Irrigation Management Plan

Googong Township Integrated Water Cycle Project

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Terms and Abbreviations

AGWR	*Australian Guidelines for Water Recycling: Managing Health and Environmental Risks (Phase 1)* (National Resource Management Ministerial Council, Environment Protection and Heritage Council and Australian Health Ministers' Conference 2006)
Ca	Calcium
$CaCl_2$	Calcium chloride
CCP	Critical control point
CEC	Cation exchange capacity
CoA	Condition of Approval
dS/m	deciSiemens per metre
EC	Electrical conductivity
ECe	Electrical conductivity of a saturated soil extract
GTPL	Googong Township Proprietary Limited
GWMP	Groundwater Monitoring Program
HACCP	Hazard Analysis and Critical Control Point
IMP	Irrigation Management Plan
IWC	Integrated water cycle
me/100g	milliequivalents/100 grams
Mg	Magnesium
N	Nitrate
NH1A	Neighbourhood 1A
NSW	New South Wales
Operator	GTPL (during process commissioning and verification) or QCC (during ongoing operation)
P	Available phosphorous
Plan	Irrigation Management Plan
PPE	Personal protective equipment
ppm	Parts per millions
PVC	Polyvinyl chloride
QCC	Queanbeyan City Council
RWQMP	Essential Sewage and Recycled Water Quality Management Plan
SoC	Statement of Commitments
SOP	Standard Operating Procedure
SWAEMP	Surface Water (and Aquatic Ecology) Monitoring Program
TN	Total nitrogen
TP	Total phosphorous

WMP	Water Management Plan
WRP	Water Recycling Plant
WSUD	Water sensitive urban design

E1 Background

Googong township employs an Integrated Water Cycle (IWC) that aims to cut the potable water consumption by up to 60% through the following measures:

- Demand reduction by means of water conservation (i.e. use of water-efficient fixtures and appliances), recycling and rainwater use initiatives.
- Retention of stormwater onsite through rainwater use and a series of Water-Sensitive Urban Design (WSUD) attributes.
- Minimising wastewater discharges by using highly treated recycled water for toilet flushing, fire fighting and topping-up of rainwater tanks.
- Using appropriately treated recycled water for open space irrigation.

The IWC includes all elements associated with the supply of potable water, the essential service provision of collection and treatment of sewage flows and transfer of treated flows into the recycled water system for re-use as well as the collection and use of stormwater.

For the IWC Project, sewage will be collected from the houses and commercial zones within the township and treated at the Water Recycling Plant (WRP). The recycled water will be used for domestic non-potable uses such as toilet flushing and outdoor irrigation. Recycled water will also be used for the irrigation of open space within the township.

For the operation of the IWC Project, Condition of Approval (CoA) D8 (e) requires Googong Township Pty Ltd (GTPL) to prepare an Irrigation Management Plan (IMP or Plan) in accordance with the relevant guidelines, as part of the Water Management Plan (WMP).

In relation to irrigation, initial studies have been completed to determine the potential risks and impacts irrigating with recycled water may have, they include:

- *A Recycled Water Irrigation Strategy*, August 2010 (of the Googong Township Water Cycle Project Environmental Assessment (EA)): prepared by Agsol Pty Ltd on behalf of GTPL. This study reviewed available soil and groundwater information and identified soil and groundwater constraints for the application of recycled water. It also included recommendations for future investigations, including monitoring and mitigation levels.
- *An Irrigation Strategy Summary*, January 2011 (a superseded version of this strategy was attached to the EA as Appendix N): prepared by Brown Consulting to provide an irrigation strategy that would promote the growth of vegetation in open spaces within the development. This strategy also developed a number of recommendations in relation to irrigation.

Both of these studies have been used to develop this IMP together with current guidelines including:

- DEC (2004) – 'Environmental Guideline' The use of effluent for irrigation.
- NHMRC (2006) – Australian Guidelines for the Use of Recycled Water.

In addition, a baseline soil monitoring program for Stage 1 of the IWC Project was completed in February 2015 and March 2016 by Agsol Pty Ltd on behalf of GTPL. The results and recommendations from this monitoring program, as outlined in *Googong Township Stage 1: Irrigation Management Plan* (Agsol 2015a), *Googong Soil Monitoring Program Report* (Agsol 2015b) and *Soil Monitoring Programme Googong Township (supplementary report)* (Agsol 2016), have also been used to develop this IMP.

E2 Purpose and objectives

This Plan forms part of the WMP for Stage 1 of the IWC Project.

This IMP has been prepared to address the requirements of CoA D8(e), as shown in Table 1. It documents the procedures and practices related to the sustainable management of irrigation of public spaces for Stage 1 of the IWC Project. It also provides a mechanism by which the operations can be monitored and continually assessed.

