set of challenges to the turf management team.
Issues are further compounded by the presence of organic matter, the course topography and profile design (sand capping) which requires additional sub surface drainage
The ongoing challenge is to strike a balance between maintaining healthy turf and addressing excessive thatch levels, taking into consideration the needs of golfers and potential impact on revenue.
The works required ahead will require significant commitment from the board to follow through with the program to return conditions
one of the most common issues observed within golf clubs is a failing of the board to listen to the experts employed by the club. Decision makers often prioritise their own judgements over those of the qualified expert. In many cases, the superintendent is the most qualified individual in the room. Unfortunately, there have been numerous instances at golf clubs where their input is rejected or disregarded. Subsequently, decisions can be made which lead to compounding of issues further down the track, which in some cases, the superintendent is unjustly held responsible for the resulting problems arising from decisions of the past.

It is imperative to take advice from resident experts who have great insight into the local environmental conditions and how the proposed programs may affect the future management of the course. The restoration process required at Ballarat will require significant support and communication from the board to members. While various alternatives are often available, the most feasible course of action in this instance involves adopting an extensive renovation plan to reestablish optimal growth conditions and, consequently, maintain consistently high-quality golfing surfaces.
Considering the replacement of each green, surround, or fairway surface is financially prohibitive, entailing prolonged disruptions to members over several years and exerting a detrimental influence on the club's financial stability.

Following a progressive renovation program will cause some disruption to members and the course, however, the course can remain open. Green renovations will proceed as usual, with a slight extension in the recovery period. The main disruptions will primarily affect the fairways and surrounds, and their management can take several forms based on the club's preferences and its commitment to an extensive program.
One approach is to divide fairways into manageable sections, addressing the most problematic areas on each hole initially, and subsequently tending to the remaining sections. Alternatively, the

entire fairway or each hole could be fully addressed simultaneously. The decisions on the most suitable course of action should be entrusted to the course superintendent and general manager.

It is estimated an extensive program over two to three years should see all surfaces returned to optimal conditions with significant improvements expected in the first year when all surfaces have been hollow cores twice. The results of this should see dryer surfaces throughout the course, improved turf quality and more consistent putting surfaces.

It is recommended to read through this draft copy and provide feedback on any areas which require further explanation or clarification.
I would be pleased to present a summary of this report to the board in the form of a power point presentation and answer any questions directly as a result of this report to ensure the club is comfortable in moving forward with the proposals contained within this report.

Please feel free to contact me at your convenience.

Yours sincerely

Bruce Macphee

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WATER ANALYSIS

CLIENT: Ballarat Golf Club
SAMPLE DESCRIPTION: as titled
DATE SAMPLED: 18th March 2022

Chemical Analysis Water Characteristics	Ideal Range	Bore
pH, units	5 - 8	8.1
Total alkalinity, as CaCO3 (calc.)	<150	260
Bicarbonate, as HCO3 (mg/L)	-	317
Carbonate, as CO3 (mg/L)	-	0
Calcium, as Ca (mg/L)	<100	27
Magnesium, as Mg (mg/L)	<100	57
Hardness, calculated as CaCO3	<150	300
Impact on Plant Growth (Total Salinity)		
Electrical conductivity (microS/cm @25C)	<750	1500
Salinity by calculation (mg/L)	<500	1000
Impact on Foliage Contact (Ion Toxicity)		
Sodium, as Na (mg/L)	<70	190
Chloride, as Cl (mg/L)	<100	340
Impact on Root Growth (Ion Toxicity)		
Sodium, as Na (meq/L)	<3	8.3
Chloride, as Cl (meq/L)	<3	9.7
Impact on Soil Structure (Na Permeability Hazard)		
Electrical conductivity (microS/cm @25C)	<750	1500
Salinity by calculation (mg/L)	<450	1000
Residual Sodium Carbonate (calc.)	<1.25	-0.84
Sodium Adsorption Ratio - SAR (calc.)	see below 1	4.8
adjSAR (calc.)	see below 1	-
Nutrients		
Nitrate, as N (mg/L)		1.0
Total Nitrogen, as N (mg/L)	see below 2	2.5
Phosphorus, total as P (mg/L)	see below 2	1.0
Potassium, as K (mg/L)	see below 2	7.8
Other		
Iron, as Fe (mg/L)	<1	0.04
Manganese, as Mn (mg/L)	<0.2	0.04
Copper, as Cu (mg/L)	<0.2	0.01
Zinc, as Zn (mg/L)	<2.0	0.02
Boron, as B (mg/L)	<2.0	0.03
Sulphur, as SO4 (mg/L)	<100	4.8

The above analyses were performed on the samples as received
1 - Refer to attached information sheet
2 - Nutrients such as nitrogen and phosphorus need to be accounted for in the fertiliser program

APPENDIX 1

Table 1: Salinity Class of Irrigation Waters

Salinity Hazard Class	COMMENTS	EC (micros/cm)
Low	Low salinity hazard, no detrimental effects on plants or soil build-up are expected.	< 750
Medium	Sensitive plants may show salts stress, moderate leaching prevents soil salt accumulation.	750 – 1500
High	Salinity will adversely affect most plants. Requires selection of salt tolerant plants, careful irrigation, good drainage and leaching.	1500 – 3000
Very High	Generally unacceptable except for very salt tolerant plants, excellent drainage, frequent leaching and intensive management.	> 3000

Table 2: Sodium Hazard of Irrigation Waters

Sodium Hazard Classification	SAR or adj SAR*	Comments
Low	< 10	Can be used on most soils without structure deterioration. Salt sensitive plants may be affected.
Medium	10 – 18	Appreciable Na hazard on fine-textured soils with high CEC. Best used on coarse textured soils with good drainage.
High	18 – 26	Harmful levels of Na accumulation on most soils. Will require intensive management –amendments, drainage and leaching.
Very High	> 26	Generally, not suitable for irrigation. Requires intensive management.
***Use SAR when HCO3 is < 120 mg/L and CO3 is < 15 mg/L. Use adj SAR when HCO3 and CO3 are higher.**		

Table 3: Sodium hazard (permeability) of irrigation water based on Residual Sodium Carbonate

RSC Value (meq/L)	Na Hazard
< 0 (ie negative)	None. Ca and Mg will not be precipitated as carbonates from irrigation water; they remain active to prevent Na accumulation on CEC sites.
0 – 1.25	Low. Some removal of Ca and Mg from irrigation water.
1.25 – 2.50	Medium. Appreciable removal of Ca and Mg from irrigation water.
> 2.50	High. All or most of Ca and Mg removed as carbonate precipitates leaving Na to accumulate. How rapidly Na buildup occurs depends on Na content of the water.

