Irrigation and soil assessment for Boyne Island Tannum Sands Golf Course

06th May 2020

AQUEDUCT CONSULTANCY

Irrigation Design and Water Harvesting

Irrigation and soil assessment for Boyne Island Tannum Golf Course

Rex Sullings, Irrigation Designer. Dip. Irri, Licenced irrigation installer, CID

Dr Paul Lamble, Principal Consultant Peak Water Consulting, CID

Dr Mick Battam, Principal soil scientist AgEnviro Solutions. CPSS. CIAg, CID

Report Limitations

This report was written in a certain way, with a certain budget, for a specific intention.

The material contained within this report is for use by Gladstone Regional Council for irrigation management at Boyne Island Tannum Sands Golf Course located at Jacaranda Drive Boyne Island QLD 4680. Limitations apply and the material contained within the report (including technical information, formats and recommendations) is not to be used by other persons, organisations other than within contexts of irrigation management at Boyne Island Tannum Sands Golf Course located at Jacaranda Drive Boyne Island QLD 4680.

Aqueduct Consultancy

21 Seventh Ave, Toukley 2263

0412 434 294

rexsullings@bigpond.com

Executive summary

Gladstone Regional Council commissioned Aqueduct Consultancy to perform an irrigation and soil condition assessment for Boyne Island Tannum Sands Golf Course. A summary of the findings is provided in this report which provides answers to the following key questions.

Has irrigation with recycled water damaged the soil structure?

Irrigation with recycled water has likely increased sodium levels within the soil, with moderate to low levels of permeability observed in the A2 horizon. These results are concerning given that lateral movement in this horizon is the primary means for removing excess water and salts from the soil profile. The application of recycled water has likely increased the topsoil pH (not a concern), with minimal changes observed in the other nutrients.

What changes are needed to allow continued irrigation with recycled water?

A risk assessment was performed and the following changes are recommended to the current practices:

- install additional signage at all access points warning the recycled water is used for irrigation;
- ideally the soil would be fully amended and turf established from sprigs using the works described in Section 7.2. In the short term, the sodicity improvements could be achieved using the following calcium dominated fertiliser program in conjunction with the application of pre-emergent herbicide, with selective herbicide to control broadleaf weeds;
    - **June:** 200 kg of gypsum;
    - **August:** fertiliser containing <u>all</u> of the trace elements e.g. 200 kg/ha of Yara Mila complex (or equivalent);
    - **October, December, February and April:** 200 kg/ha of Cal-gran aftergraze (or equivalent, but a similar balance of nutrients must be achieved;
    - **June year 2:** 200 kg of gypsum;
    - soil scientist to refine the fertiliser program after this based on soil test results;
- monitoring of additional soil chemical properties (TC, TN, nitrate, ammonium, exchangeable cations, pH, EC, available P, sulphur & micronutrients -Table 3.1) during six monthly testing;
- monitoring of additional water quality parameters including SAR (quarterly until a pattern is established) and annually of other contaminants (Table 11.1);
- connecting the tank overflow to stormwater so it does not wet fairway;
- converting the irrigation pump system from “flow start” to “pressure actuated start”;
- installing flow sensors and a controller that is capable of monitoring flow;
- amend waterlogged areas of the site that are irrigated with recycled water such as bunkers. In the short term, these bunkers should be pumped out prior to irrigating with recycled water;
- place non-potable water signage on the rainwater tank near the 9th tee which is capturing water from a roof that is receiving recycled water from tee sprinklers;
- adjust sprinklers on 12th hole so recycled water does not spray into the dam and ensures an unirrigated buffer strip of at least 2 m is maintained;
- ensure the pump shed floor has sufficient cross-fall or a drain to prevent pooling of water;
- annual audit of the irrigation system;
- inspect site routinely for wet spots (e.g. during mowing) and inspect if found;
- develop SOPs for use by staff and contractors in activities that may result in contact with recycled water (examples in Appendix B); and
- ensure staff and contractors are adequately trained according to the SOPs.

Figure E.1: The existing topdress is having no impact on the structure of the soil which is prone to hardsetting due to lack of organic matter and elevated sodium levels.

Does the site need a new irrigation system?

The existing irrigation system has significant problems and should be replaced with a system capable of applying water evenly. As the fairways are quite narrow (concentrated wear and compaction) it is recommended the new system apply water to the fly overs and up to tree lines along the fairway sides.

The ability of the irrigation system to apply water evenly (and avoid ponding) is often a function of other processes, such as how the system is procured and the quality of the installation (for example, the quality of materials and how accurately the sprinklers are installed to the design location).

It is quite common for irrigation systems to be installed as a "design and construct" project. In reality, contractors cannot accurately price the project without doing design work to ascertain for example, the quantity and sizing of materials (e.g. pipes, sprinklers, valves, pumps and control systems). Contractors are well aware that their tender will be evaluated on price and will be looking for opportunities to reduce costs to win the job. Hence, it is a common technique to increase the spacing between sprinklers and reduce the operating pressure, which in turn means smaller pumps, smaller pipes, fewer sprinklers, and ultimately lower capital costs. Unfortunately, it also means the performance of the system is compromised and it is not capable of applying water evenly or within the available operating time. Furthermore, compromises are made in the design which affect how the system can be operated and managed. These compromises would be made without Council's knowledge and do not become apparent until after the irrigation system is installed.

An alternative approach is to undertake a separate detailed design process using an independent designer. While it may take longer, such a process enables Council to shape the final design to suit the site infrastructure, likely capital budget and operating conditions. Furthermore, it enables a frank and open discussion on potential issues and compromises so Council is fully aware of the capabilities and limitations of the proposed system before it is installed. This process also means that the competitive tendering process for the installation is much less likely to impact the performance and suitability of the installed irrigation system.

Whichever procurement and design process is chosen, it is crucial that the new system applies water evenly. Hence, the new system must be:

- designed to a performance standard (e.g. scheduling coefficient of less than 1.25);
- designed by a suitably qualified, independent irrigation designer. A list of certified irrigation designers is on the Irrigation Australia website.
- installed to a performance standard (e.g. heads are within 100 mm of their design locations).

How can the system be improved in the short term?

In the short term, improvements to the existing system could be achieved by:

- replacing the irrigation controller with a "smart" controller such as the Hunter ACC2 controller which can provide advanced sensor input response, remote access and monitoring;
- installing flow, wind and rain sensors to the new controller;
- replacing greens sprinklers with Hunter I-40 #41 nozzle (could occur over time as sprinklers become unserviceable. All heads on a green should be changed at the same time;
- replacing the existing fairway sprinklers as these become unserviceable. All heads on a lateral should be replaced at the same time. For best performance replace the sprinklers on fairways with a
    - triangular spacing configuration: replace with Rain Bird 8005 #14 nozzle;
    - rectangular spacing configuration: replace with Rain Bird 6504 #16 nozzles;
- reinstating the filtration system and installing a pre filtration unit; and
- implement the revised irrigation schedule (Section 9).

Do not take advice from irrigation company sales representatives that claim their sprinkler is "equivalent". Some sprinklers may have a similar flow rate or radius of throw, but how their distribution of water is very different.

Is the tank capacity large enough?

The current tank capacity is adequate, provided inflow rates are approximately 20-30 L/s. The system would benefit from a back-up potable water supply (at least for greens and tees) for periods when recycled water is not available and for flushing the irrigation system as required.

What is the condition of the course?

The assessment found thin or weedy cover across most fairways, with better cover at the north end of the course. Whilst some of this is attributable to interruptions in water supply, thin cover would likely be an issue in many of the narrower sections of the course due to a combination of compaction, competition from tree roots, limited weed control, low levels of nutrients and soil sodicity.

Figure E.2: Bare area that may improve slightly with fertiliser and weed control, but thin cover will likely persist until the issues of tree roots and traffic management are addressed.

How can the course be improved?

In addition to having a back-up water supply and an irrigation system capable of applying water evenly, the following works could be used to improve the condition of the course:

- install root barriers so turf is not competing with trees, with this being most crucial on narrow holes, tees and greens (some can be installed in the same trench as irrigation pipes);
- implement the traffic management practices to minimise soil compaction (Section 2.2);
- amend areas of the course by either:
    - reconstruct bare areas where the turf will struggle to recover according to the works in this report (Section 7.2);
    - reconstruct the uneven and shallow areas according to the works in Section 2.5; and
    - amend areas where the turf can be recovered using the fertiliser program (Section 12.1), aeration (aggravator) and weed management (Section 12.2);
- apply wetting agent twice annually (at least to the tees, greens and steeper fairway areas).

The current topdress is regarded as far too sandy for use on the course and will result in thin turf if applied. Instead, the existing site soil can be used to fill depressions, with this able to harvested during construction of new paths or amendment of the uneven area on the 2nd hole (Section 2.5).

What will it cost?

To reconstruct the course (excluding the northern two holes)

The cost to reconstruct the course (excluding the northern two holes) by amending the soil and establishing a suitable for couch cultivar from sprigs about $1,320,000+GST, with this assumes a contractor maintains turf until 90% ground cover. However, this could be significantly reduced by having a staff member oversee turf grow in (following initial sprig establishment).

Depending on the time of year these works are performed (and the couch cultivar), acceptable turf cover could be achieved following sprigging in about a 10 to 15-week period. Reconstruction could be performed in stages that follow the installation of the new irrigation system, so 9 holes always remain in play at all times

New irrigation system

The cost to install a new irrigation system that can apply water evenly is $1,090,000+GST (Table E.1).

Table E.1.: Summary of estimated irrigation system replacement costs (excluding GST). The irrigated area is large than that watered by the current irrigation system.

BITS Golf Course	Area – ha/Unit	Rate $/Unit	Total
Greens	0.4	$80,000	$32,000
Fairways	12.3	$60,000	$738,000
Tees	0.6	$60,000	$36,000
Pump station	1	$25,000	$25,000
Filtration	1	$15,000	$15,000
Control system	1	$25,000	$25,000
Sub Total			**$871,000**
Project management	1	10%	$88,000
Contingency	1	15%	$131,000
Sub Total			**$219,000**
Budgetary Estimate			**$1,090,000**

Short term irrigation works

It is strongly recommended that the existing irrigation system be replaced with one capable of applying water evenly. However, significant improvements could be achieved by implementing the short-term works outlined in Table E.2. If performed in accordance with the new system design, many of the improvements could be used to offset the price of the new system whenever it is installed.

Table E.2: Summary of irrigation system interim improvement options (cost estimates excluding GST).

Activity	Cost
Replace the irrigation controller with a smart controller e.g. Hunter ACC2.	$3,500
Install metering and flow sensor	$3,500
Install rain sensor	$150
Replace existing pump set with more suitable multi- stage centrifugal multiple pumps set with variable speed control.	$25,000
Replace existing greens sprinklers with Hunter I-40 #41 nozzles.	$195 per head - $10,000 all heads.
Replace the existing fairway sprinklers	$135-195 per head - $45,000 all heads.
Re-instate filtration system to original specification and install new cyclonic pre filter unit.	$15,000
Implement e revised scheduling programme.	

Table of Contents

List of Acronyms and Definitions

Acronym / Term	Explanation or Definition
B	Boron
CEC	Cation Exchange Capacity – a measure of the capacity of the soil to supply key plant nutrients
CU	Christiansen's uniformity coefficient (CU) or Coefficient of Uniformity. A measure of how evenly an irrigation system applies water, CU = 100[1 – (average deviation / average depth or volume)]
Cu	Copper
DU	Distribution Uniformity. Another measure of how evenly an irrigation system applies water. Usually the Lowest Quartile (LQ) is used. DU = (Average volume of depth of lower quarter / Average volume or depth of all) x 100
EC	Electrical Conductivity, which is a measure of salinity in soil and water, usually expressed in deciSiemens per metre (dS/m)
E. coli	Escherichia coli – a bacteria commonly found in the gut of animals (including humans)
Exch.	Exchangeable
Fe	Iron
Mn	Manganese
N	Nitrogen
OM	Organic Matter
P	Phosphorus
S	Sulphur
SAR	Sodium Adsorption Ratio, which is an irrigation water quality parameter. It indicates the amount of sodium (Na) relative to calcium (Ca) and magnesium (Mg) in the water
SC	Scheduling Coefficient – A run time multiplier to ensure the driest areas receive sufficient water. Also a measure of how evenly the irrigation system applies water. SC = average depth or volume / lowest depth or volume (dry area).
SOP	Standard Operating Procedure
TC	Total Carbon
TN	Total Nitrogen
TP	Total Phosphorus
uPVC	Unplasticised Polyvinylchloride (also known as rigid PVC)
Zn	Zinc

1 Background

Boyne Island Tannum Sands (BITS) Golf Club is located at Jacaranda Drive Boyne Island. The course is 5730 metres in length and consists of 13 holes (Figure 2.2), with holes 1 to 5 replayed from different tees. Gladstone Regional Council supplies recycled water from Tannum Sands wastewater treatment plant for the irrigation of the course. Council also maintains the irrigation system and conducts monitoring in accordance with the site irrigation management plan (GRC, 2015).

In response to recent monitoring which found a decline in the soil structure, Council engaged Aqueduct Consultancy to:

- assess the condition of the soil and provide a remediation plan (if required); and
- assess the irrigation system (30 years old) to determine if it should be retrofitted or replaced.

In performing this work, due reference is made to the Guideline for low-exposure recycled water schemes (Queensland Health, 2019) and Australian Guidelines for Water Recycling (NRMMC, 2006). A summary of this work is provided in this report which was written by Rex Sullings (certified irrigation designer), Dr Paul Lamble (certified irrigation designer) and Dr Mick Battam (certified professional soil scientist & irrigation agronomist).

2 Soil physical characteristics

A soil assessment of the course was performed in February 2020 by Dr Mick Battam. The soil across most of the course consisted of:

A1 horizon: 200 to 330 mm of sandy loam that was moderately structured

A2 horizon: 170 mm thick of yellow to tan coloured loamy sand to sandy loam. Water percolating down (waves arrows) through the profile is impeded by the B horizon and moves downslope in the A2 layer (across the top of the underlying B horizon). As such, this “wet zone” would sometimes be 170 mm thick

B horizon: tan coloured sandy clay that is prone to hardsetting (insert). Typically at about 420 mm depth, but much deeper in some areas

However, in the southern sections of the course the A2 horizon consisted of 70 mm of loamy gravel overlying orange medium clay subsoil (Figure 2.2). In the far northeast corner of the site (beside the dam approaching the 12th green), the topsoil has a sandy clay loam texture and has likely been constructed by mixing soil layers together.

A1 horizon: 200 mm of sandy loam that was moderately structured. This horizon had been removed in some areas, with gravel observed at the surface.

A2 horizon: 170 mm thick of tan coloured loamy gravel. Water percolating (wavey arrows) through the profile is impeded by the clay B horizon and moves downslope in the A2 layer (across the top of the B horizon). As such, the "wet zone" would sometimes be 170 mm thick

B horizon: orange coloured medium clay that is highly compacted.

Figure 2.1: Soil observed on the 5th and 6th holes. As with the soil on other sections of the course, water that percolates through the profile is eventually stopped by the clay and moves downslope across the top of this clay horizon.

2.1 Topsoil depth

The topsoil was deep across most of the course, with the A1 horizon alone often 200 to 330 mm thick. However, the topsoil was extremely shallow in localised areas such as (Figure 2.2):

- 5th hole: in front of the tee and in the sides of the steep swale;
- 6th hole: just downslope from in front of the 5th tee and near the path close to the tee;
- 11th hole: on the southern edge of the bend;
- 12th hole: in front of the tee; and
- on steeper areas surrounding raised greens.

These areas are obvious, with the turf struggling to maintain cover and gravel often on the surface (Figure 2.3). Section 2.5 describes where additional topsoil can be obtained to amend these areas.

5th hole	**6th hole**

Figure 2.3: Areas that are struggling due to lack of topsoil.