Table 1 Condition of Approval

CoA No.	Condition requirements	Document reference
D8	1. an **Irrigation Management Plan** prepared in accordance with the relevant guidelines including *Environmental Guidelines: Use of Effluent by Irrigation* (DEC 2004) and *National Guidelines for Water Recycling: Managing Health and Environmental Risks* (National Resource Management Ministerial Council, Environment Protection and Heritage Council and Australian Health Ministers' Conference 2006) which must:	This Plan
	A. include detailed baseline data of the soil properties of the proposed irrigation areas, including salinity levels and a nutrient budget;	Section E5
	B. identify any potential off-site risks and impacts and describe measures to minimise any environmental impacts;	Sections E6, E8 and E9
	C. include a protocol for the use of recycled effluent for irrigation including application rates and restrictions; and	Sections E8, and E9 and E10
	D. include a program to monitor areas subject to irrigation.	Section E11

E3 Water sources used for irrigation

As part of the IWC Project, sewage is collected from residential and commercial premises within the township and treated at the WRP. Recycled water that meets stringent water quality requirements is then used, along with rainwater tank supplies, for domestic non-potable uses as shown in Figure 1.

Recycled water will also be used for the irrigation of open space and sports fields within the township (refer to Figure 1).

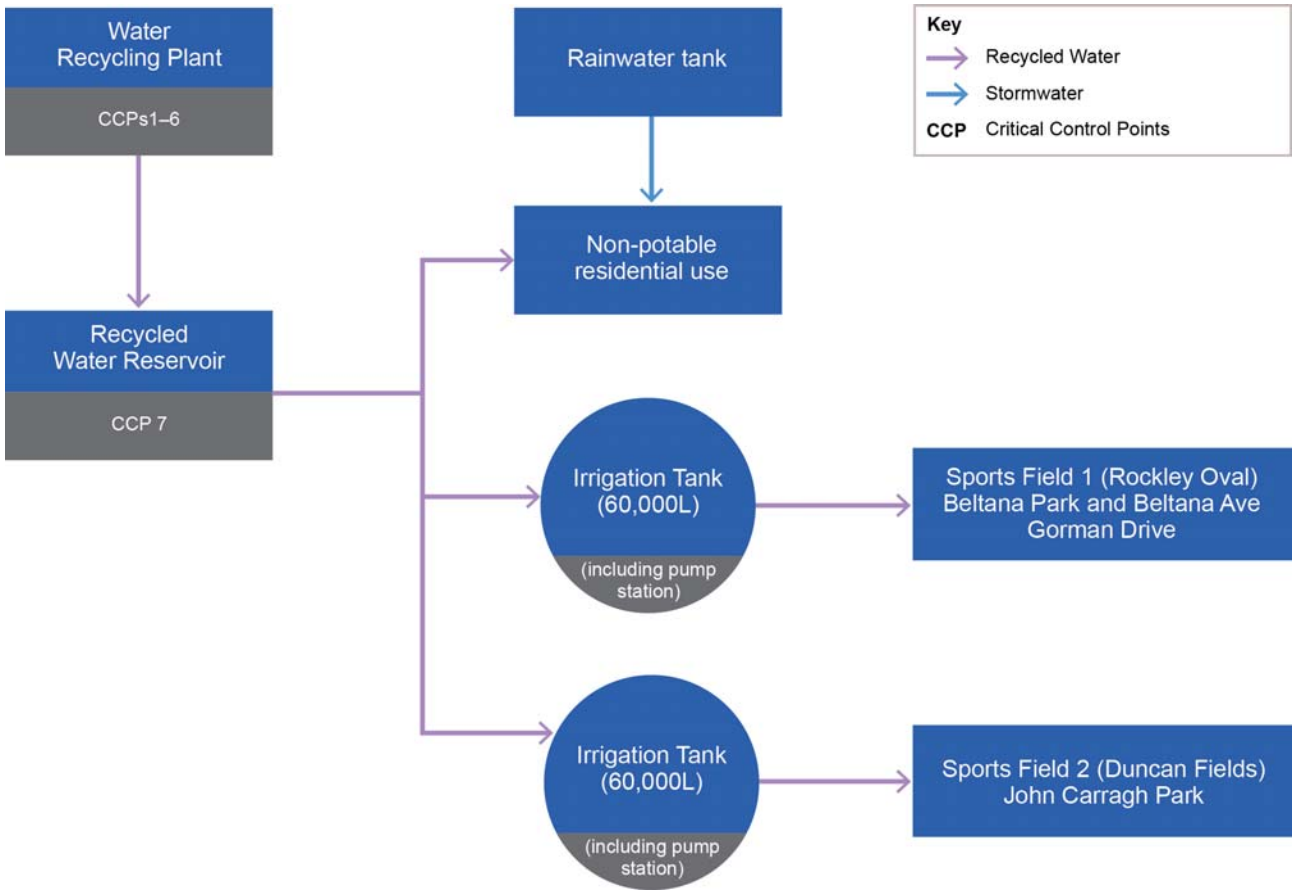


Figure 1 Irrigation water sources within Stage 1 of the IWC Project

E4 Irrigation areas

Irrigation areas within the Googong township include two sports fields, the neighbourhood parks, civic spaces in the neighbourhood centres and selected features and verges, particularly in the entrance areas to the development.