Tables 1,2 and 3 adapted from: Carrow and Duncan (1998)

Table 4: Specific ion toxicity

Parameter	No Problems	Increasing Problems	Severe Problems
Chloride			
Foliar Absorption (mg/L)	<106	>106	
Root Absorption (mg/L)	<142	142 – 355	>355
Sodium			
Foliar Absorption (mg/L)	<69	>69	
Root Absorption (SAR)	<3	3 - 9	>9
Boron	<1	1 – 2	>2

Reference: Ayers and Wescot, 1976

Ballarat GC: Sample Water Budget - Average Year

WARM SEASON GRASSES

					Warm Season Turf CF = 0.4			Warm Season Turf CF = 0.5			Warm Season Turf CF = 0.6			Warm Season Turf CF = 0.7		
	Rain mm	Effective Rainfall	Evap Pan mm	Net Evap mm	Evap Crop	Irrigated Area	Irrigation Required	Evap Crop	Irrigated Area	Irrigation Required	Evap Crop	Irrigated Area	Irrigation Required	Evap Crop	Irrigated Area	Irrigation Required
Formula	Ballarat Av monthly rainfall	0.5	Ballarat Average E-pan	Evap - Effec Rain	Net Evap x CF **(0.4)** mm	Area Ha	Irr. Deficit / Irr.Effic x Area (ML)	Net Evap x CF **(O.5)** mm	Area Ha	Irr. Deficit / Irr.Effic x Area (ML)	Net Evap x CF **(0.6)** mm	Area Ha	Irr. Deficit / Irr.Effic x Area (ML)	Net Evap x CF **(0.7)** mm	Area Ha	Irr. Deficit / Irr.Effic x Area (ML)
January	40.1	20.1	190.0	170.0	68.0	1.0	**0.91**	85.0	1.0	**1.13**	102.0	1.0	**1.36**	119.0	1.0	**1.59**
February	42.6	21.3	157.5	136.2	54.5	1.0	**0.73**	68.1	1.0	**0.91**	81.7	1.0	**1.09**	95.3	1.0	**1.27**
March	42	21.0	104.3	83.3	33.3	1.0	**0.44**	41.7	1.0	**0.56**	50.0	1.0	**0.67**	58.3	1.0	**0.78**
April	51.2	25.6	75.9	50.3	20.1	1.0	**0.27**	25.2	1.0	**0.34**	30.2	1.0	**0.40**	35.2	1.0	**0.47**
May	64.2	32.1	41.3	9.2	3.7	1.0	**0.05**	4.6	1.0	**0.06**	5.5	1.0	**0.07**	6.4	1.0	**0.09**
June	62.9	31.5	27.3	-4.2	-1.7	1.0	**-0.02**	-2.1	1.0	**-0.03**	-2.5	1.0	**-0.03**	-2.9	1.0	**-0.04**
July	66	33.0	37.4	4.4	1.8	1.0	**0.02**	2.2	1.0	**0.03**	2.6	1.0	**0.04**	3.1	1.0	**0.04**
August	73.7	36.9	44.7	7.9	3.1	1.0	**0.04**	3.9	1.0	**0.05**	4.7	1.0	**0.06**	5.5	1.0	**0.07**
September	70.6	35.3	56.8	21.5	8.6	1.0	**0.11**	10.8	1.0	**0.14**	12.9	1.0	**0.17**	15.1	1.0	**0.20**
October	66.9	33.5	85.2	51.8	20.7	1.0	**0.28**	25.9	1.0	**0.35**	31.1	1.0	**0.41**	36.2	1.0	**0.48**
November	56.2	28.1	97.9	69.8	27.9	1.0	**0.37**	34.9	1.0	**0.47**	41.9	1.0	**0.56**	48.9	1.0	**0.65**
December	49.7	24.9	143.8	119.0	47.6	1.0	**0.63**	59.5	1.0	**0.79**	71.4	1.0	**0.95**	83.3	1.0	**1.11**
Total	809.8	343.1	1341	719.1	287.6		**3.83 ML**	359.5		**4.79 ML**	431.4		**5.75 ML**	503.3		**6.71 ML**

KEY

Annual Rainfall mm			**809.8**
Evaporation Pan mm			**1341**
Crop Factor CF Warm season grasses			
Warm Season		**Poor Quality-Uneven Colour**	**0.4**
Warm Season		**Reasonable Quality**	**0.5**
Warm Season		**Above Average**	**0.6**
Warm Season		**Dense Cover-Dark Green-Lush**	**0.7**
Area Ha			**1**

Rainfall mm: Sourced from Bureau of Meteorology -Ballarat - Mean Monthly Rainfall 1908-2023

Evaporation Pan mm: Sourced from Bureau of Meteorology - Ballarat Aerodrome, 2022; Site No 089002