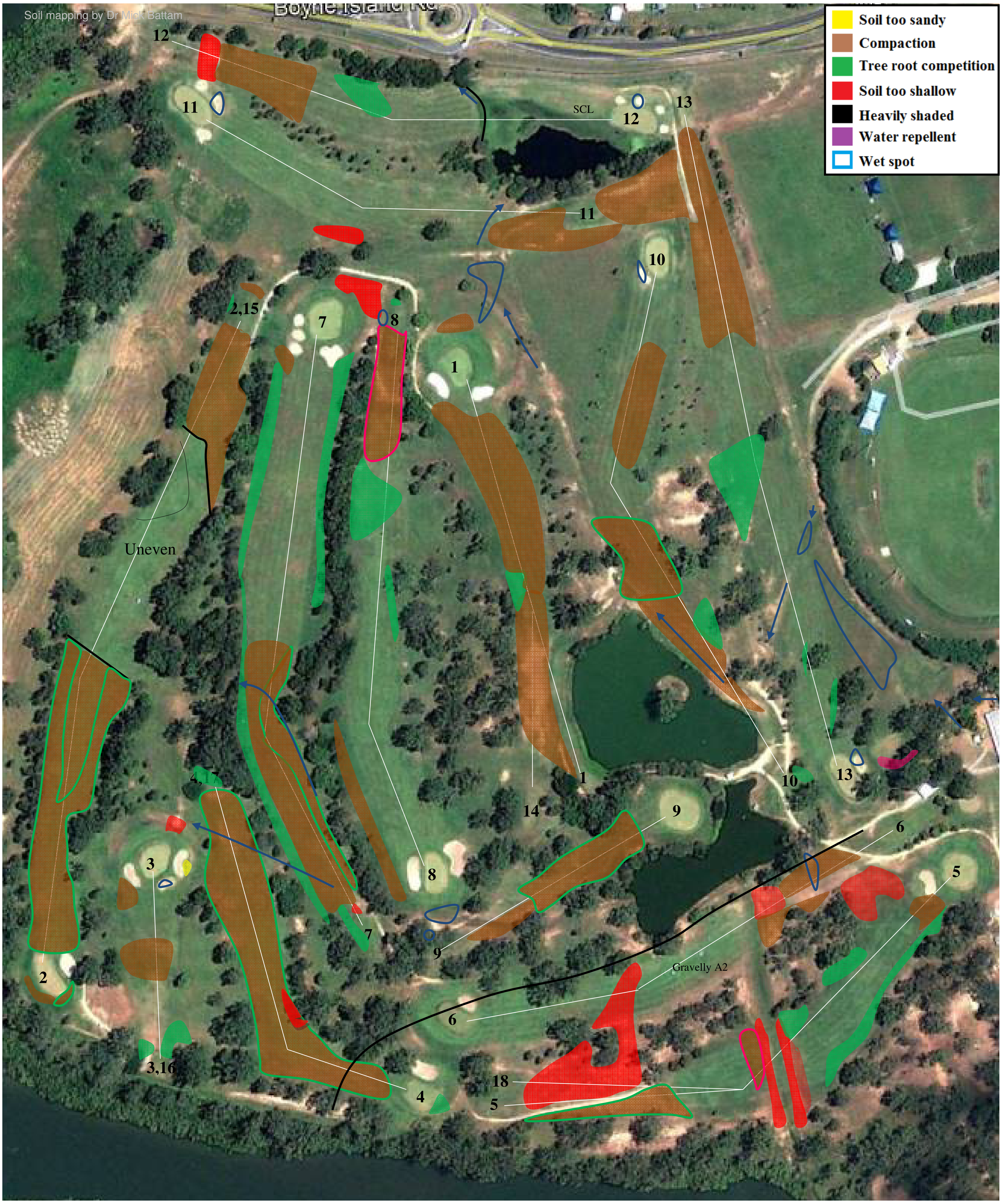

Figure 2.2: Factors limiting turf on the course. Google Earth image.

2.2 Compaction and traffic management

The topsoil was highly compacted in areas, especially on narrower fairways near the tees (Figure 2.2). Many of these problems could be overcome by effective traffic management, such as better definition of the cart access areas and using barriers. These can often be subtly installed by locating bins, garden beds or sand boxes in key locations. Wherever possible, try to locate the paths close to trees as the turf will always struggle in these areas. Due to the hardsetting nature of the soil, the importance of traffic management on this site cannot be emphasised enough.

By removing the topsoil prior to laying the path material, this will generate topsoil for use in amending shallow areas and filling depressions. The existing site soil is not only cheaper, but is far superior to the material that is currently being used for topdressing (Section 2.5).

Figure 2.4: The thin turf areas could be majorly reduced by better defining paths and using "barriers" to encourage golfers to stick to these paths. These barriers can be fences (lower left), but traffic management can often be achieved by installing additional tee blocks (lower right), garden, garbage bins, water hazards or bunkers in locations that help direct traffic. As the turf will always struggle in areas close to trees, it is often better to install paths that cover these thin turf areas (upper and lower right).

Figure 2.5: Other examples of large areas where the turf is struggling that could be minimized by better defining paths. Insert shows how hardsetting the soil can be.

2.3 Permeability

The soil is highly prone to setting hard and would benefit from the incorporation of organic matter such as finely screened composted garden organics that is made to Australian Standard AS4454. During the reconstruction process, organic material would be incorporated to a depth of 160-180mm. Infiltration testing found the topsoil and A2 horizon are relatively permeable, with the saturated hydraulic conductivity much lower in the clay subsoil (Table 2.1). These results are not surprising, with the presence and lighter texture of the A2 horizon suggesting much of the deep percolation runs downslope through this horizon, across the top of the underlying sandy clay horizon (Section 2.1).

Table 2.1: Saturated hydraulic conductivity (mm/hr) measured in the field.

Location	A1 horizon	A2 horizon	Subsoil
4th south end	41	54	-
4th north end	82	60	0
5th	65	20 (loamy gravel)	0
8th	50	5.9	-
9th	150	150	-
10th	-	15	1
11th	12	42	0
14th	4	150	-

2.4 Water repellency

Despite the recent wet weather, the soil was completely dry in some locations due to water repellency (Figure 2.6). This was often observed in areas that were either highly compacted or steep sections of the course but was likely also a major issue on the greens (author was not able to verify without digging). Water repellency could be overcome by applying a wetting agent to the course at the end of each dry season. The wetting agent is most crucial for application to the greens, but it would ideally also be applied to tees, fairways and rough areas.

Figure 2.6: Turf struggling around the perimeter of a green (upper left) due to water repellency. This was also observed on other sections of the course, with the soil almost completely dry in some locations despite recent wet weather (upper right). Water repellency can be overcome through the application of a wetting agent.

2.5 Reconstruct and harvest topsoil from the uneven area on the 2nd hole

Due to settlement of the underlying material, the playing surface is extremely uneven for about a 150 metre section of the fairway along the 2nd hole. Whilst some improvements could be achieved using topdressing, the depressions are so large in some locations that ideally this area would be reconstructed. This could be achieved in a manner that allows large amounts of topsoil to be harvested from this area, which is 200 to 350 mm deep in most locations. In order to achieve this:

- apply 15 tonne per hectare of agricultural lime to the shallow sections of the course (Figure 2.2) and cross rip these areas in at least two directions so the surface is slightly uneven, but remove any large rocks;
- strip the existing turf cover from the uneven area on the 2nd hole and spread this material on the shallow sections of the course so the growing media is at least 180 mm deep;
- striping the remaining topsoil (do NOT mix with the underlying subsoil) from the uneven areas on the 2nd hole and stockpile for reuse;
- shape the subsoil so a uniform cross-fall is achieved;
- spread the harvested topsoil so a growing media of at least 180 mm is achieved in all areas;
- mix 30 mm of finely screened composted garden organics (Appendix A) and 5 tonne per hectare of lime into the spread topsoil and sprig with a suitable couch cultivar such as Windsor Green (not Winter Green); and
- screen any remaining topsoil and stockpile for reuse (control any turf or weeds that attempt to become established in the stockpile). This screened material can be used to topdress the amended areas until an even surface is achieved.

About 400 m^3 of topsoil could be harvested from the uneven area, with this being more than enough to ensure a topsoil depth of at least 180 mm can be achieved in all areas that currently have minimal topsoil (Figure 1.1). Excess material can then be used for topdressing, with the existing site soil far superior to the sand-based material that is currently being used (Figure 2.7).

Figure 2.7: By reconstructing the uneven area on the 2nd hole (upper), about 400 m^3 of topsoil could be harvested and used to fill depressions and amend shallow areas on the course such as those on the 5th hole (insert). The existing site soil is far superior to the sand-based material that is currently being used (lower left), with the turf thin even in deep areas where it has been spread (lower right).

3 Soil chemistry

Historical soil testing measured pH, EC, TN, TP. SAR was also measured, but this is a water quality parameter and is not the best predictor for use in the interpretation of the condition of soil. These samples were taken from the:

- upper 100 mm (A1 horizon); and
- 100 to 600 mm, with the author of this report assuming these have come from the A2 horizon (relatively deep across the site), but these could have been a mixture of the A1 and A2 horizon, possibly containing some B horizon in some locations.

In addition, no samples were collected from the different soil type that was observed on the southern edge of the course. To overcome these limitations, samples were collected from unirrigated areas around BITS Golf Course and BITS Sports Fields for use as background samples (Table 3.1).

3.1 pH

The median pH of the recycled water used to irrigate BITS golf course is 7.61, with soil tests finding:

- **A1 horizon:** pH historically varied from 5.9 to 7.1, with recent testing finding 6.6 to 7.4 (5.8 to 6.6 unirrigated samples);
- **A2 horizon:** pH historically varied from 6.1 to 7.6, with recent testing finding 6.5 to 7.8 (6.5 to 7.3 unirrigated samples); and
- **B horizon:** no historical testing, with recent testing finding 7.2 to 8.5 (7.1 to 8.8 unirrigated).

The elevated pH in the topsoil appears to have increased, but is still in a range suitable for the turf grasses on the golf course. Minimal changes were observed in the pH of other layers (Table 3.1).

3.2 EC (salt levels)

Median EC of the recycled water used to irrigate BITS golf course is 1.04 dS/m. Soil tests found:

- **A1 horizon:** EC_e of 0.10 to 0.91 dS/m (0.30 to 0.39 dS/m in the unirrigated samples), with 2.1 dS/m observed in March 2018 (1.14 dS/m in unirrigated topsoil next to south creek inlet);
- **A2 horizon:** EC_e of 0.09 to 1.86 dS/m, with 0.33 to 0.93 dS/m in the unirrigated samples; and
- **B horizon:** EC_e of 1.28 to 3.83 dS/m, with 0.43 to 1.83 dS/m in the unirrigated samples.

These results suggest increases in salt levels might be occurring, but the readings appear to vary considerably over time with 2.1 dS/m observed in the A1 horizon in March 2018 (Table 3.1). This could be due to either weather conditions of unevenness in the irrigation system. Regardless of the cause, these salinity levels vary within a range that is unlikely to adversely affect the turf species on the site. Provided the site continues to drain freely, salinity levels are of minimal concern with regards to turf health.

3.3 Exchangeable cations

SAR levels in the recycled water have not been measured historically, with 4.97 and 5.5 observed in two recent samples. Soil tests found (Table 3.1):

- **A1 horizon:** calcium and potassium are marginally to deficient, with 2.4 to 9.1% exchangeable sodium levels observed, with all readings higher than the unirrigated samples;
- **A2 horizon:** calcium deficient, with potassium varying from 2.3% (deficient) to 7.1% (sufficient). High sodium levels in the irrigated (13 to 24%) and unirrigated (6.3 to 19%) samples; and
- **B horizon:** calcium and potassium highly deficient, with 22 to 33% exchangeable sodium levels (11 to 25% in the unirrigated samples).

As such, the topsoil appears to becoming higher in sodium levels, with turf likely to respond positively to the application of calcium and potassium.

3.4 Phosphorus

The median total phosphorus levels of the recycled water used to irrigate used to irrigate BITS golf course is 0.4 mg/L. Total P is a poor measure of availability, with available P levels from the soil samples finding (Table 3.1):

- **A1 horizon:** 18 (low) to 48 mg/kg (sufficient), but much than the 1.5 to 4.2 mg/kg observed in the unirrigated samples which are regarded as deficient in phosphorus;
- **A2 horizon:** deficient in irrigated (4.0 to 5.5 mg/kg) and unirrigated samples (<1 mg/kg); and
- **B horizon:** deficient in irrigated (1.4 to 2.4 mg/kg) and unirrigated samples (<1 to 1.7 mg/L).

Available phosphorus levels in the topsoil low to sufficient, with the A2 and B horizons having minimal available nutrients.

3.5 Nitrogen

The median total nitrogen levels of the recycled water used to irrigate used to irrigate BITS sportsground is 2.1 mg/L. Total N is a poor measure of availability, with N budget modelling from the soil samples finding (Table 3.1):

- **A1 horizon:** 75 to 84 kg/ha of available nitrogen, with 30 to 53 kg/ha in unirrigated samples;
- **A2 horizon:** deficient, with almost no available N in irrigated and unirrigated samples; and
- **B horizon:** almost no available nitrogen in the irrigated and unirrigated samples.

Apart from the topsoil the soil is relatively low in available nitrogen.

3.6 Sulfur

Sulfur levels were not measured in the recycled water, but would be expected to be about 2 mg/L. Based the soil samples (Table 3.1):

- **A1 horizon:** 2.9 to 9.5 mg/kg, which is more than 2.8 to 4.2 mg/kg in the irrigated sample;
- **A2 horizon:** 3 to 52 mg/kg, which is more than <1 to 1.8 mg/kg in the irrigated sample; and
- **B horizon:** 20 to 83 mg/kg, which is more than <1 to 4.4 mg/kg in the irrigated sample.

It is likely that much of this sulfur was applied via fertiliser, with sulfur a common component in many fertilisers.

3.7 Micronutrients

Micronutrient levels in the recycled water have not been measured historically, with two recent samples finding very low levels of copper and zinc. The soil tests found (Table 3.1):

- **Iron:** adequate levels in the topsoil, with marginal levels in the B horizon (deficient in unirrigated);
- **Manganese and copper and boron:** all samples deficient or marginally deficient;
- **Zinc:** most samples deficient;

Generally, the irrigated samples had more boron but lower copper and manganese levels. This is counter to what would have been expected given the rise in pH from irrigation with recycled water.

3.8 Summary of soil chemistry

The soil at BITS Golf Course has a low cation exchange capacity and is regarded as having:

- **acceptable:** pH and salinity level, with it having adequate supply of magnesium and iron;
- **available nitrogen and phosphorus:** A1 horizon has adequate supply to sustain moderate growth, with the turf unlikely to obtain any from the underlying horizons;
- **deficient or marginally low:** calcium, potassium, sulfur, manganese, copper, zinc & boron.

Irrigation with recycled water has likely increased sodium levels in the A1 and A2 horizons, with the application of fertiliser likely responsible for increases in nitrogen, phosphorus and sulfur levels.