In addition, significant volumes of water for the establishment of vegetation will also be required to stabilise the soil surface during the ongoing construction phase of the subdivision.

This IMP currently focuses on irrigation areas for Stage 1 of the IWC Project. These are located in Neighbourhood 1A (NH1A), and are shown in Figure 2. Additional irrigation areas will be incorporated into this IMP as they are developed. Alternatively, separate IMPs may be prepared for the different irrigation areas.

During Stage 1 of the IWC Project, irrigation of two sports fields will occur, each with an expected irrigation area of about 2.5 hectares. In addition, recycled water will be used to assist with the establishment of Beltana and Gorman Avenue landscaping (approximately 5.8 hectares). Beltana Park (0.5 hectares) and John Carragh Park (0.1 hectares) will also be irrigated.

E4.1 Catchment and drainage

Rockley Oval (Sports Field 1), Beltana and John Carragh Parks and most of the roadside landscaping are located within the Googong Creek catchment, a tributary of the Queanbeyan River downstream of the Googong Dam. These sites are in the local sub-catchment of Beltana Pond. When this pond fills during heavy rainfall events, water will be discharged into Googong Creek.

Duncan Fields (Sports Field 2) will drain into a stormwater retention pond in the catchment of Montgomery Creek, also a tributary of the Queanbeyan River downstream of Googong Dam.

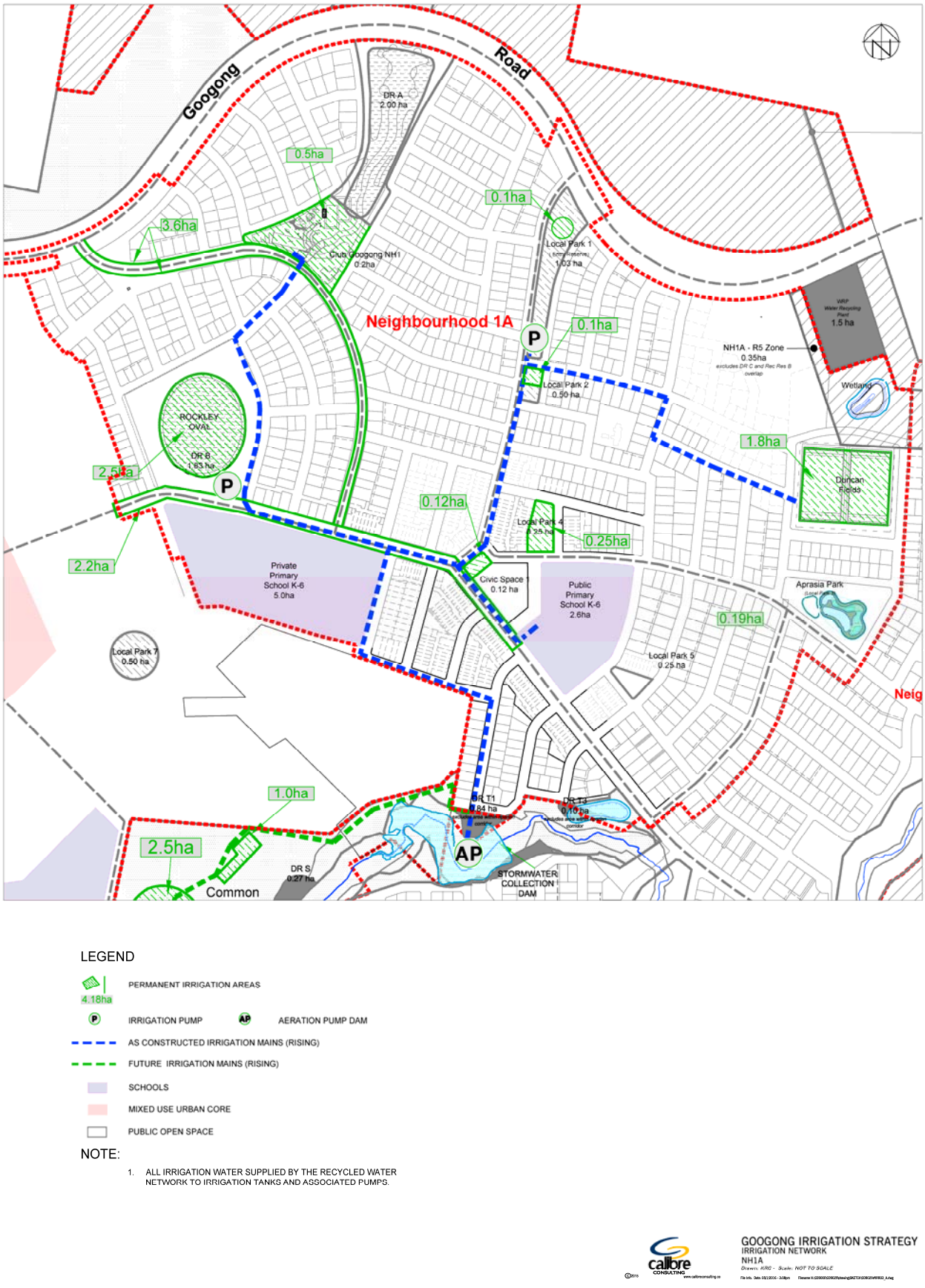
E4.2 Installed drainage system on the sports fields