Irrigation Efficiency = 0.75

(grey)	No Irrigation

Ballarat GC: Sample Water Budget - Average Year

COOL SEASON GRASSES

					Cool Season Turf CF = 0.7			Cool Season Turf CF = 0.8			Cool Season Turf CF = 0.9			Cool Season Turf CF = 1.0		
	Rain mm	Effective Rainfall	Evap Pan mm	Net Evap mm	Evap Crop	Irrigated Area	Irrigation Required	Evap Crop	Irrigated Area	Irrigation Required	Evap Crop	Irrigated Area	Irrigation Required	Evap Crop	Irrigated Area	Irrigation Required
Formula	Ballarat Av monthly rainfall	0.5	Ballarat Average E-pan	Evap - Effec Rain	Net Evap x CF **(0.7)** mm	Area Ha	Irr. Deficit / Irr.Effic x Area (ML)	Net Evap x CF **(O.8)** mm	Area Ha	Irr. Deficit / Irr.Effic x Area (ML)	Net Evap x CF **(0.9)** mm	Area Ha	Irr. Deficit / Irr.Effic x Area (ML)	Net Evap x CF **(1.0)** mm	Area Ha	Irr. Deficit / Irr.Effic x Area (ML)
January	40.1	20.1	190.0	170.0	119.0	1.0	1.59	136.0	1.0	1.81	153.0	1.0	2.04	170.0	1.0	2.27
February	42.6	21.3	157.5	136.2	95.3	1.0	1.27	109.0	1.0	1.45	122.6	1.0	1.63	136.2	1.0	1.82
March	42	21.0	104.3	83.3	58.3	1.0	0.78	66.6	1.0	0.89	75.0	1.0	1.00	83.3	1.0	1.11
April	51.2	25.6	75.9	50.3	35.2	1.0	0.47	40.2	1.0	0.54	45.3	1.0	0.60	50.3	1.0	0.67
May	64.2	32.1	41.3	9.2	6.4	1.0	0.09	7.4	1.0	0.10	8.3	1.0	0.11	9.2	1.0	0.12
June	62.9	31.5	27.3	-4.2	-2.9	1.0	-0.04	-3.3	1.0	-0.04	-3.7	1.0	-0.05	-4.2	1.0	-0.06
July	66	33.0	37.4	4.4	3.1	1.0	0.04	3.5	1.0	0.05	4.0	1.0	0.05	4.4	1.0	0.06
August	73.7	36.9	44.7	7.9	5.5	1.0	0.07	6.3	1.0	0.08	7.1	1.0	0.09	7.9	1.0	0.10
September	70.6	35.3	56.8	21.5	15.1	1.0	0.20	17.2	1.0	0.23	19.4	1.0	0.26	21.5	1.0	0.29
October	66.9	33.5	85.2	51.8	36.2	1.0	0.48	41.4	1.0	0.55	46.6	1.0	0.62	51.8	1.0	0.69
November	56.2	28.1	97.9	69.8	48.9	1.0	0.65	55.8	1.0	0.74	62.8	1.0	0.84	69.8	1.0	0.93
December	49.7	24.9	143.8	119.0	83.3	1.0	1.11	95.2	1.0	1.27	107.1	1.0	1.43	119.0	1.0	1.59
Total	809.8	343.1	1341	719.1	503.3		6.71 ML	575.2		7.67 ML	647.1		8.63 ML	719.1		9.59 ML

KEY

Annual Rainfall mm		**809.8**
Evaporation Pan mm		**1341**
Crop Factor CF	**Cool season grasses**	
Cool Season	**Poor Quality-Uneven Colour**	**0.7**
Cool Season	**Reasonable Quality**	**0.8**
Cool Season	**Above Average**	**0.9**
Cool Season	**Dense Cover-Dark Green-Lush**	**1**
Area Ha		1

Rainfall mm: Sourced from Bureau of Meteorology - Frankston - Mean Monthly Rainfall
Evaporation Pan mm: Sourced from Bureau of Meteorology -
Cranbourne Botanic Gardens; Site No 086375

Irrigation Efficiency = 0.75

No Irrigation

10th October 2023

Mr. J. Powell
Course Superintendent
Ballarat Golf Club
1800 Sturt Street
Ballarat VIC 3350

AGCSATech
Independent Turf Analysis, Design and Consultancy Services
AUSTRALIAN GOLF COURSE SUPERINTENDENTS' ASSOC.LTD
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Dear Jeff,

SAND ANALYSIS

Brief

The samples submitted for physical analysis have been tested, and the results are presented in the attached table.

Daisys Sand

Summary

- The particle size distribution falls outside the USGA Sand Specification.
- The very fine and fine sand fractions are above specification.
- The hydraulic conductivity is low and unacceptable.
- The volumetric water percentage is high.
- The aeration porosity is very low.
- The electrical conductivity is low and acceptable.
- The pH is acidic at 5.5.

Baccus Sand

Summary

- The particle size distribution falls outside the USGA Sand Specification.
- The fraction of fine sand is well above specification.
- The medium and coarse sand fraction is well below specification.
- The hydraulic conductivity is acceptable.
- The volumetric water percentage is slightly above specification.
- The aeration porosity is acceptable.
- The electrical conductivity is low and acceptable.
- The pH is acidic at 6.6.

BSS Sand

Summary

- The particle size distribution falls outside the USGA Sand Specification.
- The very fine and fine sand fractions are above specification.
- The hydraulic conductivity is below specification.
- The volumetric water percentage is slightly above specification.
- The aeration porosity is below specification.
- The electrical conductivity is low and acceptable.
- The pH is acidic at 6.6.

Brick Sand

Summary

- The particle size distribution falls outside the USGA Sand Specification.
- The very fine sand fraction is above specification.
- The hydraulic conductivity is very low and unacceptable.
- The volumetric water percentage was acceptable.
- The aeration porosity is acceptable.
- The electrical conductivity is low and acceptable.
- The pH is acidic at 6.6.

Log Hutt

Summary

- The particle size distribution falls outside the USGA Sand Specification.
- The very fine sand and fine sand fraction is above specification.
- The hydraulic conductivity is low and unacceptable.
- The volumetric water percentage was high.
- The aeration porosity is low and unacceptable.
- The electrical conductivity is low and acceptable.
- The pH is acidic at 5.4.

Comments

Daisy's sand

The elevated levels of very fine sand and fine sand increase the volumetric water content to unacceptable levels. This also affects the aeration porosity as the broad distribution of particles encourages particle packing, reducing aeration and hydraulic conductivity. This sand is unacceptable for use in turf construction or top dressing.

Baccus Sand

The sand has a very narrow particle distribution with 66% within the fine sand fraction, this can lead to a lack of sand stability, however the sand meets all other criteria and could be considered for top dressing.

BSS Sand

The elevated levels of very fine sand and fine sand increase the volumetric water content and reduce the aeration porosity. This sand would not be considered ideal for use in sports turf maintenance.

Brick Sand

The elevated levels of silt, clay and very fine sand increase the volumetric water content. The broad range of particle sizes encourages packing of particles reducing the hydraulic conductivity dramatically. This sand is considered unacceptable for use in turf maintenance.