Table 3.1a: Chemical analysis (A1 soil horizon), with the highlighting showing deficient macronutrients (red), marginally low macronutrients and deficient micronutrients (orange) and marginally low micronutrients (cream). Very low CEC values are in bold. 2019

Parameter	A1 horizon																						
	1st				2nd					5th	6th	7th				10th					Not irrigated		
	Nov 2017	May 2018	Nov 2018	May 2019	Nov 2017	May 2018	Nov 2018	May 2019	Feb 2020	Feb 2020	Feb 2020	Nov 2017	May 2018	Nov 2018	May 2019	Nov 2017	May 2018	Nov 2018	May 2019	Feb 2020	Feb 2020 rep.1	Feb 2020 rep.2	Feb 2020 rep.3
pH_w	6.4	5.9	6	5.9	6.5	6.0	6.1	6.5	7.38	7.40	7.07	6.4	6.2	6.2	6.1	6.5	6.6	6.5	7.1	6.58	5.81	5.81	6.64
EC_e[2] (dS/m)	0.44	0.48	2.10	0.54	0.57	0.21	0.28	0.10	0.91	0.87	0.66	0.31	0.37	0.39	0.69	0.19	0.75	0.56	0.27	0.53	0.39	0.30	0.35
OM (%)									4.1	4.6	4.1									3.9	3.4	3.3	2.2
Available N[1]									75	75	84									80	53	30	43
Av. P (mg/kg)[B1]									48	18	26									28	1.7	1.5	4.2
CEC (mmol/kg)									10	12	**9.7**									**8.1**	**6.4**	**6.0**	**7**
Exch. Ca (%)									53	53	55									51	46	52	74
Exch. Mg (%)									33	34	33									38	44	41	21
Exch. K (%)									5.3	4.3	5.9									9.0	3.4	3.1	3.8
Exch. Na (%)									8.6	9.1	5.6									2.4	4.2	3.1	1.2
S (mg/kg)									4.4	9.5	4.3									2.9	4.2	2.8	3.4
Zn (mg/kg)									0.94	1.1	0.82									1.2	1.7	2.1	0.6
Fe (mg/kg)									102	101	127									107	232	175	57.0
Cu (mg/kg)									0.79	1.4	0.64									0.36	1.5	1.0	1.30
Mn (mg/kg)									4.8	8.6	8.5									3.6	10	18	7.4
B (mg/kg)									0.55	0.68	0.56									0.37	0.26	0.38	0.27
TC									2.3	2.6	2.3									2.2	1.9	1.9	1.30
TN	530	1060	1220	1300	800	760	920	880	0.17	0.19	0.19	770	1120	1110	1510	610	1820	1140	1010	0.16	1300	1100	1000
Nitrate									6.0	1.1	0.91									11	5.8	4.2	5.00
Ammonium									3.3	3.0	0.73									2.0	3.5	2.0	3.50
Total P	311	275	222	221	259	202	321	230				479	527	498	548	228	437	228	219				
SAR	9.24	12	7.34	3.54	2.28	7.43	5.71	2.79				0.69	5.37	0.82	1.23	4.87	13.9	8.81	7.27				

1 based on nitrogen budget and estimated release rates of organic sources
2 converted from $EC_{1:5}$ using a factor of 10 for topsoil and 8 for subsoil
B1: Bray no.1 extract

Table 3.1b: Lower horizons chemical analysis, with the highlighting showing deficient macronutrients (red), marginally low macronutrients and deficient micronutrients (orange) and marginally low micronutrients (cream). Very low CEC values are in bold. 2019

Parameter	A2 horizon																					B horizon				
	1st				2nd					6th	7th				10th				Not irrigated			5th	10th	Non-irrigated- B		
	Nov 2017	May 2018	Nov 2018	May 2019	Nov 2017	May 2018	Nov 2018	May 2019	Feb 2020	Feb 2020	Nov 2017	May 2018	Nov 2018	May 2019	Nov 2017	May 2018	Nov 2018	May 2019	Feb 2020 rep.1	Feb 2020 rep.2	Feb 2020 rep.3	Feb 2020	Feb 2020	Feb 2020 rep.1	Feb 2020 rep.2	Feb 2020 rep.3
pH_w	6.4	6.2	6.3	6.5	6.5	6.3	6.3	6.8	8.49	7.80	6.5	6.2	6.1	6.3	7.6	7.4	7.4	7.1	6.45	7.32	6.71	7.23	7.46	7.74	7.09	8.77
EC_e[2] (dS/m)	1.18	0.35	1.44	0.40	0.57	0.34	0.27	0.09	1.86	0.46	0.18	0.23	0.22	0.41	0.48	0.68	1.64	0.96	0.25	0.93	0.33	3.53	1.28	1.83	0.43	0.87
OM (%)									0.62	1.3									1.8	0.97	0.81	1.4	0.78	0.82	0.48	0.63
Available N[1]									-17	0									6	-16	-16	-7	29	-16	15	7
Av. P (mg/kg)[B1]									4.0	5.5									<1	<1	<1	2.4	1.4	<1	<1	1.7
CEC (mmol/kg)									11	**3.8**									**7.6**	**8.4**	**5.3**	11	**6.7**	10	**7.5**	15
Exch. Ca (%)									44	37									43	33	47	47	23	27	38	32
Exch. Mg (%)									29	43									49	48	45	30	43	47	50	48
Exch. K (%)									2.3	7.1									0.94	0.84	0.19	1.3	1.0	0.53	0.51	1.5
Exch. Na (%)									24	13									6.3	19	8.1	22	33	25	11	19
S (mg/kg)									52	3.0									1.8	<1	1.1	83	20	2.2	<1	4.4
Zn (mg/kg)									<0.5	0.74									<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Fe (mg/kg)									16	34									90	25	23	24	25	9.7	12	9.7
Cu (mg/kg)									0.43	0.14									1.3	0.95	0.97	0.97	0.73	0.66	0.62	0.51
Mn (mg/kg)									2.9	0.92									5.5	11	15	9.4	6.6	3.9	6.6	11.5
B (mg/kg)									0.29	0.16									0.23	0.33	0.12	0.35	0.23	0.44	0.20	1.1
TC									0.36	0.72									1.0	0.55	0.46	0.78	0.45	0.47	0.27	0.36
TN	500	650	760	700	860	450	790	1510	0.02	0.04	400	870	870	950	230	800	750	590	700	300	<200	0.05	0.03	0.03	0.02	0.04
Nitrate									0.62	4.3									0.62	0.57	0.71	1.1	20	0.51	0.56	0.92
Ammonium									<0.1	3.9									1.5	0.64	0.54	0.42	0.79	0.34	0.55	1.4
Total P	279	152	163	164	182	151	279	235			6.5	421	442	429	108	295	148	142								
SAR	10.1	11.1	15.6	8.36	10.6	8.1	6.32	3.74			0.018	5.05	1.39	1.22	6.27	5.5	20.3	21.2								

1 based on nitrogen budget and estimated release rates of organic sources
2 converted from $EC_{1:5}$ using a factor of 10 for topsoil and 8 for subsoil
B1: Bray no.1 extract

4 Drainage

The site was inspected following 20 mm of overnight rain, with 80 mm having fallen two days prior. Most of the course drains well, with the biggest wet spot located in the rough along the east side of the 13th hole which receives surface water from the clubhouse roof and path areas. Waterlogging was also observed at the rear of the 1st green and in the swale between the 5th and 6th holes (Figure 4.1). As these wet spots are both located in rough areas that receive minimal irrigation they have an insignificant impact on the use of recycled water.

Of greater concern are irrigated areas where water lies for days, such as (Figures 4.1 and 4.2):

- **Fairway:** east side of the 13th (consider installing a surface pit or gradually filling the areas where water lies with loam so water runs downslope);
- **Green surrounds:** depression at the rear of the 8th green (gradually fill this area with loam);
- **Bunkers:** beside 3rd, 10th, 11th, 12th and 13th greens, with signs of siltation also observed in other bunkers; and
- **Paths:** beside the 8th and 9th tees. Water was also observed lying on the path in front of the 6th tee, but this area receives minimal irrigation.

Waterlogging of the path can generally be overcome by filling the wet depressions and sloping the pathways so water runs into adjacent areas that are not trafficked so it can soak away. In contrast, it is a more difficult task to overcome the waterlogging that occurs in bunkers. Whilst the addition of calcium and polymers may overcome some of these problems, it is likely that drains may need to be installed (or cleaned out) in order to allow some bunkers to drain.

Figure 4.1: Most of the course drained rapidly after rain. Waterlogging was observed in localised areas such as the rough areas (upper), with these of minimal concern as they receive minimal irrigation. Of greater concern are areas that remained waterlogged for days yet are likely to be irrigated with recycled water such as bunkers and paths near tees (lower).

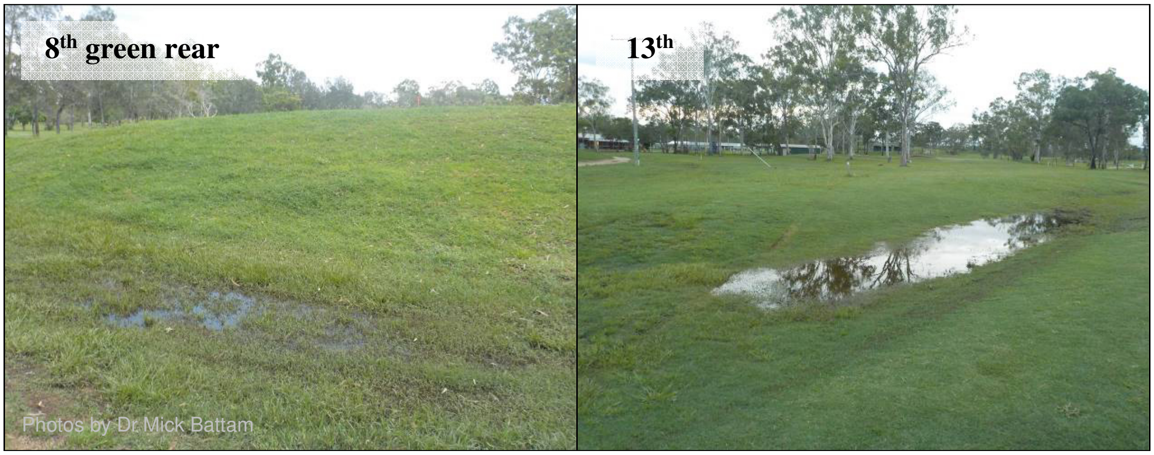

Figure 4.2: Waterlogging in low spots that could be overcome by gradually filling these areas with loam (do NOT use sand or waterlogging will persist), so surface water can flow downslope. Consider installing a surface drain in the 13th fairway swale, with this area receiving run on from the golf course buildings (via the rough) and BITS Sports Ground.

5 Spray drift

Rainwater is harvested from a small roof area that provides shelter for golfers waiting near the 9th tee. Unfortunately, spray drift is likely to result in some recycled water landing on the roof that captures rainwater (Figure 5.1) or the adjacent drinking bubbler. Apparently, this bubbler has been decommissioned. If this is correct, ideally, it would be removed. Alternatively, the bubbler should be located under the roof with a backing barrier to prevent it being covered by spray drift. Additionally, the rainwater tank outlet should have non-potable water signage installed.

To avoid recycled water being sprayed on the roof, it is recommended that the irrigation system be designed so water is sprayed away from the roof, with low angle sprinklers used in the adjacent areas.

Figure 5.1: Due to its close proximity to the 9th tee, recycled water is likely to spray onto the adjacent roof that is harvesting rainwater or the adjacent drinking bubbler (insert). The irrigation system needs to be set up so this does not occur.

6 Trees

Tree roots are a major problem on this course, with thin turf observed along the edge of almost all fairways, especially those that are narrow (Figure 2.1). Tree roots were also causing problems in:

- **Tees:** on the 3rd, 4th, 5th (Figure 6.1), 7th, 10th and 16th holes, with minor issues also observed on the 2nd and 8th holes; and
- **Greens:** likely on the 2nd, 4th, 13th and the adjacent green. Due to concerns raised about damage to the greens, the author was unable to verify which greens actually had tree roots.

Ideally these problems would be overcome by installing a high-density polyethylene sheet such as "root barrier" (manufactured by Polyfabrics Australasia or equivalent). This should be installed to a depth of about 800 mm at this site. If the cost is prohibitive then this should at least be considered for installation around the effected greens (verify first whether roots are an issue), tees and on the narrower fairways that are struggling to maintain turf cover e.g. 4th hole.

In the short term the roots could be pruned using a slicer such as the earthquake. Alternatively, the invading roots could be manually pruned using a sharp spade to cut a deep slice around the perimeter of the affected greens or tees. The dead patches in the tees will continue to increase in size until the offending roots are cut. Wherever possible, locate paths in areas where tree roots are adversely affecting the turf so these struggling areas are covered (Section 2.3).

Figure 6.1: Thin turf from tree roots was observed on some greens (upper left) and tees (upper right), but was a major problem along the side of most fairways. Whilst a root barrier should be installed in some locations, routine aeration with the earthquake would root prune.

Figure 6.2: Bare area that may improve slightly with fertiliser and weed control, but thin cover will likely persist until the issues of tree roots and traffic management are addressed.

7 Weeds

7.1 Existing ground cover

Major weed problems were observed across much of the course (northern holes had less issues), with the highest infestation generally observed in areas that were:

- compacted (Section 2.3);
- subject to competition from tree roots (Section 6); and/or
- around the site perimeter, with the surrounds providing a significant source of weed seed.

The most common weeds were Japanese spindle, khaki weed, medic and crab grass, but paspalum could also be considered a weed on the fairways. Whilst a selective herbicide could be used to reduce the numbers of weeds, turf cover is so limited in some locations that it is likely that the use of herbicides will result in minimal ground cover in some areas.

7.2 Reconstruction

If a new irrigation system is installed, then consideration should be given to reconstructing the areas watered by the new system by:

- spraying out the existing ground cover in irrigated areas until it is dead;
- amending the soil fully by incorporating the dead turf, 30 mm of finely screened composted garden organics (Appendix A) and 5 tonne per hectare of lime to a depth of at least 160 mm using a rotary hoe. Do NOT skimp on soil amendment or the thin turf will again develop;
- installation of tree root barriers;
- installation of traffic management works (define paths and areas not to be trafficked); and
- establishing a suitable couch cultivar established from sprigs.

Depending on the time of year these works are performed (and the couch cultivar), acceptable turf cover could be achieved following sprigging in about a 10 to 15-week period. To perform these works over the entire course (except the northern two holes) would cost about $1,320,000+GST, with this assumes a contractor maintains turf until 90% ground cover. However, this could be significantly reduced by having a staff member oversee turf grow in (following initial sprig establishment).

Reconstruction could be performed in stages that follow the installation of the new irrigation system and tree root barriers (crucial), so that 9 holes always remain in play at all times.

Figure 7.1: Given the large numbers or weeds and areas of compacted bare ground (insert), consideration should be given to spraying out the existing ground cover, amending the soil (so it is less prone to hard setting) and establishing a suitable turf cultivar from sprigs.

8 Irrigation

Gladstone Regional Council supplies recycled water from Tannum Sands wastewater treatment plant for the irrigation of the course. The irrigation system applies water to about (Table 8.1):

- 0.84 ha of tees;
- 8.56 ha of fairways; and
- 1.97 ha of greens and surrounds.

The system was installed about 30 years ago, with many of the components (except for the main lines) having been upgraded since then. An irrigation assessment was performed by Rex Sullings and Dr Paul Lamble in February 2020, with the findings presented below.

8.1 Irrigation assessment limitations

Prior to the commencement of the irrigation assessment, and due to a Blue Green algal bloom in the WWTP Council limited the use of recycled water. Irrigation was ceased on the sites until the water quality improved. To enable the irrigation assessment to proceed, a small volume of recycled water was supplied to the tanks directly from the treatment plant, bypassing the holding lagoon. This was used to pop up the irrigation heads and observe their operation, as well as to flag a selection of heads for the GPS survey.

The limited amount of available water constrained the assessment process. To avoid direct contact, sprinkler operating pressures were not measured, but estimated based on visual inspection.

Table 8.1: Irrigated areas (approximate) on the golf course.

Hole	Tees	Fairways	Greens + surrounds
1	400	4800	1400
2	700	10,200	1300
3	400	600	1900
4	280	4300	1500
5	750	8500	1400
6	800	5800	1300
7	400	11,500	1200
8	450	7200	1500
9	550	1300	1600
10	800	9300	1700
11	800	6700	1600
12	900	6400	1200
13	500	9000	1600
14	300	Shared	Shared
15	Shared	Shared	Shared
16	Shared	Shared	Shared
17	Shared	Shared	Shared
18	Shared	Shared	Shared
Practice green			500
Area near 13th green	400		
Total golf (ha)	**0.84**	**8.56**	**1.97**

8.2 Water supply

There are three storage tanks (about 44 kL each) located on the golf course (Figure 8.2), with these supplied with recycled water on a demand basis from a storage lagoon at the wastewater treatment plant. The nearby BITS Sports Grounds share their water supply with BITS Golf Course. Based on past watering practices and experience with efficient irrigation systems at many other locations, the sites drawing on this water would typically have flow rates of:

- **soccer fields:** 5-10 L/s;
- **AFL field:** 5-10 L/s; and
- **Golf Course:** 20-30 L/s.

Council staff have indicated that recycled water inflows into the tanks occur as tank levels decrease (usually during irrigation). Staff also advised he transfer pumps can deliver recycled water from the treatment plant to the tanks at a maximum rate of 50 L/s. However, with control valves in place this flow can be limited to 20-25 L/s (to both Dennis Park and BITS Golf Course) in order to supply water simultaneously to other users (e.g. QAL Red Mud Dam). Subject to hydraulic considerations, inflow rates into the tanks should be similar to irrigation demands to avoid the irrigation systems running out of water. This will also avoid the need to expand the existing storage capacity.

Furthermore, the recent shutdown (>4 weeks) due to water quality issues highlighted the need for a backup water supply. To overcome these problems, it is recommended that the following works be implemented:

- Install water meters and telemetry (either connect to existing SCADA or use 4G enabled data loggers) to monitor inflow rates; and
- Back up potable supply for flushing the irrigation system and/or to maintain turf cover when recycled water is unavailable.