The two sports fields have incorporated a special drainage system that allows most of any excess irrigation and/or rainfall not held in the first 30 to 50 cm of soil to drain through the constructed stormwater management system to the retention ponds or dams upstream of Googong and Montgomery Creeks.

The level fields have been constructed by cut and fill to establish a relatively impermeable base. At both sports fields the bases have been overlain with agricultural pipe embedded in coarse gravel and then overlain with loamy sand topsoil (Sports Field 1) or sand and topsoil (Sports Field 2). The agricultural pipe directs excess soil water to the main drainage system associated with Beltana Pond (Sports Field 1) or Montgomery Creek (Sports Field 2).

The gravel layer allows the sandy topsoil to retain more water than if it were sitting straight on the clayey fill material. This “perched water table” in the upper root-zone soil gives the turf a larger reserve of water, which allows longer times between irrigations and provides time for added fertilisers to be taken up by the growing plant. The drainage system is constructed in a herring-bone design using 100 mm diameter ag line. The pipes are laid six to eight metres apart on a slope of approximately one in 100 and feed into 150 mm collector ag lines that radiate in from the perimeter of the ground.

The slope of these collector pipes vary from one in 90 to one in 130 and drain into the perimeter drainage pipe of 150mm diameter smooth slotted polyvinyl chloride (PVC) pipe. Each collector pipe feeds into this perimeter pipe. The grade of the perimeter drain is one in 250, sloping either to the east or west side of the oval and discharges to the major stormwater structures to the north and south of Sports Field 1.



LEGEND

- PERMANENT IRRIGATION AREAS (4.18ha)
- IRRIGATION PUMP (P)
- AERATION PUMP DAM (AP)
- AS CONSTRUCTED IRRIGATION MAINS (RISING)
- FUTURE IRRIGATION MAINS (RISING)
- SCHOOLS
- MIXED USE URBAN CORE
- PUBLIC OPEN SPACE

NOTE:

1. ALL IRRIGATION WATER SUPPLIED BY THE RECYCLED WATER NETWORK TO IRRIGATION TANKS AND ASSOCIATED PUMPS.

GOOGONG IRRIGATION STRATEGY
IRRIGATION NETWORK
NH1A

Figure 2 Irrigation areas in the Googong township (Stage 1 of the IWC Project)

E5 Baseline monitoring

E5.1 Monitoring methodology

An assessment of the pre-development soil capability was conducted by Agsol Pty Ltd in 2010, and is outlined in Section 4.1.3 of the WMP. However, as the terrain and drainage for the IWC Project is currently being established, baseline soil monitoring was undertaken in February 2015 and March 2016 to determine soil baseline data, as discussed below.

The baseline monitoring addresses two distinct components of the recycled water reuse project.

Firstly it establishes the baseline soil conditions on the two sports fields (Figure 2) that will be permanently irrigated with recycled water (Figure 1). As this water will potentially be of a lower quality than the recycled water used in households the day to day management of these sites is addressed in Standard Operating Procedures (SOPs) identified in this IMP.

Secondly the monitoring establishes the baseline conditions of low lying areas that were considered at risk of becoming saline as a result of prolonged use of recycled water in both the open space areas and from garden irrigation in residential households (Agsol 2010). As only the highest quality recycled water (from a human health perspective) will be used in home-garden irrigation an IMP is not necessary. However the recycled water will contain higher concentrations of potential pollutants of ground and surface waters such as salt, nitrogen and phosphorus than conventional potable water supplies. Hence the monitoring of soil conditions in low lying areas will allow the ongoing assessment of the environmental sustainability of the scheme and will act to alert future managers of the Googong development of unexpected impacts in a timely manner.

E5.1.1 Sampling areas

Ten soil sampling sites were established within the Stage 1 area of the IWC Project. The sites were located at the following sites:

- Two sites (Sites 1 and 2) were located in open sports field areas.
- The eight remaining sites (Sites 3 to 10) were located at determined ‘at-risk’ sites in low-lying areas.