Log Hutt Sand

The elevated levels of very fine sand and fine sand increase the volumetric water content and reduce the aeration porosity. This sand would not be considered ideal for use in sports turf maintenance.

If you have any queries, please do not hesitate to contact me.

Yours sincerely

Bruce Macphee

AGCSATech

AUSTRALIAN SPORTS TURF MANAGERS' ASSOCIATION LTD.
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SOIL PHYSICAL ANALYSIS

CLIENT: Ballarat Golf Club
SAMPLE DESCRIPTION: As Titled
DATE SAMPLED: 11th September 2023

Particle size distribution (retained)	Sieve (mm)	USGA Specification Recommendation		Sample 1 Daisy's	Sample 2 Baccus	Sample 3 BSS	Sample 4 Bricks	Sample 5 Log Hutt
Fine Gravel	>2.00	< 3	total particles < 10	0	0	0	0	0
Very Coarse Sand	1.00 - 2.00			0	0	0	3	0
Coarse Sand	0.50 - 1.00	total particles > 60		5	0	2	24	15
Medium Sand	0.25 - 0.50			30	27	20	35	37
Fine Sand	0.15 - 0.25	< 20		30	66	36	17	36
Very Fine Sand	0.05 - 0.15	< 5	total particles < 10	26	6	40	13	19
Silt plus Clay	<0.05	< 5		9	0	3	8	2
Physical characteristics at 30 cm tension								
Bulk Density (g/cm^3)		1.2 - 1.6		1.60	1.42	1.43	1.54	1.54
Total Porosity (%V/V)		35 - 55		39.8	46.6	45.9	41.8	43.5
Volumetric Water (%V/V)		15 - 25		33.2	26.9	33.0	23.0	32.9
Aeration Porosity (%V/V)		15 - 30		6.6	19.7	12.9	18.8	10.9
Hydraulic conductivity @ 16 drops (mm/hr)		> 150		15	333	131	2	177
Hydraulic conductivity @ 32 drops(mm/hr)		> 150		14	269	121	1	140
Chemical characteristics								
pH-1:5 water		5 - 7		5.5	6.6	6.6	6.0	5.4
Electrical conductivity-1:5 water (dS/m)		<0.2		0.06	0.06	0.01	0.01	0.01
Salinity (ppm)		<600		174	177	33	30	30

Tests performed by Civil Test Pty Ltd

AGCSATech
Analytical, Diagnostic and Consultancy Services

SOIL NUTRIENT ANALYSIS

Club: **Ballarat Golf Club** *Date:* **22-Mar-22**

State: **VIC** *Test Requested By:* **Jeff Powell**

Sample Description	Units	Optimum Range	GRN 07	GRN 11
pH (1:5 water)	-	6 - 7	8.2	7.8
pH (1:5 CaCl2)	-	-	7.4	7.2
Electrical Conductivity (1:5 water)	dS/m	< 0.2	0.24	0.32
Total Soluble Salts (calc)	mg/kg	< 600	713	950
Phosphorus (Olsen)	mg/kg	12 - 20	10	9
Potassium (calc)	mg/kg	-	129	112
Extractable cations				
Calcium	meq/100g	-	2.35	2.18
Magnesium	meq/100g	-	1.84	1.77
Sodium	meq/100g	-	0.76	0.84
Potassium	meq/100g	-	0.33	0.29
Calcium / Magnesium ratio	-	2 - 5	1.3	1.2
Base Saturation				
% Calcium	% of cations	65 - 70	44	43
% Magnesium	% of cations	15 - 20	35	35
% Sodium	% of cations	< 3	14	17
% Potassium	% of cations	5 - 10	6	6
Trace Elements				
Copper	mg/kg	> 0.4	1.9	2.3
Iron	mg/kg	> 5	39	50
Manganese	mg/kg	> 2	5.0	6.6
Zinc	mg/kg	> 1	7.2	10.0
Turfgrass Species			BG	BG
Turf Use			GRN	GRN

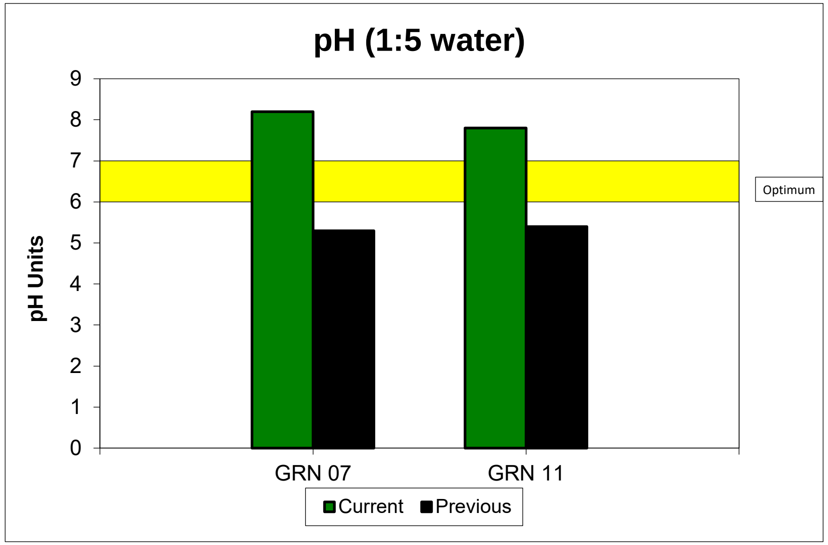
Turfgrass species: BG=Bentgrass, CC=Couchgrass (common), CH=Couchgrass (hybrid), Poa=Poa annua, RG=Ryegrass, K=Kikuyu, M=Mixed sward