The location of the storage tanks and pumping station are shown in Figure 8.1.

Figure 8.1: Water storage tanks and pump station located at BITS Golf Course.

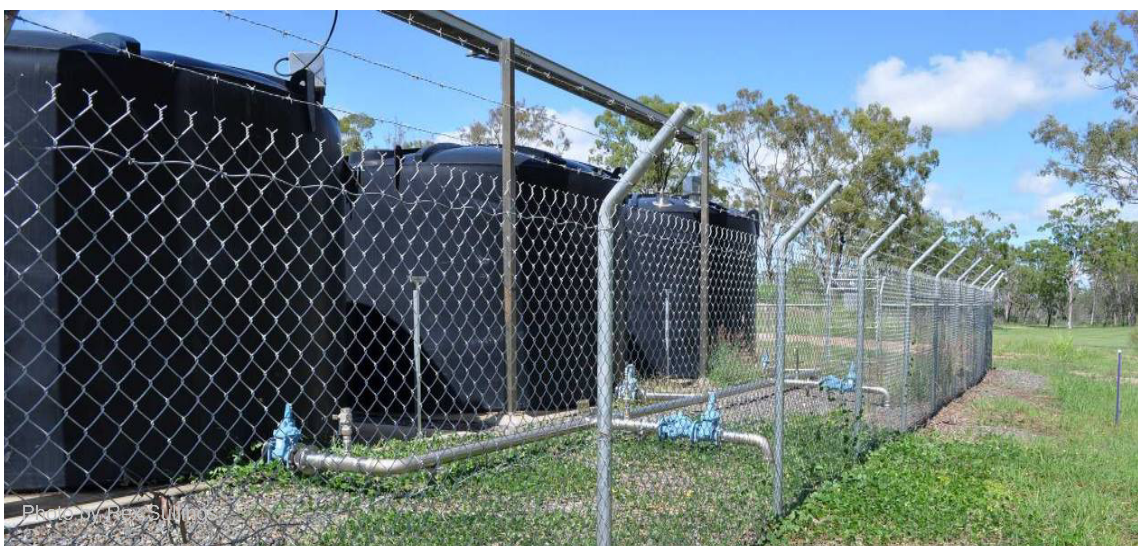

Figure 8.2: Water storage tanks located at BITS Golf Course.

8.3 Irrigation Pump Station

The irrigation pumps are in the pump shed on the golf course (Figure 8.3). There are two separate pump sets in the pump room, with one supplying the golf course and the other supplying the sports fields. The pumps are Southern Cross MGC14A-F model 80X50-250 22kW with a 229-mm diameter impeller. These pumps have a nominal duty range of approximately 10 L/Sec (1100 kPa) to 28 L/Sec (850 kPa), with a pump performance curve provided in Appendix C.

The pumps configuration should be reconsidered, with single impeller single stage centrifugal pumps such as these are generally more suited to supplying a stable volume output, even if variable speed controllers are installed. By comparison, golf course irrigation systems typically have varying flow rates as the system is being used to water different sized areas, with greens, tees and fairways often having sprinklers with different flow demands. For these variable demand systems, multistage pump sets (with variable speed control) are a much more suitable alternative.

Figure 8.3: Irrigation pump station.

8.4 Filtration

Reportedly the internal elements of the filters have been previously removed due to issues with frequent blocking. This is a risky practice and the filters should be reinstated to fully functioning condition as a matter of urgency. If frequent blocking is problematic the matter should be investigated in more detail, with a view to providing for pre filtering to remove the bulk turbidity load prior to the water reaching the filter (e.g. a cyclonic filter or a coarser primary filter unit). Ultimately, installing additional filtration at the wastewater treatment plant prior to recycled water delivery to the individual sites may be a more efficient, effective and economical option.

8.5 Irrigation main and lateral line hydraulics

The irrigation main lines are smaller than those that are typically used for a golf course and are indicative of design practices employed by contractors engaged via a design and construct process. Similarly, the irrigation lateral lines are smaller than those usually found in golf course irrigation systems. The smaller pipe sizes are restrictive and hamper the possibilities for system improvements.

It is financially prohibitive to replace main lines and laterals, yet it is these very components which are the primary cause for concern in relation to the age of the irrigation assets at this site. This is particularly a concern with uPVC piping which begins to experience repetitive failures of the fittings and piping after around 20-25 years of service.

8.6 Irrigation controller

Irrigation is automated by 2 Hunter ICC2 conventionally wired controllers which can operate up to 16 stations (can be expanded to 32 stations). This type of controller is primarily aimed at the higher residential and lower commercial markets and is not well suited for use on a golf course. At the time of the inspection the controller (Figure 8.5):

- had no sensor inputs active: a wind and rain sensor is located on the outside of the pump shed (Figure 8.4), but these are connected to the pump control panel. Presumably, the sensors prevent the pumps from operating when it rains or is windy;
- remote controller output is not active; and
- had no pump start connection active, indicating the pumps operate autonomously to the controller.

It is suggested that the sensors be connected to the irrigation controller, especially if the controller is upgraded to a Hunter ACC2 unit or similar. The pumps already operate autonomously on a self-activated start system and could continue to do so.

Figure 8.4: Weather sensors on the pump shed.

It is recommended the existing controllers be replaced with a controller/s, with features and functions appropriate to a golf course. For example, a Hunter ACC2 is a cost-effective unit that has a:

- flow management function appropriate for a golf course of this level. The flow management function allows this controller to operate as many stations concurrently as the system hydraulics can accommodate. The controller will continue to operate the maximum number of stations concurrently until the entire programme has been completed. This function is ideal in situations such as this where there are time restrictions on operation.
- "conditional response" function which allows the controller to react proactively to sensor inputs. For example, in the event of rainfall it is possible to manage the sensors in such a way that rather than simply shut down the entire system, the controller can respond by activating a particular programme which may, for example, water the greens only to ensure they receive watering even in the event of a light rainfall event. Further a smarter controller can "pause" an irrigation cycle in the event of a water supply failure or high wind event for example , and then complete the water cycle when that condition recovers to normal.

Figure 8.5: Irrigation controller (left) and control cabling (centre), with remote controller connection (right).

8.7 Irrigation Management.

Due to operating time constraints staff are routinely irrigating multiple areas at any one time. Several solenoid control valve wires have been "doubled up" at the controller output terminals. This practice can result in dramatically reductions in operating pressures and generally results in very uneven watering which was clearly evident during irrigation of the nearby AFL Oval (Figure 8.6). This situation may be largely avoided with an upgrade to an irrigation controller with flow management capability, as suggested in Section 8.6.

Figure 8.6: Irrigation station on AFL Oval operating as a single station (upper left) and in conjunction with another station (upper right). Further examples of low operating pressures in the lower images.

8.8 Sprinklers

Several makes and models of sprinklers are present on this site. The most alarming aspect of this is the presence of many different sprinkler heads on the greens (Figure 8.7), with most greens having a mixture of at least two types of heads. The 9th green which had sections that were struggling at the time of the inspections had 3 different types of sprinkler.

The presence of so many different types of sprinklers for the greens, tees and fairways presents a management challenge and is not conducive to good distribution uniformity. Each sprinkler has a different range of throw and flow rate and vastly different distribution characteristics. It may seem reasonable to replace a sprinkler with another make and model that seems to be “similar”, but this common industry practice results in very uneven watering. Even sprinklers such as the Rain Spray and the Rapid Rain models, which use a similar style of nozzle, have a similar flow rate and radius. As such, it would be expected that they have similar performance, but THEY DO NOT.

Different sprinklers (even when fitted with precisely the same nozzle) do not necessarily provide the same performance in terms of the evenness of distribution of water over the target area. The different effects of the sprinkler and the nozzles along with the operating pressure result in different distribution patterns along with different application rates. The presence of different sprinklers on a common irrigation lateral line is not a good practice, however common it may be, and cannot result in even distribution of water.

Figure 8.7: A sampling of the many different types of sprinkler present at the BITS Golf Course greens – Rain Spray, Rapid Rain, Rain Bird Eagle 700, Perrot and Hunter I-25.

Tees

The tees sprinklers are also Hunter I-25 models fitted with #15 nozzles. Again, the positions of the sprinklers were likely dictated by the original design which was for the Rain Spray sprinklers and the Hunter I-25 is a reasonable choice and fit for this application.

Fairways

The most common sprinklers on the fairways are Hunter I-25 models fitted with a grey (#15) nozzle, but a small number of other makes and models were also observed. Whilst the Hunter I-25 sprinkler is generally considered to be a sports field sprinkler, it is a reasonable choice for this golf course as many of the fairways are mostly quite narrow. The spacing (which was likely dictated by the original design for the Rain Spray heads, which would seem to have been the original head for the fairways as well as the greens) also provides a reasonable fit for this sprinklers range of operation.

Greens

The sprinklers of each of the greens were observed and the makes and models recorded (Table 8.2). Due to the mixture of makes, models and nozzles it is estimated that the scheduling coefficient of these green would range from 1.4 to 1.6 (or more). By comparison, a well-designed greens irrigation system will have a Scheduling Coefficient in the order of 1.15 to 1.2.

The various heads should be routinely replaced as they fail, using a single make and model sprinkler. When a sprinkler fails on a green, all the sprinklers on that green should be replaced at the same time with Hunter I-40 fitted with a #41 nozzle. This sprinkler/nozzle combination will provide a reasonably even watering of the greens and hence represents a vast improvement over the performance of the current mixture of heads. As well as applying water more evenly, the Hunter gear drive heads will have several advantages over the many existing impact sprinklers, including:

- less maintenance due to a reduction in wear and tear of moving parts;
- no failures due to ingress of dirt and contaminants into the open can of the impact heads; and
- no stoppages due to grass and/or roots intrusion into the open can of the impact style heads.

Whilst the gear drives will have a longer run time, it will be possible to operate more heads concurrently due to the lower flow rate of the Hunter I-40s. To avoid having different heads on the same line, all the sprinklers over an entire green should be replaced together. As sections of the 9th green were struggling at the time of this inspection it is recommended these be replaced immediately.

Table 8.2: A sampling of the different sprinklers watering the BITS Golf Course greens.

Green	Rain Spray	Rapid Rain	Rain Bird 700	Perrot	Hunter I-25	Unidentified
1st	3					1
2nd	3	1				
3rd	4					
4th	3			1		
5th	2			2		
6th	2	1			1	
7th	1	1	2			
8th	4					
9th	1	2		1		
10th			5			
11th		1	3			
12th	2				2	
13th	4					

8.9 Irrigation Sprinklers Condition

Although sprinklers were not operated on the golf course due to concerns with the water quality, the sprinklers generally appeared to be in good condition but several heads were sitting too low. These should be adjusted so the heads sit flush with the soil surface.

8.10 Operating Pressures

Due to the water quality available at the time of the assessments and the potential health risks associated with water contact, operating pressures were not measured. Instead these were estimated from sprinkler performance and would likely be in the range of 350-450 kPa. Several performance data sets are provided using these operating pressures, with this provided in Section 8.13 below.

8.11 Sprinkler Layout and Spacing

Good irrigation design revolves around the placement of sprinklers in a regular grid layout such as square, rectangular, or triangular configurations. Greens in particular require the irrigation system provide very even coverage over the entire target area. This can only be achieved through the accurate placement of the sprinklers in relation to the designed pattern and spacing. Uneven application across the target area creates numerous undesirable effects from both over and under watering.

The survey plans of the irrigation system were examined in detail and the spacing and configuration data recorded. The data was then analysed to determine the performance efficiency of the various configurations that are present on this site. All sprinklers are controlled as a block i.e. they are attached in groups to a lateral supply line which is controlled by a solenoid valve. Blocked sprinklers are connected in groups which are connected to a single solenoid valve.

Greens

The spacing and configuration of the green's sprinklers revealed that only six (1st, 3rd, 5th, 7th, 8th and 9th) of the thirteen greens had sprinkler layouts that could be considered "regular". The sprinkler layout on the remainder of the greens were far too "skewed" to enable a reasonable assessment to be conducted. Most of the remainder of the greens had layout configurations which were more akin to a parallelogram (2nd, 4th, 6th and 12th). These configurations were certainly not "regular" and are certainly not likely to have even reasonable key performance indicators.

Additionally, two of the remaining greens (10th and 11th) have an elongated shape which would require a larger number of sprinklers to provide adequate and efficient coverage through a rectangular sprinkler layout. The layout of the sprinklers for these greens seem to have been dictated by the designer/contractor's desire to provide as few sprinklers as was practically possible. The sprinklers basically "surround" the green which admittedly does give coverage to the entire target area, but is not conducive to even coverage and efficient and effective irrigation of the target area. While this configuration of sprinklers is common practice in the design and construct portion of the industry it is not good practice and results in very poor irrigation efficiency performance. Had these elongated greens been provided with a rectangular layout with perhaps six rather than five sprinklers then it would have been possible to apply water relatively evenly.

The greens sprinklers layout configurations are graphically displayed in the plan at Appendix C which outlines the shapes created by the area bounded by the sprinklers. The more irregular this shape, the less likely the sprinklers are to provide efficient and effective irrigation coverage.

Table 8.3: Variation in sprinkler spacing on greens.

Parameter	1st	3rd	5th	7th	8th	9th
Spacing (m)	19.1 X 19.2	18.8 X 18.8	18.9 X 18.7	18.9 X 19.0	19.8 X 18.6	17.9 X 17.9

Fairways

Fairway sprinklers on this site are configured in either a triangular pattern (1st, 2nd, 3rd, 4th, 5th, 6th, 7th, 8th and 9th) or a rectangular patter (10th, 11th, 12th and 13th). The sprinkler layouts for the fairways are generally quite regular, particularly when compared to the patterns of several of the greens.

A sampling of the spacing of the fairway sprinklers were measured, recorded and analysed (Table 8.4). The analysis found the spacing variation ranged from very poor to very good. These results suggest that either irrigation system was poorly set out or it was installed very inaccurately, with some sprinkler spacing varying by up to 7.3 m in some locations.

8.12 Irrigation System Coverage

It is very easy to comment on the coverage of an irrigation system on greens, as the perimeter of the green is clearly defined. In contrast, it is difficult to comment on the fairway coverage without having access to the information and instructions which would have been provided to the designer. Hence, the following comments will be more generalised in relation to the coverage of the fairways and tees.

Greens

Coverage of the greens is generally good in that the entire area of the greens receives water, but unfortunately the sprinklers are irregularly spaced around several greens.

For each green, all the sprinklers operate as a single block supplied by a common lateral line controlled by a single solenoid valve. With this configuration all the sprinklers operate together for the same period of time. In contrast, a contemporary golf course greens irrigation system utilises valve in head sprinklers for the greens. This allows individual control over each sprinkler, so different run times can be used for half and quarter circle arcs to ensure the same depth of water is applied.

A more efectively designed contemporary irrigation system will also have "back to back" sprinklers for the greens where a second set of sprinklers provides coverage for the areas surrounding the greens. These back to back sprinklers are part circle sprinklers and adjusted so one set of sprinklers irrigate the green, with the second set of sprinklers irrigating only the areas surrounding the green. Again these additional heads are valve in head to provide individual control over the sprinklers and to provide far more effective management of the irrigation system.

Table 8.4: Sprinkler spacing information fairways, with highlighting showing layouts where the variation in spacing is very large (red), large (orange) and moderate (cream).

Fairway	Configuration	Direction	Average	Smallest	Largest	(m)	(%)
1st	Triangular	Between rows	17.9	16.6	19.8	3.3	17
		Along rows	16	15.6	16.3	0.7	4
2nd	Triangular	Between rows	18.2	17.1	19.4	7.3	12
		Along rows	16.2	15.6	16.6	1	6
6th	Triangular	Between rows	17.8	16.8	19.5	2.7	14
		Along rows	16	15.4	16.6	1.1	7
7th	Triangular	Between rows	18	16.2	19.7	3.5	18
		Along rows	16.5	16.1	18.2	2.1	12
8th	Triangular	Between rows	17.5	14.7	19.5	4.8	25
		Along rows	16.7	14.7	17.9	3.2	18
10th	Rectangular	Between rows	17.9	17.1	18.7	1.6	9
		Along rows	18.2	17.9	18.4	0.5	3
11th	Rectangular	Between rows	17.9	16.6	19.7	3.1	16
		Along rows	18.4	16.9	21.4	4.5	21
13th	Rectangular	Between rows	18	17.7	18.3	0.7	4
		Along rows	17.9	17.2	18.2	1	5

Fairways and Tees

The fairway and tees sprinklers are also “blocked”. This is considered acceptable, especially for the fairways which typcically do not require the same degree of detail in management as the greens.