The locations of the ten soil sampling sites were logged by a surveyor, and are shown in Figure 3.

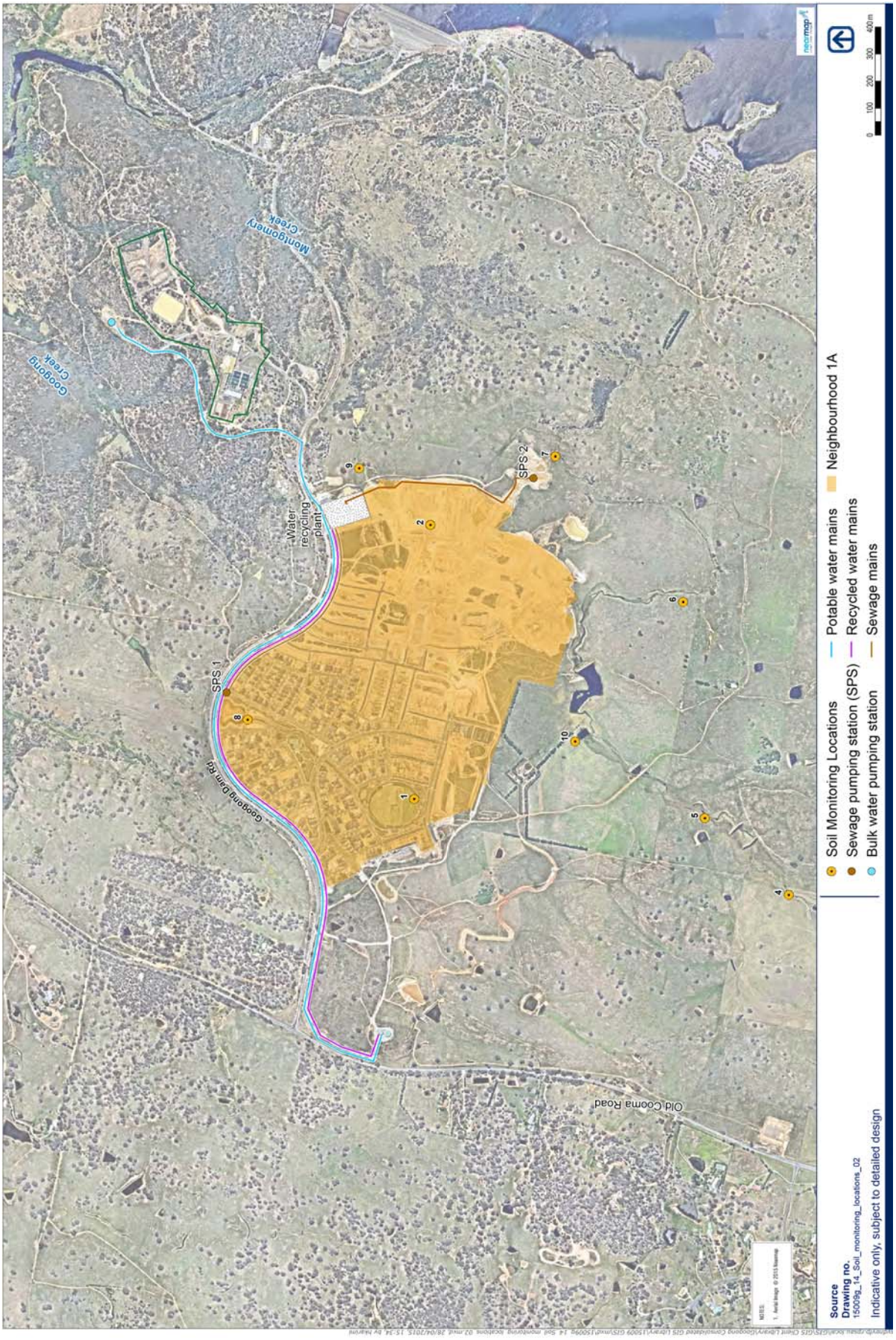


Figure 3 Baseline soil monitoring locations

E5.1.2 Sampling methodology

Sampling of surface soil and soil profile was undertaken on the 2 to 4 February 2015 (primary monitoring round) and 31 March 2016 (supplementary monitoring round) by a contractor accredited by the Australian Society of Soil Science Incorporated. The primary sampling round in February 2015 was undertaken under ideal soil moisture conditions. According to the automated weather station at the WRP, the rainfall received during the previous month was around 102 mm. This is almost double the January average for the region.

At each site (see Figure 3) a composite sample was collected from five cores within a 10 m^2 area around the survey marker. A 100 mm Jarrett auger was used to collect samples from four depth increments (0-20 cm; 20-40 cm; 40-70 cm and 70 to 100cm).

A field description of all the sites is provided in Table 2.