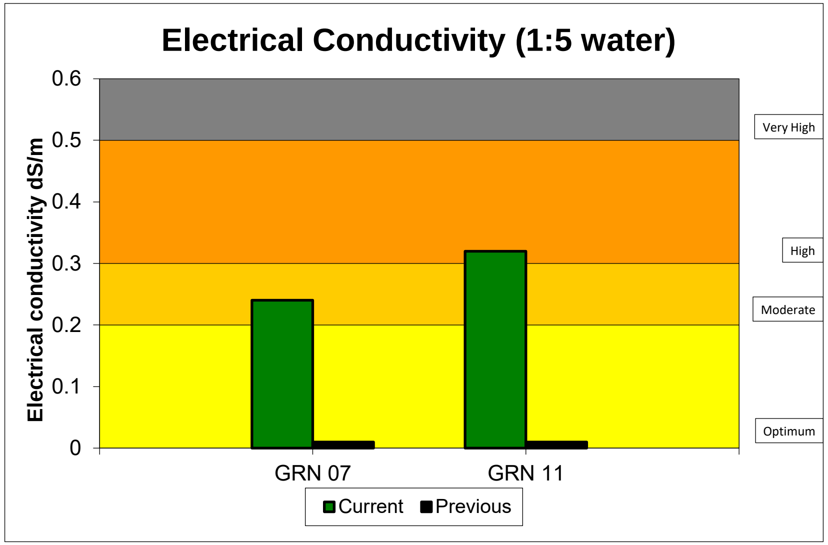
Turf Use: Grn=Golf green, FW=Fairway, T=Tee, G=Garden Bed, BG=Bowling green, SF=Sportsfield, RT=Racetrack, L=Lawn

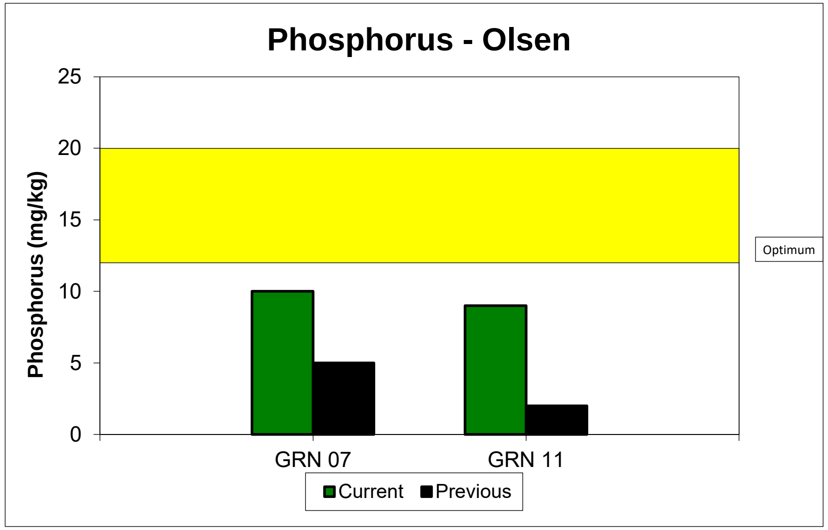
Analytical, Diagnostic and Consultancy Services

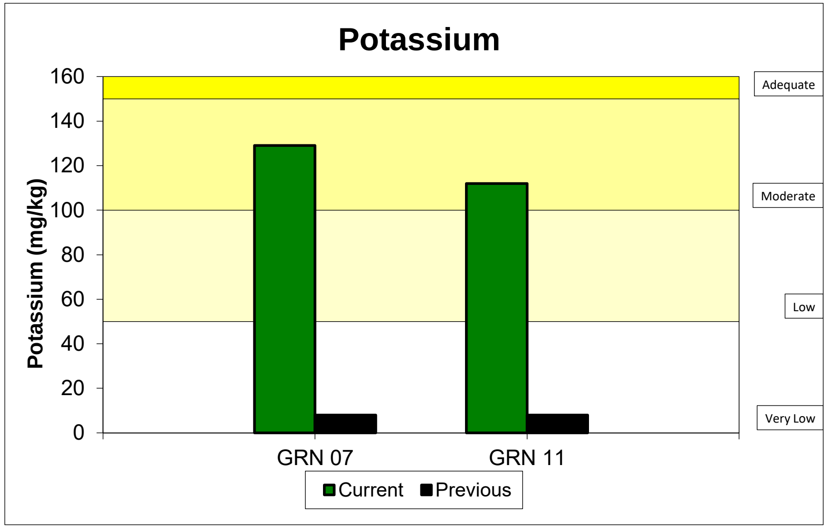
SOIL NUTRIENT ANALYSIS

Club:	**Ballarat Golf Club**	*Date Sampled:*	**22-Mar-22**
State:	**VIC**	*Test requested by:*	**Jeff Powell**