The coverge of the fairways is generally quite good and it seems that some thought has gone into determining which portions of the fairways should receive irrigation and those which can survive without irrigation. Several areas around the course do not receive irrigation and again this is not uncommon practice as areas such as the “fly over” (from the tee to the fairway) areas do not require as much attention as the landing areas of the fairways. It is not at all uncommon to let these areas “fend for themselves” and these areas are often considered to be part of the “rough” which generally receives very little in the way of maintenance.

8.13 System performance

With the constraints of the water quality it was not considered reasonable to conduct detailed operating pressure tests of the irrigation system. It was decided instead to provide performance information over a range of pressures at which the system is likely to be operating. The results of these analyses are detailed below.

Greens

It seems quite apparent that the original irrigation system design was based around the use of the Rain Spray 260 FC series sprinklers. These are still the most common sprinklers present on the greens although there are several alternative heads on some of the greens.

The greens which have the most regular spacing/layout configuration were selected for assessment, with less even watering likely to occur on the other greens. Eight possible nozzle and operating pressure combinations for the existing sprinklers were considered. The best performing and most likely combination was the 260FC fitted with the 16 X 10 nozzle operating at about 400 kPa. Whilst the performance indicators of this combination appear to be quite good (Table 8.5), it must be remembered that this is the best possible configuration. Many of the alternate combinations performed very poorly and may more accurately reflect the system performance.

Table 8.5: Key performance of assessed existing greens sprinklers, with highlighting showing layouts where the application is uneven (red), moderate (orange) and even (green).

Parameter	1st	3rd	5th	7th	8th	9th
Scheduling coefficient (SC)	1.18	1.17	1.17	1.17	1.27	1.21
Coefficient of uniformity (CU, %)	87	87	87	87	87	87
Distribution uniformity (DU, %)	84	83	83	84	84	83
Application rate (mm/hr)	11.8	12.2	12.2	12.0	11.7	13.5
Current application volume (kL)	12.74	12.74	12.74	12.74	12.74	14.15
Current application depth (mm)	8.9	9.2	9.2	9.0	8.8	11.3
Current weekly application depth (mm)	26.7	27.6	27.6	27.0	26.4	33.9

It should also be noted that the assssment is based on the assumption that all the sprinklers on any green have the same make and model of sprinkler with the same nozzle and operating pressure combination. The presence of mixed make, model and nozzle combinations will have a detrimental effect on the efficiency performance of the irrigation systems and as such the actual performnace of the greens irrigation will be considerably worse than indicated here.

As it was noted, there are several alternate sprinklers already on site and these were also assessed. These include the:

- **Rapid Rain sprinkler:** which was not considered a suitable alternative as it is an impact drive sprinkler of the same type as the existing Rain Spray heads and consequuently has the same undesirable characteristics;
- **Perrot sprinklers:** were also rejected as these are designed for much larger areas of coverage than are present on this site. In addition they are also a very cost prohibitive alternative and detailed performance data has not been made available by the manufacturers or independent laboratories for these sprinklers and their efficiency performance cannot be assessed;
- **Rain Bird 700 series golf heads:** were assessed and these heads performed well, but were rejected on the basis of their flow rates which are significantly higher than the existing sprinklers. Consequently, the system hydraulics (main lines and lateral lines) will not accommodate the larger flow rates without significant dynamic pressure losses which will not allow these heads to operate at the pressures they require for efficient performance; .
- **Hunter I-40 fitted with a #41 nozzle:** was found to be the best potential alternative to the existing heads (Table 6.6). This is a gear drive sprinkler similar to those currently used on the fairways and tees and does not have the undesirable characteristics of the existing impact drive heads. The Hunter I-40 sprinkler is also considered to be a cost effective sprinkler as they retail for about $150 per unit for the premier stainless steel riser 150 mm pop up version.

It should be noted that while the application rates for the recommended sprinkler combination are indicated as "poor" on the irrigation performance indicator matrix below, this is somewhat irreleveant in this instance. In this case, the lower application rates for the recommended sprinklers will work to the advantage of the turf manager as the lower flow rates will provide more opportunities for running irrigation stations concurrently while still maintaining suitable operaing pressures. This may in turn reduce the operating run time for each irrigation cycle.

Table 8.6: Key performance parameters for a suitable replacement sprinkler (Hunter I-40 #41 nozzle), with highlighting showing layouts where the application is uneven (red), moderate (orange) and even (green).

Parameter	1st	3rd	5th	7th	8th	9th
Scheduling Coefficient (SC)	1.16	1.17	1.17	1.15	1.18	1.26
Coefficient of Uniformity (CU, %)	88	87	87	87	87	85
Distribution Uniformity (DU, %)	84	84	84	84	84	78
Application Rate (mm/hr)	6.9	7.1	7.1	7.0	6.8	7.9

Fairways and Tees

Again, it seems apparent that the original design was based on using Rain Spray 260 FC series sprinklers. These sprinklers have almost all been replaced with Hunter I-25 sprinklers (#15 nozzles). The Hunter I-25 #15 nozzle combination was assessed at a range of potential operating pressures.

The fairways with the most regular spacing/layouts were selected for assessment. The existing sprinkler and nozzle combinations performed relatively well for those fairways with a triangular pattern, but not with the rectangular configuration (Table 8.7). The use of a triangular layout is not surprising as these tend to result in more even for impact drive sprinklers. It is difficult to explain why the design process used both triangular and rectangular spacing configurations.

Table 8.7: Key performance parameters of existing fairway sprinklers, with highlighting showing layouts where the application is uneven (red), moderate (orange) and even (green).

Parameter/Green No	1st	2nd	6th	7th	8th	10th	11th	13th
Spacing Configuration	△	△	△	△	△	▭	▭	▭
Scheduling Coefficient (SC)	1.2	1.28	1.18	1.21	1.2	1.46	1.48	1.78
Coefficient of Uniformity (CU, %)	91	92	92	91	91	82	82	83
Distribution Uniformity (DU, %)	87	87	88	87	87	75	75	75
Application Rate (mm/hr)	11.2	10.8	11.2	10.5	11.0	9.8	9.7	9.9

Note: The sprinklers of the 10th, 11th and 13th fairways had a rectangular spacing configuration while the remainder of the fairways assessed were configured in a triangular pattern.

Several alternate heads were assessed for efficiency performance at the existing fairway sprinkler spacings. Two viable alternatives were found, one for the fairways with a triangular spacing configuration (Rain Bird 8005 #14 @ 414 kPa) and another for fairways with a rectangular layout (Rain Bird 6504 #16 @ 414 kPa). The performance for these heads are detailed in Table 8.8.

Table 8.8: Potential alternative heads for the fairways - performance indicators, with highlighting showing layouts where the application is uneven (red), moderate (orange) and even (green).

Parameter/Green No	1st	2nd	6th	7th	8th	10th	11th	13th
Spacing Configuration	△	△	△	△	△	▭	▭	▭
Scheduling Coefficient (SC)	1.14	1.13	1.15	1.13	1.13	1.32	1.32	1.33
Coefficient of Uniformity (CU, %)	85	91	90	91	90	81	81	81
Distribution Uniformity (DU, %)	76	87	86	87	87	76	76	77
Application Rate (mm/hr)	10.2	9.9	10.3	9.9	10.0	12.5	12.2	12.6

8.14 How good could it be?

Greens

A well-designed and accurately installed new irrigation system irrigation system will apply water far more evenly than the existing systems. This will not only reduce the likelihood of ponding, but also the risk of localised accumulation of salts that can occur when irrigating with recycled water. There will also be a significant reduction in the annual irrigation requirements, with about 4.7% less water needed on the greens during a median year (Table 6.9).

Table 8.9: Key performance indicators for a well-designed greens irrigation system, with highlighting showing layouts where the application is uneven (red), moderate (orange) and even (green). Overall reduction of 4.7%.

Parameter	**1st**	**3rd**	**5th**	**7th**	**8th**	**9th**
Scheduling Coefficient (SC)	1.15	1.15	1.15	1.15	1.15	1.15
Coefficient of Uniformity (CU, %)	90	90	90	90	90	90
Distribution Uniformity (DU, %)	85	85	85	85	85	85
Application Rate (mm/hr)	12.5	12.5	12.5	12.5	12.5	12.5
Water Use reduction (%)	**7%**	**2.7%**	**2.7%**	**4.2%**	**13.9%**	**-4.5%**

Fairways and Tees

A well-designed new irrigation system could have the following key performance indicators and resulting water savings. More importantly a new, appropriately designed irrigation system will apply water far more evenly than the existing systems and will present less risks associated with the ponding that is likely to occur with less efficiently designed systems.

Table 8.10: Key performance indicators for a well-designed fairways and tees irrigation system, with highlighting showing layouts where the application is uneven (red), moderate (orange) and even (green). Overall reduction of 10.4%.

Parameter	1st	2nd	6th	7th	8th	10th	11th	13th
Scheduling Coefficient (SC)	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1
Coefficient of Uniformity (CU, %)	94	94	94	94	94	94	94	94
Distribution Uniformity (DU, %)	92	92	92	92	92	92	92	92
Application Rate (mm/hr)	13.5	13.5	13.5	13.5	13.5	13.5	13.5	13.5
Water Use reduction (%)	**3.1**	**2.8**	**4.9**	**4.8**	**2.5**	**16.5**	**16.8**	**17.3**

8.15 Irrigation recommendations

Install a new system

The irrigation system at BITS Golf Course is not able to irrigate the course evenly. Whilst the system does provide coverage to the entire target area, it applies water very unevenly, especially to the greens. To overcome these problems with water supply the following works are recommended:

- replace the ageing and dilapidated irrigation system with a more efficient and effective contemporary designed system which will provide a far more effective outcome and will be more compliant with requirements around the use of recycled water. To ensure to ensure the system applies water evenly it is crucial the system be:
    - designed to a performance standard (scheduling coefficient of less than 1.25);
    - designed by a suitably qualified, independent irrigation designer. A list of certified irrigation designers is on the Irrigation Australia website; and
    - installed to a performance standard and tolerances (e.g. heads are within 100 mm of their design locations).
- Upgrade water supply infrastructure to incorporate:
    - water meters and telemetry (either connect to existing SCADA or use 4G enabled data loggers) to monitor inflow rates; and
    - back up potable supply for flushing the irrigation system or to maintain turf cover when recycled water is not available.

The ability of the new irrigation system to apply water evenly (and avoid ponding) is often a function of other processes, such as how the system is procured and the quality of the installation (for example, the quality of materials and how accurately the sprinklers are installed to the design location).

It is quite common for irrigation systems to be installed as a “design and construct” project. In reality, contractors cannot accurately price the project without doing design work to ascertain for example, the quantity and sizing of materials (e.g. pipes, sprinklers, valves, pumps and control systems). Contractors are well aware that their tender will be evaluated on price and will be looking for opportunities to reduce costs to win the job. Hence, it is a common technique to increase the spacing between sprinklers and reduce the operating pressure, which in turn means smaller pumps, smaller pipes, fewer sprinklers, and ultimately lower capital costs. Unfortunately, it also means the performance of the system is compromised and it is not capable of applying water evenly or within the available operating time. Furthermore, compromises are made in the design which affect how the system can be operated and managed. These compromises would be made without Council's knowledge and do not become apparent until after the irrigation system is installed.

An alternative approach is to undertake a separate detailed design process using an independent designer. While it may take longer, such a process enables Council to shape the final design to suit the site infrastructure, likely capital budget and operating conditions. Furthermore, it enables a frank and open discussion on potential issues and compromises so Council is fully aware of the capabilities and limitations of the proposed system before it is installed. This process also means that the competitive tendering process for the installation is much less likely to impact the performance and suitability of the installed irrigation system.

In the short term, improvements could be achieved by:

- replacing the irrigation controller with a "smart" controller such as the Hunter ACC2 controller which can provide advanced sensor input response, remote access and monitoring (connect wind and rain sensor to the new controller);
- installing flow sensors and monitoring that is connected to the irrigation controller to improve system management;
- replacing the existing greens sprinklers with Hunter I-40 #41 nozzle – note this can be carried out over time as sprinklers become unserviceable. All heads on a green should be changed at the same time so that all sprinklers are the same on a green;
- replacing the existing fairway sprinklers as these become unserviceable. All heads on a lateral should be replaced at the same time. For best performance the sprinklers on fairways with a triangular spacing configuration should be replaced with Rain Bird 8005 fitted with #14 nozzle, whilst fairways with a rectangular spacing configuration should be replaced with Rain Bird 6504 fitted with #16 nozzles;
- reinstating the filtration system and installing a pre filtration unit to remove the bulk of the foreign material prior to reaching the main filter; and
- implement the revised scheduling programme recommended in the following section of this document.

Do not take advice from irrigation company sales representatives that claim their sprinkler is "equivalent". Some sprinklers may have a similar flow rate or radius of throw, but how they distribute water is very different.

Table 8.11: Summary of irrigation system improvement options (exclude GST).

Activity	Cost
Replace the irrigation controller with a smart controller e.g. Hunter ACC2.	$3,500
Install metering and flow sensor	$3,500
Install rain sensor	$150
Replace existing pump set with more suitable multi- stage centrifugal multi pump set with variable speed control.	$25,000
Replace existing greens sprinklers with Hunter I-40 #41 nozzles.	$195 per head or $10,000 for all greens heads.
Replace the existing fairway sprinklers	$135-195 per head or $45,000 for all fairway heads.
Re-instate filtration system to original specification and install new cyclonic PRE filter unit.	$15,000
Implement the revised scheduling programme	Staff time

9 Irrigation scheduling

9.1 Current watering program

At the time of the assessment the site was receiving minimal irrigation due to water quality issues with the recycled water. During periods when supply is available the:

- fairways typically receive 20 to 22-minute irrigation events four times a week; and
- greens typically receive 40 to 45-minute irrigation events three times a week.

No information was available on the schedule used to water the tees.

9.2 Irrigation schedule for golf course

Tees

The tees would ideally receive 4 mm watering (irrigation or rain) events:

- September to May: daily; and
- Winter: every second day.

Irrigation events should be skipped according to the above schedule if significant rainfall occurs, which is defined as more than 6 mm for this site.

Fairways

The fairways would ideally receive 3.5 mm watering (irrigation or rain) events:

- September to May: every second day; and
- Winter: twice a week.

Based on the current system layout the run time needed to apply this volume of water would be about 22 to 32 minutes per station.

Greens

The greens would ideally receive 4.5 mm watering (irrigation or rain) events:

- September to May: every second day; and
- Winter: twice a week.

Based on the current system the run time needed to apply this volume of water would be about 25 to 35 minutes per station.

Syringe watering in extreme heat

Greens and tees would ideally be syringe watered (5-minute watering event) in the heat of the day during extremely hot/dry conditions to cool the turf.

9.3 Irrigation demand for golf course

Assuming irrigation events are skipped following significant rainfall events (>6 mm), the current irrigation requirements (as distinct from current usage) for the golf course is estimated to be:

- 66.4 ML in a wet year (90 percentile);
- 78.0 ML in a typical year (median); and
- 81.9 ML in a dry year (10 percentile).

However, if an irrigation system was installed that is capable of applying water evenly then the current demand for the current irrigated area would be about 67.5 ML. Alternatively, the same volume of water could be applied annually, with the new system used to water a larger area of the golf course.

10 Recycled water quality

Unlike potable water, significant amounts of nutrients, salts and organic matter can be present in recycled water. To ensure these components do not adversely affect the environment or condition of the fields, salt and nutrient balance modelling should be performed. According to Queensland Health (2019) the recycled water from Tannum Sands WWTP would be classified as Class C.

10.1 pH

Monitoring over the past year found the median pH of the recycled water used in the BITS Golf Course tanks is 7.63 (ranging from 6.61 to 8.99). Recent testing of the soil pH in the irrigated areas found it varied from 6.6 to 7.4 (5.9 to 7.4 observed in the historical testing), with this more than the 5.8 to 6.6 observed in the unirrigated samples. These results suggest the topsoil pH has increased which is not surprising given that it would be expected to tend towards that of the recycled water. As such, pH is of minimal concern with regards to the irrigation of BITS Golf Course with recycled water from Tannum Sands WWTP.