Table 2 Description of soil monitoring sites

Site	Location (55H)	Surface conditions	'Average' description (cm)	Sampling conditions
1	N: 6078002 E: 0702588	Recently laid couch turf. Evidence of patchy fertiliser application.	0-(25-50) yellow clayey sand sharp to; (25-70) coarse grey gravel fill sharp to; (25-100) red mottled medium to heavy clay with stone and gravel fill.	Moist soil. Ag pipe laid within gravel layer. Evidence of patchy fertiliser application.
2(a) sampled February 2015	N: 6077943 E: 0703601	Recently compacted. Bare surface. Some exposed rock	0-70+ yellow brown clayey sand with rock /gravel inclusions.	Heavy compaction and rock inclusions limit depth of auguring.
2(b) sampled March 2016	N: 6077920 E: 0703729	Recently turfed and irrigated with town water	0-(15-40) reddish brown sand sharp to; (15-40)-(40-55) dark brown clay loam fill to (sometimes with gravel applied to subsurface irrigation or drainage lines); (40-55)-(50-95) orange or yellow-grey mottled sandy clay fill with rock inclusions. Then augur refusal due to large rock inclusions.	Large rock inclusions limit depth of sampling.
3	N: 6076016 E: 0701912	Reedy growth on flat drainage plain.	0-(25-50) dark brown sandy or silty loam or clay loam gradual to; (25-50) light grey or yellow mottled sandy clay sharp to; (40-100) mottled brown grey sandy to medium clay.	Moist. Perched water table at 70 cm.

Site	Location (55H)	Surface conditions	'Average' description (cm)	Sampling conditions
4	N: 6076617 E: 0702233	Narrow floodplain adjacent to ephemeral stream	0-(30-35) dark brown sandy loam; (30-50) light greyish mottled sandy clay; 50+ grey brown mottled medium clay.	Perched water table at around 70 cm. Rock encountered at site furthest away from stream.
5	N: 6076926 E: 0702517	Foot-slope adjacent creek	(0-20) pale greyish brown fine sandy loam to; 20-(30-40) bleached and mottled greyish brown to; 40+ bright yellow medium to heavy clay some mottles.	Moist.
6	N: 6077007 E: 0703316	Lower slope-rock outcrop nearby.	0-20 grey sandy loam; 20-30 bleached sandy loam; 30-45 grey sandy loam; 45-85 orange grey clayey sand (weathering regolith).	Rock from 45 cm. Deepest hole 85 cm.
7	N: 6077480 E: 0703854	Foot slope below dam.	0-15 dark brown clayey sand; 15-30 light brown clayey sand then hard rock.	Rock from 15 cm.
8(a) sampled February 2015	N: 6078622 E: 0702883	Foot-slope above creek just before main dam on Googong Dam Road.	0-25 fill (brown clay sand gravel and small stones)	Topsoil has been washed off exposing subsoil. Site at serious risk of erosion.
8(b) sampled March 2016	N: 6078617 E: 0702878	Foot-slope above creek just before main dam on Googong Dam Road.	0-40 cm light brown clay sand with gravel and small stones. Augur refusal 25-40 cm.	Junca species have colonised drainage line and surrounds. Drought hardy perennials are colonising upslope areas.
9	N: 6078205 E: 0703810	Drainage plain below WRP. Rocky outcrop nearby	0-20 brown sandy loam; (20-(30-50) pale grey/yellow mottled clayey sand-bleached; (30-85) bright yellow brown mottled clay.	Rock encountered between 45 and 85 cm.
10	N: 6077407 E: 0702801	Foot-slope below 'Bunyip' above dam.	0-(15-20) brown or grey clayey sand; (15-30)-(20-50) bleached clayey sand; (30-50) greyish brown or yellow sandy clay to 100 cm.	Grey and brown colours closer to dam.

E5.1.3 Laboratory analysis

Based on Table 5.2 of the *Environmental Guidelines: Use of Effluent by Irrigation* (DEC 2004), the composites soil samples collected at each monitoring site were set to the NATA registered Soil Conservation Service Scone Research Laboratory for analysis of the following constituents:

- pH.
- Electrical conductivity (EC).
- Nitrate (N).
- Total nitrogen (TN).
- Available phosphorus (P).
- Total phosphorus (TP).
- Exchangeable sodium percentage.
- Heavy metals and pesticides.
- Phosphorus sorption capacity.

E5.2 Results

E5.2.1 Sports fields

Rockley Oval (Sports Field 1)

Site 1 samples were taken on a recently established sporting field.

The field survey identified that there was up to 50 cm of sandy topsoil overlying a gravel layer (with installed drainage pipes) up to 70 cm before clayey fill material was reached (depths for these layers were highly variable). Recent rainfall meant that a perched water table sat on top of the clay layer, suggesting that the clayey fill material will not absorb excess nutrients that are applied.