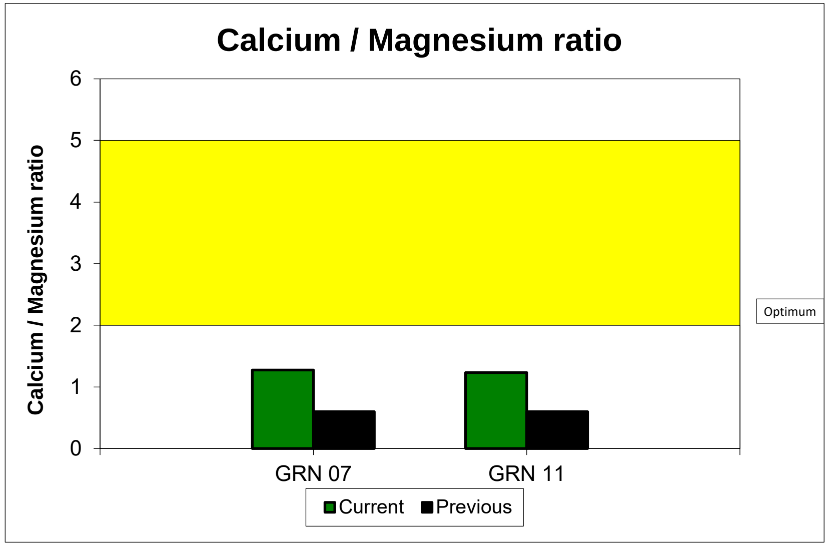


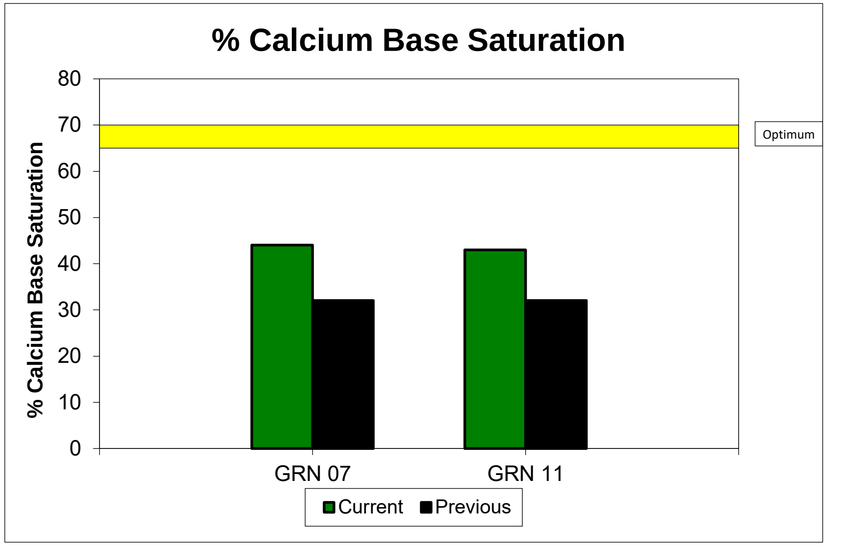


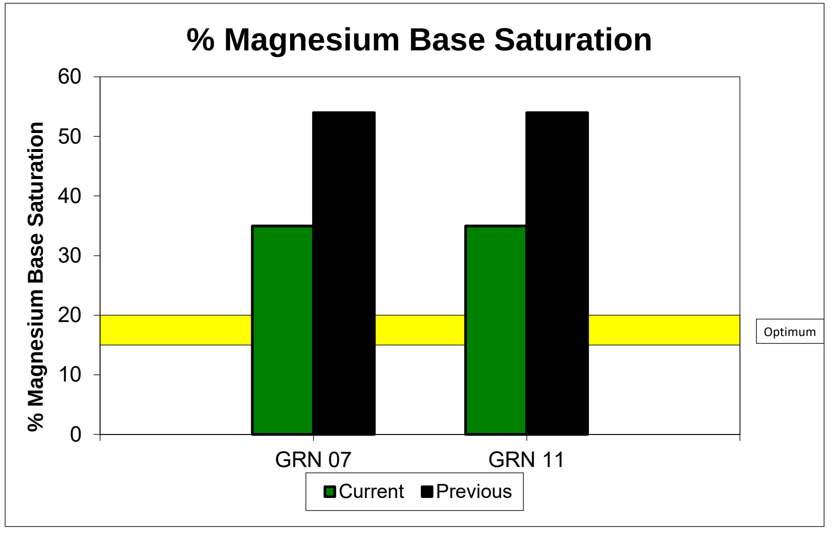
SOIL NUTRIENT ANALYSIS

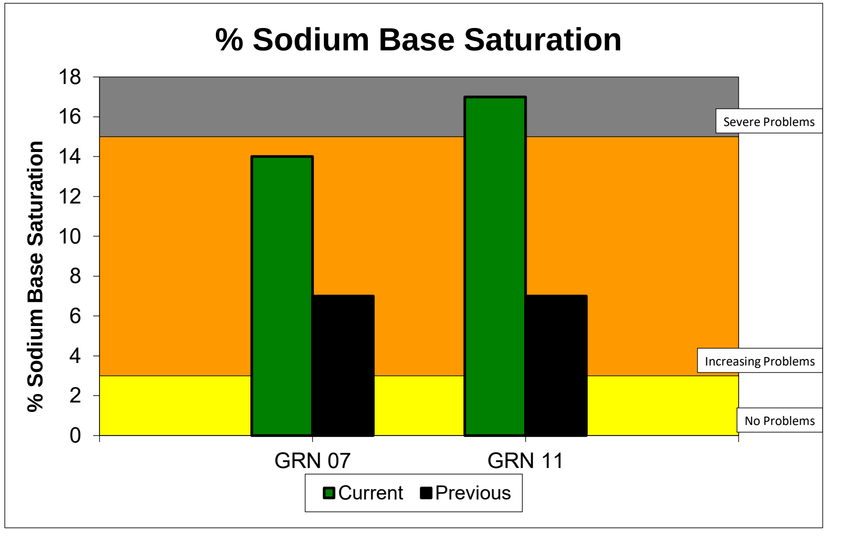
Club: **Ballarat Golf Club**
State: **VIC**