10.2 Nitrogen

Monitoring over the past year found the median total nitrogen levels in the recycled water used to irrigate BITS Golf Course is 2.1 mg/L (ranging from 0.2 to 5.1 mg/L). Based on the irrigation requirements of the site, the amount of nitrogen applied in the irrigation water would be less than about 25 kg/ha annually, which is only a small portion of the turf requirements. Given the soils are naturally low in nitrogen it is not surprising to find that low levels of available nitrogen were observed in the lower horizons (Section 3).

Although nitrogen is of minimal concern with regards to irrigation, monitoring found that total nitrogen levels are often higher in the dam located adjacent to the 12th fairway (Figure 10.1). As faecal coliform levels are often higher in this relative to the dam across the road it is likely due to either direct over spray or run-off from the irrigation system (Alpha Concepts, 2017 to 2019). To prevent this from occurring the sprinklers in this area should be adjusted to ensure an unirrigated buffer of at least 2 m is maintained around the side of the dam. It should be noted that some of the nutrients in this dam may be the result of runoff from fertilisers applied to the adjacent fairways.

Figure 10.1: Close proximity of the dam on the 12th hole to the fairway, with six monthly monitoring finding BOD, TP and TN are often higher then observed in the control dam.

10.3 Salt

Monitoring over the past year found median EC levels in the recycled water of 1.04 dS/m (ranging from 0.85 to 1.62 dS/m). Recent soil tests found the topsoil EC_e varied from 0.53 to 0.91 dS/m, but in the past readings as high as 2.1 dS/m have been observed. Most of the turf grasses on the course are moderately tolerant of salinity, but significant reductions in growth are expected in paspalum and Queensland blue if the soil EC_e levels become significantly higher than 2 dS/m (Stevens *et. al*., 2008). As such, the relatively low permeability observed in localised areas in the topsoil and A2 horizon (Table 1.1) are concerning, with major salinity problems likely to develop rapidly if the profile struggles to leach salts.

10.4 Sodium

High levels of sodium can reduce the infiltration rate of a soil, potentially leading to waterlogging and salt accumulation. Based on SAR measured in two recycled water samples, there is a slight to moderate likelihood of decline in soil infiltration (Figure 10.2). Based on recent soil testing:

- **A1 horizon:** exchangeable sodium percentage (ESP) of 2.4 and 9.1%, which is more than the 1.2 to 4.2% in the unirrigated samples;
- **A2 horizon:** ESP of 13 to 24%, with 6.3 to 19% observed in the unirrigated samples; and
- **B horizon:** ESP of 22 to 33% which is similar to the 11 to 25% in the unirrigated samples.

These results suggest sodium levels are increasing and have already exceeded the 6% value at which soil structural problems are more likely to occur. To ensure the site continues to drain effectively, it is recommended that significant amounts of calcium be routinely applied to the site in the fertiliser program. In addition, ongoing monitoring of ESP levels within the soil are needed.

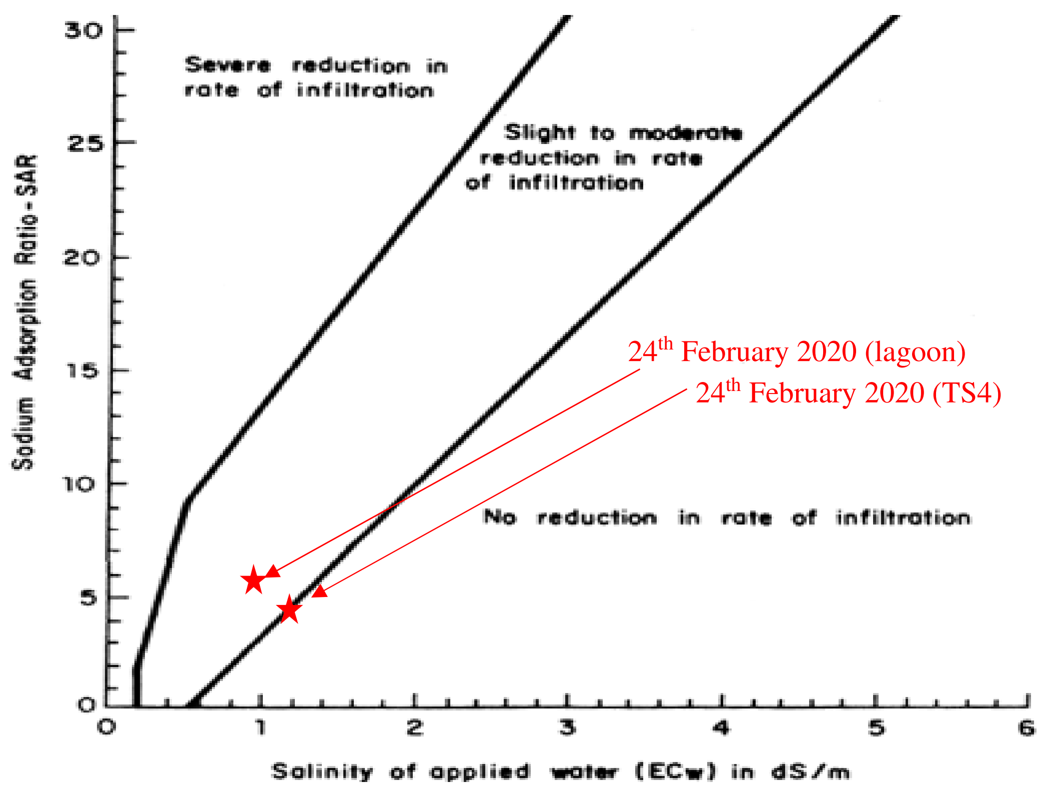

Figure 10.2: Water sampling results showing there is a slight to moderate likelihood of decline in soil infiltration rate due to the ratio of sodium and salt within the recycled water.

10.5 Phosphorus

Monitoring over the past year found the median total phosphorus levels in the recycled water used to irrigate BITS Golf Course is 0.4 mg/L (ranging up to 2.0 mg/L). Based on the irrigation requirements of the site, the amount of phosphorus applied in the irrigation water would be less than 5 kg/ha annually, which is only a small portion of the turf requirements. Given the soils are naturally low in phosphorus, levels of this nutrient in the recycled water are of minimal concern at BITS Golf Course.

10.6 Organic loading

Weekly monitoring during 2019 found median BOD levels of 2 to 21 mg/L, with a median of 7 mg/L (Table 6.2). Recent testing also found oil and grease levels below detection limits in the tank water, with very low levels (7 mg/L) measured in the lagoon. As such, these are of minimal concern with regards to the irrigation of sites involved in this study.

10.7 Other contaminants

Minimal information was available on levels of other contaminants in the recycled water. Based on two samples taken on 24th February 2020 PAHs, surfactants, organochlorine and organophosphate pesticides were below detection limits. Low levels of metal were also observed over this period, with all readings well below the ANZECC and ARMCANZ (2000) limits for sites receiving long-term irrigation (Table 6.2). Ideally, periodic testing for these potential contaminants would be conducted.

10.8 Bacteria

Weekly monitoring during 2019 found *E. coli* counts of 12.1 (median) and 401.7 CFU/100 ml (95 percentile). These reading are lower than the 1,000 CFU/100 ml (95 % of tests) for Class C recycled water (Queensland Health, 2019). To avoid direct contact with Class C recycled water, the guidelines recommend site access be restricted during irrigation events (Queensland Health, 2019). However, direct contact can still occur if waterlogged areas are watered with recycled water.

When the course was inspected recently following rain, water was observed lying for days in several greenside bunkers, with these typically wet by sprinklers watering the greens. This is concerning as golfers will likely retrieve their wet ball from ponded areas and some may even attempt to play from semi waterlogged areas. To prevent this from occurring it is recommended that irrigated areas that are prone to waterlogging be amended. In the short term, green side bunkers should be pumped out prior to commencing irrigation events (Figure 10.3).

Figure 10.3: Water lied in this bunker for several days after rain (left). If these areas were irrigated then there is a high chance of golfers coming into direct contract with recycled water. Water also lied in the path areas that were watered by tee sprinklers (right).

Table 10.1: Recycled water characteristic. Shading indicates the component is classified as low (not shaded), medium (orange) or high strength (red) in accordance with DEC (2004) which regards 5 times ANZECC and ARMCANZ (2000) value for long long-term irrigation.

Property	Target	Lagoon discharge	Chlorine contact tank	Tank a	Tank b	ANZECC & ARMCANZ (2000)[1]
pH	6 to 8.5	6.55 (min) 7.2 (med) 8.44 (max)	6.52 (min) 6.91 (med) 7.45 (max)	6.61 (min) 7.49 (med) 8.9 (max)	6.68 (min) 7.65 (med) 8.99 (max)	
EC (dS/m)	<1.6	0.8 (min) 0.99 (med) 1.6 (max)	0.78 (min) 0.96 (med) 1.8 (max)	1.0 (min) 1.0 (med) 1.3 (max)	0.85 (min) 1.0 (med) 1.6 (max)	
Suspended solids (mg/L)	<30	5 (min) 18 (med) 38 (max)	5 (min) 18 (med) 38 (max)	5 (min) 18 (med) 38 (max)	5 (min) 18 (med) 38 (max)	3
BOD (mg/L)[3]		2 (min) 6 (med) 20 (max)	1 (min) 3 (med) 16 (max)	2 (min) 6 (med) 20 (max)	2 (min) 7 (med) 21 (max)	2
SAR		5.50	4.97			
Turbidity (NTU)		2 (min) 7 (med) 21 (max)	1 (min) 3 (med) 9 (max)	1.45 (min) 7.97 (med) 16.9 (max)	1.43 (min) 8.44 (med) 19.1 (max)	
TN (mg/L)	<15	0.6 (min) 2.3 (med) 11 (max)	0.2 (min) 2.1 (med) 5.1 (max)	Not measured	Not measured	0.3
Total phosphorus, as P (mg/L)	<3	0.5 (med) 1.8 (max)	0.4 (med) 2.0 (max)	Not measured	Not measured	0.02
UV transmission (%)						
Calcium (mg/L)		29	46			
Magnesium (mg/L)		17	18			
Potassium (mg/L)		20	14			
Sodium (mg/L)		151	157			
Iron (mg/L)						
Ammonia (mg/L)			0.001 (min) 0.041 (med) 1.04 (max)			
Nitrate and nitrite (mg/L)			0.109 (min) 1.16 (med) 4.24 (max)			
Cyanide (mg/L)						-
Sulphur, as SO_4 (mg/L)						
Total alkalinity (mg/L)						
Carbonate (mg/L)						
Bicarbonate (mg/L)						
Hydrogen sulphide (mg/L)						
Boron, as B (mg/L)						
Chloride as Cl (mg/L)						
Chlorine as Cl (mg/L)						
Chlorophyll a (mg/L)						
Oil and grease (mg/L)						
Total Phenols (mg/L)						
Non-ionic surf. (mg/L)						
Ionic surfactants (mg/L)						

Property	Target	Lagoon discharge	Chlorine contact tank	Tank a	Tank b	ANZECC & ARMCANZ (2000)[1]
Biological						
Faecal coliforms CFU/100ml		0 (min) 1 (med) 8.66 (95 perc) 263.1 (max)	0 (min) 1 (med) 1 (95 perc.) 1 (max)			
Enterococci (col/100mL)						
E. coli (col/100 ml)				0 (min) 7.4 (med) 401.7 (95) 517.2 (max)	0 (min) 12.1 (med) 110.7 (95) 648.8 (max)	
Coliform (cfu/100 ml)						
PAHs						
Acenaphthene (ug/L)			<1.0	<1.0		
Acenaphthylene (ug/L)			<1.0	<1.0		
Anthracene (ug/L)			<1.0	<1.0		
Benz(a)anthracene (ug/L)			<1.0	<1.0		
Benzo(a)pyrene (ug/L)			<0.5	<0.5		
Benzo(b)fluoranthene (ug/L)			<1.0	<1.0		
Benzo(g.h.i)perylene (ug/L)			<1.0	<1.0		
Benzo(k)fluoranthene (ug/L)			<1.0	<1.0		
Chrysene (ug/L)			<1.0	<1.0		
Dibenz(a.h)anthracene (ug/L)			<1.0	<1.0		
Fluoranthene (ug/L)			<1.0	<1.0		
Fluorene (ug/L)			<1.0	<1.0		
Indeno(1.2.3.cd)pyrene (ug/L)			<1.0	<1.0		
Naphthalene (ug/L)			<1.0	<1.0		
Phenanthrene (ug/L)			<1.0	<1.0		
Pyrene (ug/L)			<1.0	<1.0		
Total PAHs			<0.5	<0.5		10
Total PCB (ug/L)						
Organochlorine pesticides						
DDT + DDE + DDD (ug/L)		<0.5	<0.5			
Aldrin + Dieldrin (ug/L)		<0.5	<0.5			
Chlordane (ug/L)		<0.5	<0.5			
Endosulfan sulphate (ug/L)		<0.5	<0.5			
Endrin (ug/L)		<0.5	<0.5			
Endrin aldehyde (ug/L)		<0.5	<0.5			
Endrin ketone (ug/L)		<2.0	<2.0			
Heptachlor (ug/L)		<0.5	<0.5			
Heptachlor epoxide (ug/L)		<0.5	<0.5			
HCB (ug/L)						

Property	Target	Lagoon discharge	Chlorine contact tank	Tank a	Tank b	ANZECC & ARMCANZ (2000)[1]
BHC alpha (ug/L)		<0.5	<0.5			
Lindane (ug/L)						
Methoxychlor (ug/L)		<2.0	<2.0			
Other OC Pesticides (ug/L)		ND	ND			
Organophosphate pesticides						
Chlorpyrifos (ug/L)		<0.5	<0.5			
Diazinon (ug/L)		<0.5	<0.5			
Malathion (ug/L)		<0.5	<0.5			
Parathion (ug/L)		<2.0	<2.0			
Other OP pesticides		ND	ND			
Metals						
Aluminium (ug/L)		<1	2			5000
Arsenic (ug/L)		<0.1	<0.1			100
Beryllium (ug/L)						100
Cadmium (ug/L)						10
Chromium (ug/L)		<1	<1			100
Cobalt (ug/L)						50
Copper (ug/L)		1	7			200
Iron (ug/L)						200
Lead (ug/L)		<1	<1			2000
Lithium (ug/L)						2500
Manganese (ug/L)						200
Mercury (ug/L)		<0.1	<0.1			2
Molybdenum (ug/L)						10
Nickel (ug/L)		<1	1			200
Selenium (ug/L)						20
Silver (ug/L)						
Zinc (ug/L)		7	18			2000

1 ANZECC and ARMCANZ (2000) value for long long-term irrigation

11 Recycled water irrigation management

The following discussion describes the practices that should be employed on the site when irrigating with recycled water. These recommendations are based on industry literature and draw on the best practice information contained in:

- Queensland Health (2019) Guideline for low-exposure recycled water schemes;
- Offices of the Natural Resource Management Ministerial Council Environment Protection and Heritage Council Australian Health Ministers Conference (2006) "Australian guidelines for water recycling: managing health and environmental risks (Phase1)"; and
- Standards Australia (2010) Handbook 246 "Australian Standards Guidelines for Managing Risk in Sport and Recreation".

The main concerns that are addressed by these practices are public safety (microbes in the recycled water) and protection of the environment (chemicals in the recycled water).

11.1 Recycled water identification

Signs should be located in prominent positions at irrigation site entry points that clearly identify that recycled water is not suitable for drinking or human exposure. These signs should be monitored for theft, vandalism or deterioration. In addition:

- compliance with all applicable plumbing requirements to prevent cross-connection with drinking pipes. As such, all pipe work including taps and should be colour-coded (lilac) and marked in accordance with AS/NZS 3500.5:2000 (Section 2.16.6.1);
- visible signs (in accordance with AS/NZS 3500.1:2000) must be attached to all fixtures and storage tanks to indicate;
- valve boxes should be lilac coloured and marked "recycled water – do not drink". Valve boxes along the mainline should be locked, with site valve boxes either locked or bolted down. Valve keys must be removed;
- lilac cap sprinklers; and
- compliance with other relevant items of the AS/NZ 3500.