The laboratory results for Site 1 are shown in Table 3. They indicate that the soil in the plant root zone (0-700 mm) is not saline and is neutral to slightly alkaline. The couch grass cover will tolerate the slightly elevated pH. Over time an expected build up of organic matter in the soil could result in a slight lowering of pH, although the pH of the applied recycled water will also affect soil pH.

The topsoils are sodic but this is only a concern in soils with relatively high clay content. In this case the texture of this soil is sand or clayey sand. However the sandy nature of the soil also results in a very low cation exchange capacity (CEC) and consequently any applied nutrients in excess of plant requirements will leach during significant rainfall events. This potential issue will be managed through implementation of appropriate fertiliser application and irrigation scheduling, as outlined in SOPs 3 and 4.

Background nitrogen concentrations are observed to be very low. Irrigation with recycled water will provide potassium and trace elements but little in the way of phosphorus and nitrogen.

Background concentrations of heavy metals and pesticides in the 0-20 cm layer at Site 1 are well below guidelines for urban backyards, as shown in Table 4.

Due to the soil's poor nutrient holding capacity and the potential for excess nutrients to leach into the stormwater system and potentially into the Queanbeyan River catchment it is critical that:

- Total fertiliser applications (particularly nitrogen and phosphorus) do not exceed the amount that can be taken up by the grass.
- Any fertiliser is applied in small amounts frequently.
- Applications of fast acting fertilisers are to be avoided in favour of slow acting fertilisers.

Table 3 Site 1 – laboratory analysis results (red denotes a significant management issue and orange a minor issue)

	Units	Depth (0-200 mm)	Depth (200-400 mm)	Depth (400-700 mm)	Depth (700-1000 mm)	Desirable result
Texture		Sand	Clayey sand	Clay loam sandy	Clay loam sandy	Loam to clay loam
EC	dS/m	0.02	0.06	0.14	0.14	
Effective electrical conductivity (ECe)		0.26	0.7	1.5	1.5	<4
pH (1:5 water)		6.8	7.8	8.7	8.8	5.0-7.0
pH (1:5 $CaCl_2$)[1]		5.5	6.7	7.4	7.7	5.0-5.5
CEC	me/100g	2.1	5.8	12.1	20.3	>10
Exchangeable sodium	me/100g	0.4	0.4	0.7	0.8	<1
Exchangeable potassium	me/100g	0.3	0.3	0.3	0.2	>0.5
Exchangeable calcium	me/100g	1.4	2.4	7.9	14.1	>5
Exchangeable magnesium	me/100g	0.6	0.8	3.6	5.3	>1.6
Exchangeable aluminium	me/100g	0	0	0	0	0
Total exchangeable cations	me/100g	2.7	3.9	12.5	20.4	>10
Exchangeable sodium percentage	%	14.8	10.3	5.6	3.9	<6
Ca/Mg ratio		2.3	3			>2
Phosphorus sorption	mg/kg	60	90	180	230	>300
Available phosphorous	mg/kg	46	38	10	2	>25
Total phosphorous	ppm	110	153	231	255	
Total nitrogen	%	0.04	0.04	0.05	0.05	>0.1
Nitrate	mg/kg	2.4	2.9	2.2	2.2	>10

Note: 1. $CaCl_2$ is less subjective to seasonal variations

Table 4 Site 1 – metal and pesticide laboratory analysis results for the 0-20 cm layer

Metal	Guideline[1]	Site 1	Pesticide	Guideline	Site 1
Silver (mg/kg)	n/a	<1	DDT, DDE, DDD (mg/kg)	<60	<1
Arsenic (mg/kg)	<25	1	Aldrin and Dieldrin (mg/kg)	<2	<1
Lead (mg/kg)	<75	3	Chlordane (mg/kg)	<13	<1
Cadmium (mg/kg)	<5	<0.5	Endosulfan (mg/kg)	<68	<1
Chromium (mg/kg)	<25	3	Endrin (mg/kg)	<3	<1
Copper (mg/kg)	<1500	2	Heptachlor (mg/kg)	<2	<1
Manganese (mg/kg)	<950	25	HCB (mg/kg)	<3	<1
Nickel (mg/kg)	<100	1	Methoxychlor (mg/kg)	<75	<1
Selenium (mg/kg)	<50	<1	Other organochlorine pesticides (mg/kg)		
Zinc (mg/kg)	<1850	8	PCBs (mg/kg)	<0.25	<1
Mercury (mg/kg)	<10	0.00			
Beryllium (mg/kg)	<15	<1			
Boron (mg/kg)	<1125	1			
Cobalt (mg/kg)	<25	1			
Iron (%)		0.4			
Aluminium (%)		0.28			

Note: 1. Residential with garden/accessible soil (home grown produce <10% fruit and vegetable intake (no poultry), also includes childcare centres, preschools and primary schools).