Date Sampled: **22-Mar-22**
Test requested by: **Jeff Powell**





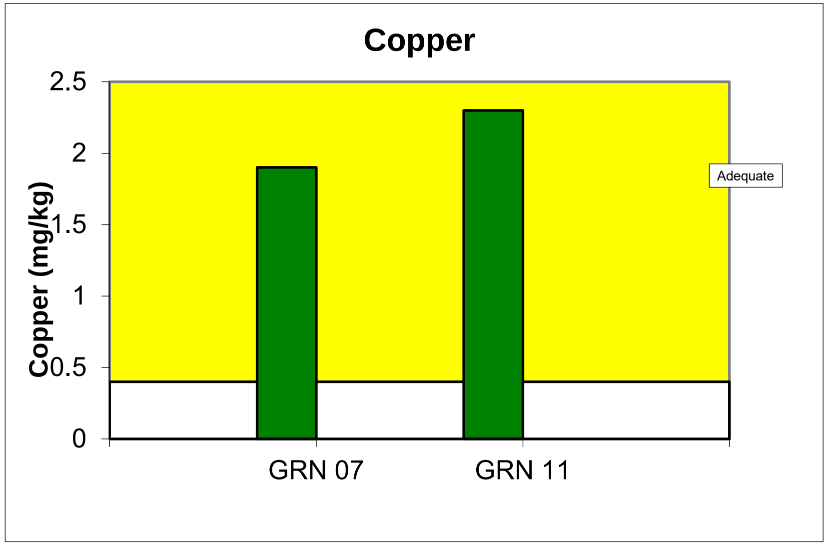


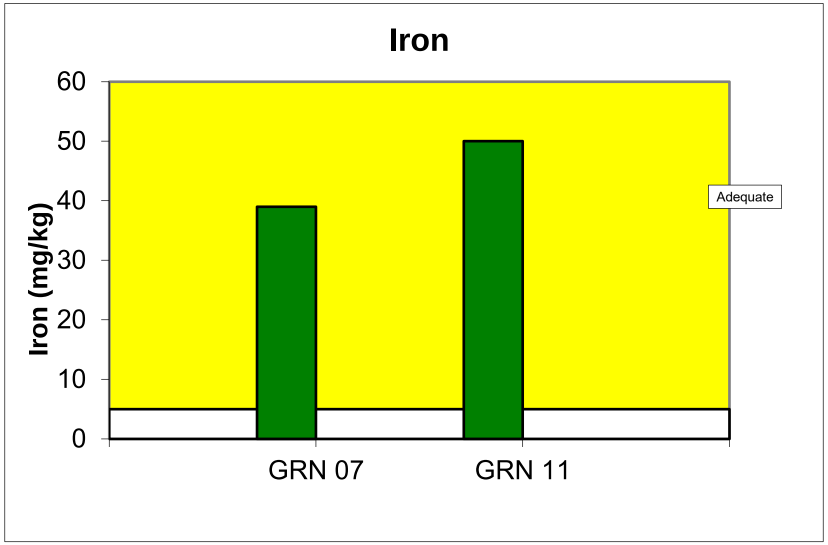


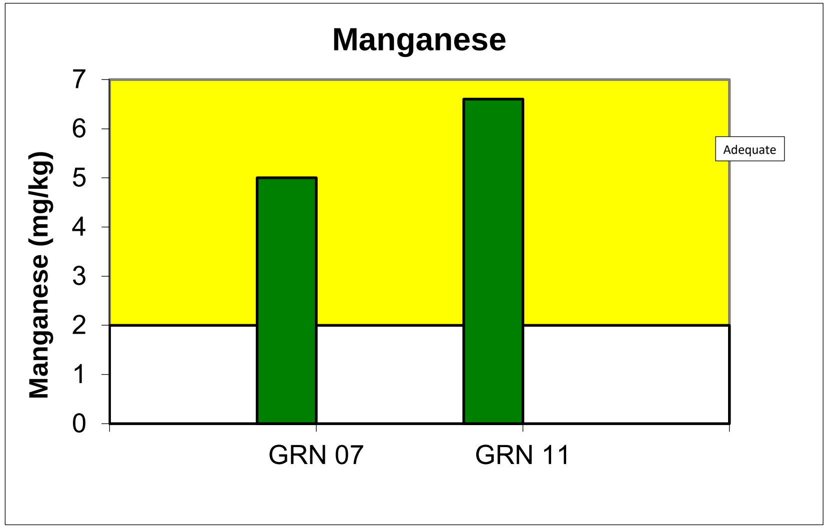
SOIL NUTRIENT ANALYSIS

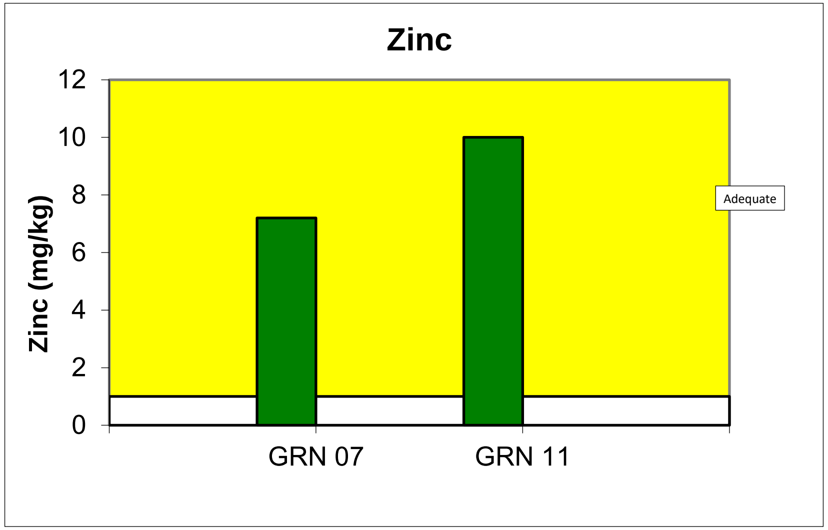
Club: **Ballarat Golf Club**
State: **VIC**

Date Sampled: **22-Mar-22**
Test requested by: **Jeff Powell**









SOIL NUTRIENT ANALYSIS

Club:	**Ballarat Golf Club**
State:	**VIC**
Date Sampled:	**Tuesday, 22 March 2022**
Test Requested by:	**Jeff Powell**

RECOMMENDATIONS

1. SOIL pH (water)

Soil pH is a measure of the soils acidity (pH < 7) or alkalinity (pH > 7). Turfgrasses are adapted to a wide range of soil pH's, however, the optimum growing conditions occur at a pH that is slightly acid to neutral (6.0 - 7.0).
Excessive acidity can result in the increased solubility of aluminum and manganese, which can reach toxic levels in acid soils. Excessively alkaline soils can result in micronutrient deficiencies.

The adjustment of soil pH with the use of liming agents or sulfur can improve nutrient availability, increase turf vigour and more favorable microbial activity.

GRN 07 The pH is moderately alkaline. Where the pH is less than 8.5 it is preferrable to apply micronutrients to compensate for any deficencies.

GRN 11 The pH is slightly alkaline and no amendment is necessary.

2. ELECTRICAL CONDUCTIVITY (SALINITY)

Electrical Conductivity (EC) is a convenient method for measuring soil salinity. An increase in EC or soil salinity is due to an accumulation of salts that can come from a wide range of sources such as irrigation water, fertilizers and gypsum and at high levels can be detrimental to turf growth and soil physical properties. The ion composition (e.g. sodium (Na), calcium (Ca) etc.) of the salts determines the type and severity of the problems that may occur.

Increasing salinity levels can be due to thatch accumulation, restricted drainage, soil compaction, excessive fertilization and high salinity water. The impact of salinity is closely related to the salinity tolerance of the turfgrass species involved and the ability to leach accumulated salts from the rootzone.

For further information refer to: "Salt affected turfgrass sites - assessment and management" by R.N. Carrow and R.R.Duncan 1998, Ann Arbor Press.

GRN 07 The salinity level is moderate and will have little or no adverse effect on turfgrass growth.

GRN 11 The salinity level is moderate and will have little or no adverse effect on turfgrass growth.