Complete pipe work plans should be maintained that show the location (and depth) of mainlines, pipes, sprinklers, valves, water meters, controllers and storage tanks. Recycled water management plans should be provided to contractors and staff when performing works near the mainline or on sites connected to the scheme. These plans should be updated whenever changes are made to the system.

All drinking water meters (and taps) should be fitted with backflow prevention device as per Gladstone Area Water Board. A cross connection audit should be undertaken prior to commissioning of the effluent irrigation system.

11.2 Irrigation system design

The irrigation systems should be designed so appropriate buffers are maintained between where the recycled water is being applied relative to where members of the public could be present. For irrigating with Class C recycled water, Queensland Health (2019) recommends:

- no run-off from irrigation. Hence, the application rate of the sprinkler system should not exceed the soil infiltration rate, with a rain sensor needed to prevent irrigation during rain;
- no ponding of recycled water: to prevent this from occurring the site should not be prone to waterlogging and a flow sensor should be installed to prevent irrigation if a major leak occurs;
- no overspray, with a minimum buffer distance of 25 m; and
- spray drift control.

The irrigation systems should also be designed to ensure the recycled water does not contaminate any source of water used as a supply of drinking water (e.g. dam or bore).

11.3 Performing irrigation events

For irrigating with Class C recycled water, Queensland Health (2019) recommends restricted access during irrigation events (and for four hours after irrigation in the case of sporting fields). To ensure no water ponding has occurred ideally the irrigated area should be inspected following irrigation events (can occur during mowing). Hand watering should be performed by appropriately trained staff in accordance with the safe work method statements (Appendix C).

11.4 Operational procedures for staff

Work involving direct contact with recycled water should be performed by appropriately trained staff in accordance with the site standard operating procedures (SOPs) that ensure works are completely in a safe and environmentally responsible manner. Procedures would be required for activities such as:

- general hygiene;
- hand watering;
- syringing;
- performing works on irrigation system;
- handling recycled water spills or wet spots;
- response to recycled water ingestion;
- inducting new site workers; and
- incident reporting.

11.5 Irrigation audits

An audit of the irrigation system performance should occur at least annually. The audit should examine all system components (supply head works, storage tank, pump station, pipework, valves and sprinklers) and involve activities such as:

- fixing leaks/breakages, replacing worn components and adjusting misaligned sprinklers so they are set flush with surface, vertical and have correct arc angle;
- pressure testing and hydraulic assessment; and
- system performance assessment e.g. uniformity testing.

These works should be performed by an appropriately skilled person such as a certified irrigation designer (CID) or certified irrigation agronomist (CIAg). Consideration should be given to developing staff so they hold these irrigation certifications and can perform the work effectively.

11.6 Ongoing monitoring

Monitoring intensity and frequency should be performed in relation a risk assessment (NRMMC 2006), with typical considerations discussed below.

<u>Recycled water monitoring</u>

In addition to weekly testing of *E. coli* levels (Queensland Health, 2019), the chemical properties of recycled water can change over time, particularly in response to weather conditions. As such, water quality reports from the scheme supplier should be examined for any significant changes (e.g. spikes in salt levels) and the amount of nutrient applied via irrigation. In addition, monitoring is needed of these parameters that can adversely affect infiltration (SAR and salt) or result in the accumulation of toxins in the soil. Fewer samples and/or less frequent testing can occur over time once any patterns in water quality have been established.

<u>Soil monitoring</u>

A typical sampling program for monitoring environmental hazards in soil is provided on page 169 of NRMMC (2006), with:

- annual monitoring of the topsoil (pH, salinity, sodium, calcium, potassium, magnesium, potential contaminants, total nitrogen, total phosphorus and boron); and
- biannual monitoring of the subsoil (pH, salinity, sodium, calcium, potassium, magnesium, total nitrogen and total phosphorus).

Fewer samples and/or less frequent testing can occur over time once any changes in soil chemistry have been established. However, some testing will still be needed for ongoing fertiliser management at the site which must encapsulate the nutrients applied in the recycled water.

Surface water monitoring

A typical sampling program for monitoring environmental hazards in surface water is provided on page 171 of NRMMC (2006), with:

- quarterly monitoring of pH, salinity, total nitrogen, total phosphorus and aluminium; and
- annual monitoring of chlorophyll-a
- intense rain even monitoring of pH and total phosphorus.

However, sampling frequency will depend on scheme specific factors, with fewer samples and/or less frequent testing able to occur once patterns are established. Bores should be located up-gradient of the irrigated area, within the irrigation area, down gradient of the irrigated area and adjacent to storage dams.

Groundwater monitoring

A typical sampling program for monitoring environmental hazards in groundwater is provided on page 170 of NRMMC (2006), with:

- quarterly monitoring for ground water level, pH, salinity, total nitrogen, nitrate and total phosphorus; and
- annual monitoring of exchangeable cations (calcium, magnesium, potassium and sodium), SAR, bicarbonate, iron and aluminium.

However, sampling frequency will depend on scheme specific factors, with fewer samples and/or less frequent testing able to occur once patterns are established. Bores should be located up-gradient of the irrigated area, within the irrigation area, down gradient of the irrigated area and adjacent to storage dams.

12 Risk assessment of current management practices

The current site practices do not align with all of the recommended recycled water irrigation management practices describe in Section 11. To identify areas where significant improvements could be achieved a risk assessment was performed comparing current and recommended management practices (Table 10.1). The assessment was performed in accordance with Standards Australia (2010) Handbook 246 "Australian Standards Guidelines for Managing Risk in Sport and Recreation", which involves ranking each potential hazard with regards to likelihood of occurrence and severity of outcome.

12.1 High priority changes

Practices that would reduce the risk of irrigating BITS Golf Course with recycled water from high/moderate to low levels if implemented include:

- increasing calcium addition in the fertiliser program so the sodicity problem is corrected. As the soil is deficient in many nutrients it would ideally be amended with compost and gypsum (Section 7.2). In the short term the following fertiliser program should be used for all play areas on and around the fairways where weed control is performed by:
    - **June:** 200 kg of gypsum;
    - **August:** fertiliser containing <u>all</u> of the trace elements e.g. 200 kg/ha of Yara Mila complex (or equivalent);
    - **October, December, February and April:** 200 kg/ha of Cal-gran aftergraze (or equivalent, but a similar balance of nutrients must be achieved;
    - **June year 2:** 200 kg of gypsum;
    - soil scientist to refine the fertiliser program after this based on soil test results;
- monitoring of additional soil chemical properties (TC, TN, nitrate, ammonium, exchangeable cations, pH, EC, available P, sulphur & micronutrients -Table 3.1) during six monthly testing;
- monitoring of additional water quality parameters including SAR (quarterly until a pattern is established) and annually of other contaminants (Table 11.1);
- connecting the tank overflow to stormwater so it does not wet fairway;
- converting the irrigation pump system from "pump start" to "pressure actuated start";
- installing flow sensors and a controller that is capable of monitoring flow so irrigation can be shut off in the event of a break or unusual flow to an irrigation station;
- amending waterlogged areas that are irrigated with recycled water such as greenside bunkers. In the short term, these bunkers should be pumped out prior to irrigating with recycled water;
- do not allow the public to use rainwater from the tank near the 9th tee which is capturing water from a roof that is receiving recycled water from tee sprinklers (Section 5);
- adjusting sprinklers on 12th hole so recycled water does not spray into the dam and ensures an unirrigated buffer strip of at least 2 m is maintained (Figure 10.1);
- ensuring the pump shed floor has sufficient cross-fall or a drain to prevent pooling of water;
- conducting an annual audit of the irrigation system to identify faults;
- inspect site routinely for wet spots (e.g. during mowing) and inspect if found;
- develop SOPs for staff/contractors in activities that may result in recycled water contact. Some appropriate practices may already be used, these should be formalised. Examples are provided (Appendix B), but these require additional input by staff on topics such as:
    - general hygiene;
    - hand watering;
    - syringe watering;
    - works on the irrigation system;
    - handling recycled water spills & wet spots;
    - response to recycled water ingestion;
    - inducting new site workers; and
    - incident reporting
- ensure staff and contractors are adequately trained to perform work according to the SOPs.

To demonstrate Council has taken due care in advising site users, additional signs should be installed at all access points stating, for example "WARNING – RECYCLED WATER – DO NOT DRINK".

12.2 Minimising risks due to interruptions in supply

To minimise the risks associated with interruptions in the water supply on turf it is crucial to:

- have back-up supply of potable or dam water for irrigating at least the greens and tees;
- install an irrigation system capable of applying water evenly so water is not wasted;
- install root barriers so turf is not needing to compete with trees (most crucial on narrow holes, see Figure 2.1). By ensuring the irrigation mainline and/or laterals are located in specific areas, the root barrier could be installed in the same trench. Root barriers are needed on:
    - tees: 3rd, 4th, 5th, 7th, 10th and 16th holes, with issues also observed on the 2nd and 8th;
    - greens: likely on the 2nd, 4th, 13th and the adjacent green;
- reconstructing bare areas where the turf will struggle to recover by:
    - installing a root barrier and/or appropriate traffic management strategies to ensure the cause of poor turf performance is addressed;
    - amending the soil so it has a higher water holding capacity using the works outlined in Section 7.2 (works for amending shallow areas is provide in Section 2.5);
    - sprigging turf (must have even irrigation) or laying sod grown on sandy soil;
    - ensuring effective management practices are implemented so acceptable turf cover can be maintained (will include the use of pre-emergent herbicides to control weeds);
- amending areas where acceptable turf cover could be achieved from existing ground cover by:
    - adjusting the fertiliser program to address not only the sodicity problems, but deficiencies in nutrients (Section 12.1);
    - reducing compaction on the course by managing traffic using the strategies in Section 2.2 and aerating at least annually to 180 mm depth using a solid tine aerator such as the aggravator (council should consider purchasing this machine);
    - ensuring effective weed management practices are used on the course. Wherever possible, a pre-emergent herbicide should be used to control the germination of weed seed, with this likely to be very effective at controlling crab grass. A selective herbicide will need to be applied to control broadleaf weeds on the course;
- apply wetting agent twice annually (at least to the tees, greens and steeper fairway areas)

Most of these practices will result in significant improvement in turf cover, with excellent results likely if performed in conjunction with the installation of a new irrigation system. As the fairways are quite narrow (concentrates wear and compaction) it is recommended that the new system apply water to the fly overs and up to the tree lines. Following installation a cross-connection check should occur.

12.3 Other changes

Those activities that provide a relatively minor improvement to risk management on the site, but should be considered for implementation include:

- monthly checks of water balance by Council to ensure no leakage in the site supply pipe;
- compare flow into and out of the storage tanks to ensure leakage is not occurring;
- marking of recycled water pipes, valves, taps, sprinklers and quick coupling valves (QCVs);
- lilac valve boxes that are lockable with recycled water signage;
- amend all areas prone to waterlogging (not just those that are irrigated with recycled water);
- flow alarm sensor on storage tank overflow to back up pressure transducer.

The marking of the irrigation system components should occur if new irrigation system is installed.

Table 12.1: Risk assessment for irrigation of BITS Golf Course with recycled water.

	Current situation				**If addi**
Potential hazard	**Existing control measures**	**Consequence rating[1]**	**Likelihood rating**	**Risk rating**	**Additional con**
Supply of substandard water resulting in human contact with pathogens or chemicals	• Weekly monitoring of water quality in the treatment plant storage pond, chlorine contact tank including faecal coliform levels • Weekly monitoring of water quality levels in the BITS storage tanks including *E. coli* levels • irrigate at night when course is not being used	Minor	Unlikely	Low	• install more pr water signage or around perimete
Supply of substandard water resulting in environment receiving harmful chemicals or high loading of nutrients/salts/sodium	• weekly monitoring of a limited range of chemical in recycled water • six monthly monitoring of a limited range of soil, groundwater and surface water chemical parameters	Minor	Possible	Medium	• monitoring of quality param SAR (quarterly) other contamina • monitoring of chemical prope exchangeable ca
Leak or break in the site supply line resulting in: • runoff/drainage loss to environment and erosion • surface ponding and human contact	• inflow water meter • scheme supplier has flow alarm shutoff for major leaks	Minor	Unlikely	Low	• monthly checks by Council • inspection of p routinely
Faulty level control causing overflow of storage tank resulting in: • runoff/drainage loss to environment and erosion • surface ponding and human contact	• pressure transducer level measurements	Minor	Unlikely	Low	• flow alarm sen transducer • connect tank stormwater so fairway • Recycled water procedure

	Current situation				If additional measures were adopted			
Potential hazard	**Existing control measures**	**Consequence rating[1]**	**Likelihood rating**	**Risk rating**	**Additional control measures**	**Consequence rating[1]**	**Likelihood rating**	**Risk rating**
Storage tank leakage resulting in: • runoff/drainage loss to environment and erosion • surface ponding and human contact	• routinely inspect storage for leaks or wet spots on the ground (would occur during weekly sampling) • downslope turf area routinely inspected for wet spots (during mowing)	Negligible	Possible	Low	• compare flow from meters prior to and after storage tank	Negligib le	Rare	Low
Loss of water supply resulting in injury from turf water stress	• scheme provider to notify golf course of interruptions to supply	Minor	Likely	Mediu m	• back up potable or dam water at least for greens and tees • amend soil so it has a higher water holding capacity • install root barriers so turf is not needing to compete with trees for water • sprig or oversow sections of the course where the turf is thin (amend soil first), with weeds taken over in places • adjust herbicide, fertiliser and aeration program so better turf cover can be achieved • apply calcium so combat sodicity • manage traffic and aerate so better turf cover can be maintained • apply wetting agent twice annually (at least to the tees, greens and steeper fairway areas)	Minor	Rare	Low

	Current situation				If additional measures were adopted			
Potential hazard	**Existing control measures**	**Consequence rating[1]**	**Likelihood rating**	**Risk rating**	**Additional control measures**	**Consequence rating[1]**	**Likelihood rating**	**Risk rating**
Loss in pathogen control during storage	• Weekly monitoring of water quality levels in the BITS storage tanks including *E. coli* levels • irrigate at night when course is not being used • screen overflow to stop bird/rodent entry • Recycled water signage on entry points and around perimeter of tanks which is fenced off	Moderate	Rare	Low		Negligib le	Rare	Low
Cross connection resulting in human ingestion	• plan of recycled water pipeline for use in plumbing	Moderate	Rare	Low	• cross connection audit by certified plumber • marking of recycled water pipes, valves, taps, sprinklers and QCVs	Modera te	Rare	Low
Leakage in pumping station resulting in water pooling and human contact	• routinely inspect pump station for leaks or breakages • sufficient cross-fall on pump shed floor to prevent pooling	Negligible	Rare	Low	• drain or sufficient cross-fall on pump shed floor to prevent pooling of water	Negligib le	Rare	Low
Irrigation water continues to flow into the mainline (after pumps have stopped due to pressure head from tanks). The irrigation system solenoid valves can remain open due to insufficient line pressure when pumps stopped. NB: situation would not have existing prior to installing tanks when recycled water pumped from dam	• most of site has acceptable surface drainage and infiltration rate	Minor	Likely	Mediu m	• convert the pump systems from "pump start" to "pressure actuated start" to ensure solenoid valves have sufficient pressure to close positively • amend waterlogged areas that are irrigated with recycled water such as bunkers where water lies	Minor	Rare	Low

	Current situation				**If additional measures were adopted**			
Potential hazard	**Existing control measures**	**Consequence rating[1]**	**Likelihood rating**	**Risk rating**	**Additional control measures**	**Consequence rating[1]**	**Likelihood rating**	**Risk rating**
Break or leak in site mainline or lateral resulting in (keep in mind system is 30 years old): • runoff/drainage loss to environment and erosion • surface ponding and human contact	• regular inspection of mainline route • site has acceptable soil infiltration rate	Moderate	Unlikely	Medium	• flow monitoring and alarmed shut off for irrigation controller • Recycled water spill management SOP • amend all areas prone to waterlogging	Minor	Unlikely	Low
Broken solenoid valve resulting in extended irrigation of an areas and waterlogging (keep in mind system is 30 years old)	• routine inspection after irrigation (e.g. when mowing) looking for wet spots • most of site has acceptable surface drainage and infiltration rate	Moderate	Unlikely	Medium	• flow monitoring and alarmed shut off for irrig. controller • Recycled water spill management SOP • amend waterlogged areas that are irrigated with recycled water such as bunkers where water lies • annual irrigation audit • inspect site routinely for wet spots (e.g. during mowing) and inspect if found	Negligib le	Unlikely	Low
Broken or leaking solenoid valve resulting in pooling in the valve box and/or surrounding areas (keep in mind system is 30 years old)	• most of site has acceptable surface drainage and infiltration rate	Minor	Possible	Medium	• flow monitoring and alarmed shut off for irrigation controller • inspect site routinely for wet spots (e.g. during mowing) and inspect if found • Recycled water spill management SOP • SOP for system repairs • annual irrigation audit	Minor	Unlikely	Low

	Current situation				If additional measures were adopted			
Potential hazard	**Existing control measures**	**Consequence rating[1]**	**Likelihood rating**	**Risk rating**	**Additional control measures**	**Consequence rating[1]**	**Likelihood rating**	**Risk rating**
Leak or break in sprinkler resulting in (keep in mind system is 30 years old): • runoff/drainage loss to environment and erosion • surface ponding and human contact	• routine inspection after irrigation (when mowing) • most of site has acceptable surface drainage and infiltration rate	Minor	Possible	Medium	• flow alarm shutoff for major leaks and unusual flow • amend waterlogged areas that are irrigated with recycled water • annual irrigation audit	Minor	Unlikely	Low
Spray or drift onto public paths or adjacent properties resulting in human contact	• irrigate at night or when low use • buffer of much more than 25 m to adjacent properties • sensor to prevent irrigation in windy conditions	Minor	Rare	Low		Minor	Rare	Low
Spray hitting drinking bubblers resulting in human contact	• Bubbler near the 9th tee is relatively protected from direct spray from recycled water.	Minor	Possible	Medium	• do not allow the public to use rainwater from the tank near the 9th tee captures water from a roof that receives recycled water from tee sprinkler	Minor	Rare	Low
Spray hitting water bodies and resulting in nutrient loss to environment (keeping in mind that monitoring found higher TN levels in the 12th dam)	• low levels of nutrients in recycled water, with minimal contaminant recently observed • sensor to prevent irrigation in windy conditions • monitoring of water quality in 12th dam is performed at 6 monthly intervals	Minor	Possible	Medium	• adjust sprinklers on 12th hole so recycled water does not hit dam and an unirrigated buffer strip of at least 2 m is maintained	Minor	Unlikely	Low
Ground water nutrient or biology is changed by deep drainage losses from areas irrigated with RW	• groundwater was generally more than 5 m below the surface, with the subsoil relatively impermeable • groundwater quality is monitored at 6 monthly intervals	Minor	Rare	Low		Minor	Rare	Low

	Current situation				If additional measures were adopted			
Potential hazard	**Existing control measures**	**Consequence rating[1]**	**Likelihood rating**	**Risk rating**	**Additional control measures**	**Consequence rating[1]**	**Likelihood rating**	**Risk rating**
Water lying for extended periods in depressions or areas of the site that results in human contact or increased soil salinity	• infiltration rate of soil is able to enable water to soak away in a short time • rain sensor to prevent pumping during or 24 hours after rain	Minor	Likely	Medium	• amend fertiliser program to include more calcium so sodicity problem is corrected • cycle soak irrigation regime • amend waterlogged areas that are irrigated with recycled water	Minor	Unlikely	Low
Site users are accidently wet with recycled water during an events	• irrigate at night or when low use	Minor	Unlikely	Low	• Recycled water signage on entry points and around perimeter	Minor	Unlikely	Low
Unauthorised person operates a valve so the irrigation system and comes into contact with the recycled water		Minor	Rare	Low	• lilac valve boxes saying recycled water that are lockable	Minor	Rare	Low
Site worker comes into contact with the recycled water e.g. performing irrigation system repairs	• staff use appropriate hygiene practices prior to eating or smoking • pathogen testing of tanks	Minor	Likely	Medium	• staff and contractors trained to work as per SOPs, with procedure if ingestion occurs	Negligib le	Possible	Low

13 Irrigation System Cost Estimates

Cost estimates for the replacement of the irrigation system at Boyne Island Tannum Sands Golf Course are presented in Table 13.1. In addition, estimates for the annual operating costs are presented in Table 13.2.

Table 13.1: Summary of estimated irrigation system replacement costs (excluding GST).

BITS Golf Course	Area – ha/Unit	Rate $/Unit	Total
Greens	0.4	$80,000	$32,000
Fairways	12.3	$60,000	$738,000
Tees	0.6	$60,000	$36,000
Pump station	1	$25,000	$25,000
Filtration	1	$15,000	$15,000
Control system	1	$25,000	$25,000
Sub Total			**$871,000**
Project management	1	10%	$88,000
Contingency	1	15%	$131,000
Sub Total			**$219,000**
Budgetary Estimate			**$1,090,000**

Table 13.2: Summary of estimated irrigation system annual costs (excluding GST)

BITS Golf Course	Area – ha/Unit	Rate $/Unit	Total
Maintenance & Operating Costs	14	$2,500	$35,000
Depreciation (25 year life)	4% pa	$1,090,000	$43,600
Sub Total			**$78,600**
Contingency	1	15%	$11,800
Budgetary Estimate			**$90,400**

14 Conclusions

Gladstone Regional Council commissioned Aqueduct Consultancy to perform an irrigation and soil condition assessment for Boyne Island Tannum Sands Golf Course. A summary of the findings is provided in this report which was written by Rex Sullings, Dr Paul Lamble and Dr Mick Battam.

Condition of the course

The assessment found thin or weedy cover across most fairways, with better cover at the north end of the course. Whilst some of this is attributable to interruptions in water supply, thin cover would likely occur in many of the narrower sections of the course due to a combination of compaction, competition from tree roots, limited weed control, low levels of nutrients and soil sodicity. These problems could be overcome by:

- installing a back-up water supply for periods when recycled water is not available;
- installing root barriers so turf is not competing with trees, with this being most crucial on narrow holes, tees and greens (some can be installed in the same trench as irrigation pipes);
  - implementing the traffic management practices to minimise soil compaction (Section 2.2);
  - amending areas of the course by:
    - reconstructing bare areas where the turf will struggle to recover according to the works in this report (Section 7.2);
    - reconstructing the uneven and shallow areas according to the works in Section 2.5; and
    - amending areas where the turf can be recovered using the fertiliser program (Section 12.1), aeration (aggravator) and weed management (Section 12.2);
  - applying wetting agent twice annually (at least to the tees, greens and steeper fairway areas).

The current topdress is regarded as far too sandy for use on the course and will result in thin turf if applied. Instead, the existing site soil can be used to fill depressions, with this able to harvested during construction of new paths or amendment of the uneven area on the 2nd hole (Section 2.5).

Soil assessment findings

The soil is low in nutrients and prone to hardsetting, with compaction observed across most of the course. Irrigation with recycled water has likely increased sodium levels in the soil, with moderate to low levels of permeability in the A2 horizon. These results are concerning given that lateral movement in this horizon is the primary means for removing excess water and salts from the soil profile.

Irrigation assessment findings

The existing irrigation system has significant problems and should be replaced with a system capable of applying water evenly.

The ability of the irrigation system to apply water evenly (and avoid ponding) is often a function of other processes, such as how the system is procured and the quality of the installation (for example, the quality of materials and how accurately the sprinklers are installed to the design location).

Whichever procurement and design process is chosen, it is crucial that the new system applies water evenly. Hence, the new system must be:

- designed to a performance standard (e.g. scheduling coefficient of less than 1.25);
- designed by a suitably qualified, independent irrigation designer. A list of certified irrigation designers is on the Irrigation Australia website.

- installed to a performance standard and tolerances (e.g. heads are within 100 mm of their design locations).

As the fairways are quite narrow (concentrated wear and compaction) it is recommended the new system apply water to the fly overs and up to the tree lines along the fairway sides. Additional storage capacity is also needed, with the existing tanks being inadequate. Ideally, an alternative water source would be available for irrigating the site during periods when recycled water is not available.

Recycled water irrigation management

A risk assessment was performed and the following changes are recommended to the current practices:

- install additional signage at all access points warning the recycled water is used for irrigation;
- ideally the soil would be fully amended and turf established from sprigs using the works described in Section 7.2. In the short term, the sodicity improvements could be achieved by adopting the following calcium dominated fertiliser program described in this report;
- monitoring of additional soil chemical properties (TC, TN, nitrate, ammonium, exchangeable cations, pH, EC, available P, sulphur & micronutrients -Table 3.1) during six monthly testing;
- monitoring of additional water quality parameters including SAR (quarterly until a pattern is established) and annually of other contaminants (Table 11.1);
- connecting the tank overflow to stormwater so it does not wet fairway;
- converting the irrigation pump system from “flow start” to “pressure actuated start”;
- installing flow sensors and a controller that is capable of monitoring flow;
- amend waterlogged areas of the site that are irrigated with recycled water such as bunkers. In the short term, these bunkers should be pumped out prior to irrigating with recycled water;
- do not allow the public to use rainwater from the tank near the 9th tee which is capturing water from a roof that is receiving recycled water from tee sprinklers;
- adjust sprinklers on 12th hole so recycled water does not spray into the dam and ensures an unirrigated buffer strip of at least 2 m is maintained;
- ensure the pump shed floor has sufficient cross-fall or a drain to prevent pooling of water;
- annual audit of the irrigation system;
- inspect site routinely for wet spots (e.g. during mowing) and inspect if found;
- develop SOPs for use by staff and contractors in activities that may result in contact with recycled water (examples in Appendix B); and
- ensure staff and contractors are adequately trained according to the SOPs.

Appendix A: Compost characteristics

All composted garden organics applied to the field must meet the following criteria:

1) Has passed through a 8 mm (square grid) screen;
2) Meets the requirements of AS 4454 'Composts, soil conditioners and mulches' (2012) including the toxicity growth test and is either:
    a. Certified to AS 4454 (2012); OR
    b. Supplied by a quality endorsed company.
3) Has an $EC_{1:5}$ less than 3.5 dS/m;
4) Has a pH greater than 5.0 and less than 8.2; and
5) Has a C:N ratio less than 20:1.

To demonstrate compliance with the above criteria, the compost supplier must:

6) Provide a batch test certificate from an accredited laboratory proving the compost complies with the above criteria;
7) For certified compost product, provide the certification certificate for the certified compost product; and
8) For quality endorsed companies, provide the quality certification certificate.

No delivery of compost should be accepted at the site until the above criteria have been demonstrated in writing.

Alternative

If composted garden organics meeting this standard is not available from a local supplier then composted paunch contents could be used, but it should be mixed into the loam topsoil.

Warning

Do NOT allow suppliers to substitute organic amenders as they differ greatly in their characteristics, with the fibrous nature of the product as important as its chemical characteristics. Contact the author if unsure, with many products useless in improving soil structure which is a key factor at this site.

Appendix B: Example standard operating procedures

Examples of standard operating procedures have been provided, but these require modification by staff to ensure that procedures and site-specific requirements are fully encapsulated. Other formal procedures that should also be developed include general hygiene, incident reporting and induction records for staff/contractors.

Procedure	Performing syringe irrigation events on days of extreme heat		
Procedure authorised by		Dated	
Purpose	Establish a procedure for the irrigation with recycled water from that does not have an adverse effect on turf, environment or humans.		
1. Ensure site has appropriate signage (check routinely for theft or vandalism) at all access points warning uses that recycled water is used on the site and that it is not for drinking			
2. Check recent water quality reports provided by the scheme provider to ensure levels of salts or other nutrient will not adversely affect turf			
3. Hold up play on the green/s that are to be syringe watered and ensure players are more than 25 m from the sprinklers			
4. Run the syringe watering event (~5 minutes)			
5. Check not only the green, but around sprinkler heads that no water has pooled as a result of the irrigation event			
6. Permit play to continue and move the next green to be syringe watered			

Procedure	Hand watering		
Procedure authorised by		Dated	
Purpose	Establish a procedure for hand watering with recycled water does not have an adverse effect on turf, environment or humans.		
1. Cover any wounds to prevent contact with recycled water, in some cases this can be assisted through the use of PPE e.g. gloves			
2. Ensure a wash bottle of clean water is available for rinsing eyes or mouth if accidental ingestion occurs			
3. Ensure portable billboard sign has been set up next to the area being hand watered warning users that recycled water is used on the site and that it is not for drinking			
4. Check recent water quality reports provided by the scheme provider to ensure levels of salts or other nutrient will not adversely affect turf			
5. Inspect soil to ensure that it is not water repellent (apply wetting agent to treat)			
6. Cover or restrict access to prevent people from accidently stepping into open valve box e.g. place bill board recycled water warning sign across it			
7. Ensure hose is used in a manner that prevents leaks onto the person performing the watering			
8. Ensure other people are not in the vicinity and restrict access if required			
9. Apply water evenly across the area being watered ensuring spray drift does not blow onto either the operator or other people. Ensure minimal ponding and/or surface water runoff occurs			
10. Prevent access to any areas where surface water ponding has occurred			
11. Disconnect and drain the recycled water from the hose. Remove the valve key and place the lockable lid back over the valve box so it is closed when not in use			
12. Wash hands and other area of skin that has become wet using soap and potable water. Any clothing wet during hand watering should be removed for laundry.			
13. Report any major body exposure (ingestion, facial contact), skin rashes or illness to the park			

Procedure	Managing recycled water spills		
Procedure authorised by		Dated	
Purpose	Establish a procedure for handing recycled water lying on the surface		
1. Cover any wounds to prevent contact with recycled water, in some cases this can be assisted through the use of PPE e.g. gloves			
2. Ensure a wash bottle of clean water is available for rinsing eyes or mouth if accidental ingestion occurs			
3. Ensure portable billboard sign has been set up next to the area that is wet warning users that recycled water is being used and that it is not for drinking			
4. If a major recycled water spill occurs then it should be fenced off until the water can discharge into the stormwater drains and soak away			
5. If water is ponded deeply (e.g. more than 20 mm) a small pump could be used to spread the water onto adjacent areas so it can soak away. Otherwise a hose could be used to drag the water onto adjacent areas where it could soak in			
6. Prevent access to the area until the recycled water has sufficient time to soak away, assisting (step 5) if the water is likely to take long periods of time to dissipate e.g. 4 hours			
7. Identify the cause of the recycled water spill (e.g. sprinkler throwing onto pathway, broken lateral or sprinkler) and switch off the offending section of the irrigation system until repairs or adjustments are performed			
8. Wash hands and other area of skin that has become wet using soap and potable water. Any clothing wet during hand watering should be removed for laundry.			
9. Report significant spills to the park manager			
10. Report any major body exposure (ingestion, facial contact), skin rashes or illness to the park manager			

Procedure	Performing works on the irrigation system		
Procedure authorised by		Dated	
Purpose	Establish a procedure for performing works on the recycled effluent irrigation system that does not have an adverse effect on turf, environment or humans.		
1. Cover any wounds to prevent contact with recycled water, in some cases this can be assisted through the use of PPE e.g. gloves			
2. Ensure the person performing the works has a map of the irrigation system and location of other buried infrastructure e.g. power, gas and potable water			
3. Ensure a wash bottle of clean water is available for rinsing eyes or mouth if accidental ingestion occurs			
4. If appropriate and/or where possible turn off the water on the section of the irrigation system where the works are being performed			
5. Ensure portable billboard sign has been set up next to the area that is being repaired warning uses that recycled water is being used and that it is not for drinking			
6. If water is ponded then implement the works outlined in the recycled water spill management procedure			
7. Provide appropriate fencing around the area to prevent access			
8. Excavate the required area using safe work method statement for digging and appropriately cover any holes until works have been completed			
9. Perform works on the irrigation system. Unless the recycled water pipes can be clearly identified (confirm with site supervisor) the water will need to be tested to confirm that the pipe is carrying recycled water (generally has an electrical conductivity more than 0.5 dS/m)			
10. Upon completion the works should be tested prior to backfilling			
11. Backfill excavated area, placing subsoil in the lower sections of the hole and topsoil in the upper areas			
12. Wash hands and other area of skin that has become wet using soap and potable water. Any clothing wet during hand watering should be removed for laundry.			
13. Report any major body exposure (ingestion, facial contact), skin rashes or illness to the park manager			
14. Check the flow alarm sensor to ensure irrigation is shut off during a break or major leak			
15. Inspect repaired area following first irrigation events for leaks or wet spots including pathways			
16. Perform a full audit (pressure and uniformity testing) of irrigation system at least once a year			

Appendix C: BITS Golf Course Greens Sprinkler Layout Configuration