3. PHOSPHORUS (Olsen)

Phosphorus is an essential element for turf growth and in particular photosynthesis and the production of proteins and new cells and is therefore very important for the rapid extension of shoots and roots. Seedlings and immature turf need a higher concentration of phosphorus than more mature and established turf.

Phosphorus as a nutrient must be carefully monitored because in excessive amounts there is the potential for it to move into the wider environment. This is of particular concern on sandy soils that have a low phosphorus retention index (PRI).

GRN 07 The phosphorus level is adequate for most turfgrasses. If re-seeding, apply a high phosphorus fertilizer (P 5 - 10%) at 1.0kg/100m2.

GRN 11 The phosphorus level is adequate for most turfgrasses. If re-seeding, apply a high phosphorus fertilizer (P 5 - 10%) at 1.0kg/100m2.

4. POTASSIUM

Potassium plays an essential role in the growth and maintenance of turfgrasses. In particular, potassium toughens cell walls, increasing the plants resistance to wear, heat stress and attack by diseases. High sand content rootzones have very low potassium retention and require regular, light applications of potassium fertilizer in order to meet turfgrass needs.

GRN 07 The potassium level is moderate and no additional potassium is required, however, it is recommended to make regular, light applications of potassium to sustain this level.

GRN 11 The potassium level is moderate and no additional potassium is required, however, it is recommended to make regular, light applications of potassium to sustain this level.

---

5. % CALCIUM BASE SATURATION

Calcium is an important macronutrient that is found in relatively large quantities in turfgrasses, ranking just behind nitrogen and potassium. Calcium is an important constituent of cell walls, it is required for meristem growth, neutralizes potentially toxic substances in the cell and when in abundance enhances root growth.

Calcium ions also influence the uptake of potassium and magnesium and it is important to maintain a balance between each of these essential nutrient ions.

GRN 07 The % calcium is very low and it is recommended to make six (6) applications of gypsum (CaSO4) at 5kg/100m2 (0.5 tonne/ha) over the next 18 months. Soil samples need to be taken after 12 months in order to check the program.

GRN 11 The % calcium is very low and it is recommended to make six (6) applications of gypsum (CaSO4) at 5kg/100m2 (0.5 tonne/ha) over the next 18 months. Soil samples need to be taken after 12 months in order to check the program.

---

6. % MAGNESIUM BASE SATURATION

Magnesium is an important macronutrient that is involved in several important physiological processes including; being a constituent of chlorophyll, influences the movement of phosphorus within the plant and involved with many enzyme systems in the plant.

Magnesium deficiencies are mostly observed on acidic sandy soils that are easily leached. On magnesium deficient sites a rapid response usually occurs (i.e. green up of turf) when a soluble magnesium source is applied.

GRN 07 The % magnesium is high and no additional magnesium need be applied.

GRN 11 The % magnesium is high and no additional magnesium need be applied.

7. % SODIUM BASE SATURATION

Sodium is often associated with high salinity and in high concentrations can be very damaging to soil structure and cause direct injury to the plant. On high clay content soils, increasing sodium levels will result in; soil dispersion, breakdown in soil structure and reduced soil permeability. On sandy soils, sodium has little or no effect on soil structure, however, it will damage root systems and accumulate in the plant causing injury and eventually death of the plant.

GRN 07 The % sodium is marginal and indicates a potential for increasing problems and it is recommended to apply gypsum at 10kg/100m2 (1tonne/ha) and to continue regular monitoring. Where gypsum is recommended for % calcium adjustment use this application rate.

GRN 11 The % sodium is very high and indicates that there will be severe problems due to sodium uptake by the plant. It is recommended to apply gypsum at 10kg/100m2 (1tonne/ha) with a repeat application in 6 months. Close monitoring is essential and it is recommended to re-test 6 months after each application of gypsum. Where gypsum is recommended for % Calcium adjustment use that rate of application.

Water quality must be checked, as this is likely to be the main source of sodium.

8. CALCIUM - MAGNESIUM RATIO

GRN 07 There is an imbalance between calcium and magnesium. The applications of gypsum will assist in restoring the balance

GRN 11 There is an imbalance between calcium and magnesium. The applications of gypsum will assist in restoring the balance

Trace Elements

Trace Elements

The importance of Trace elements which are also referred to as micronutrients lies in their role as catalysts in enzymatic reactions. Amounts required are generally low, however deficiencies are usually associated with sands low in CEC or conditions that limit the availability of soluble nutrient concentrations.

To avoid deficiencies it is advised to ensure soils are maintained within a suitable pH range.

9. COPPER

Copper deficiencies are mostly observed on sandy soils that are easily leached. Soils high in iron, manganese, zinc or phosphorus can also contribute to copper deficiency.

Repeated use of copper based fungicides can lead to toxicity, especially on acid soils

GRN 07 No additional copper is required at this stage.

GRN 11 No additional copper is required at this stage.

---

10. IRON

Turfgrass managers use iron primarily to enhance color. Iron plays an important role as a component of proteins and enzymes involved in respiration, nitrogen metabolism and in the synthesis of chlorophyll.

Iron is the mirconutrient most commonly in short supply in turf soils. Some of the most common causes include high soil Ph, excessive thatch, waterlogging or excessive applications of phosphorus, manganese, copper and zinc.

Iron deficiency symptoms show up as a chlorosis in the younger, upper leaves of the plant in contrast to N deficiencies, which result in chlorosis of the older, lower leaves.

GRN 07 No additional iron is required at this stage.

GRN 11 No additional iron is required at this stage.

---

11. MANGANESE

Manganese is an important micronutrient associated with cell wall lignification of roots and as an activator of several enzymes. Manganese is also needed for the photosynthesis and for the making of poteins.

Deficiencies are generally associated with alkaline soils or soils high in iron, copper or zinc.

GRN 07 No additional manganese is required at this stage.

GRN 11 No additional manganese is required at this stage.

12. ZINC

Zinc plays a role in the production of hormones that control extension growth such as root and stem elongation and leaf expansion.

Deficiencies are generally associated with alkaline soils, some coarse sandy soils or excessive application of phosphorus and nitrogen fertilizers.

GRN 07 No additional zinc is required at this stage.

GRN 11 No additional zinc is required at this stage.