Duncan Fields (Sporting Field 2)

Samples at Site 2 were taken on two occasions due to the progress of the sports field establishment:

- February 2015 - site levelled with cut and fill and well compacted, no topsoil.
- March 2016 - established sports field, topsoil and grass cover present.

The laboratory results for Site 2(a), sampled in February 2015, are shown in Table 5. The laboratory results for Site 2(b), sampled in March 2016, are shown in Table 6.

The subsoil at Sporting Field 2 was found to be sodic in the subsoil at the site sampled in February 2015. However the subsoil of the site sampled in April 2016 was not sodic, even at depth. The subsoil of both sporting fields has been compacted so as to have a very low hydraulic conductivity. Consequently this layer will have almost no capacity to absorb excess water or nutrient.

The topsoil was not found to be sodic. As the texture of the topsoil is sand or clayey sand this would not be a concern if sodicity rises over time. The sandy nature of the soil results in a very low CEC and consequently any applied fertiliser in excess of grass requirements will leach during significant rainfall events.

The topsoil pH was found to be slightly elevated and the topsoils showed little reserves of nitrogen. Phosphorus levels are more than adequate. Ongoing application of ammonium nitrate, applied in small amounts frequently, is recommended to sustain good grass cover. No other soil fertilisers or ameliorants appear necessary to sustain turf growth under a recycled water irrigation regime.

Table 5 Site 2(a) – laboratory analysis results (red denotes a significant management issue and orange a minor issue)

	Units	Depth (0-200 mm)	Depth (200-400 mm)	Depth (400-700 mm)	Depth (700-1000 mm)	Desirable result
Texture		Sandy clay	Clayey sand	Clayey sand	Sandy clay	Loam to clay loam
EC	dS/m	0.2	0.18	0.16	0.28	
Effective electrical conductivity (ECe)		2.6	2.0	1.8	2.5	<4
pH (1:5 water)		9.4	9.5	9.4	9.3	5.0-7.0
pH (1:5 $CaCl_2$)[1]		7.9	8.1	7.9	8.0	5.0-5.5
CEC	me/100g	20.5	19.3	25.0	20.3	>10
Exchangeable sodium	me/100g	4	3.9	4.2	3.9	<1
Exchangeable potassium	me/100g	0.3	0.3	0.2	0.2	>0.5
Exchangeable calcium	me/100g	4.4	4.0	4.0	4.0	>5
Exchangeable magnesium	me/100g	10	8.7	9.3	8.2	>1.6
Exchangeable aluminium	me/100g	0	0	0	0	0
Total exchangeable cations	me/100g	18.7	16.9	17.7	16.3	>10
Exchangeable sodium percentage	%	21.4	23	23.7	23.9	<6
Ca/Mg ratio		0.4	0.5			>2
Phosphorus sorption	mg/kg	140	130	150	150	>300
Available phosphorous	mg/kg	7	8	12	12	>25
Total phosphorous	ppm	130	120	204	182	
Total nitrogen	%	0.03	0.02	0.02	0.02	>0.1
Nitrate	mg/kg	2.3	2.0	1.9	2.0	>10

Note: 1. $CaCl_2$ is less subjective to seasonal variations

Table 6 Site 2(b) – laboratory analysis results (red denotes a significant management issue and orange a minor issue)

	Units	Depth (0-200 mm)	Depth (200-400 mm)	Depth (400-700 mm)	Depth (700-1000 mm)	Desirable result
Texture		Sand	Clayey sand	Sandy loam	Sandy clay	Loam to clay loam
EC	dS/m	0.04	0.05	0.08	0.04	
Effective electrical conductivity (ECe)		0.6	0.6	1.0	0.4	<4
pH (1:5 water)		7.9	7.4	7.7	6.6	5.0-7.0
pH (1:5 $CaCl_2$)[1]		6.8	6.7	7.0	6.0	5.0-5.5
CEC	me/100g	2.9	6.2	9.8	8.3	>10
Exchangeable sodium	me/100g	0.1	0.3	0.4	0.3	<1
Exchangeable potassium	me/100g	0.3	0.3	0.4	0.4	>0.5
Exchangeable calcium	me/100g	1.3	2.2	3.8	2.3	>5
Exchangeable magnesium	me/100g	1.2	2.7	4.1	3.9	>1.6
Exchangeable aluminium	me/100g	0	0	0	0	0
Total exchangeable cations	me/100g	2.9	6.2	9.8	8.3	>10
Exchangeable sodium percentage	%	0.3	0.5	0.4	0.4	<6
Ca/Mg ratio		1	0.8			>2
Phosphorus sorption	mg/kg	60	140	160	210	>300
Available phosphorous	mg/kg	41	23	7	5	>25
Total phosphorous	ppm	140	158	254	173	
Total nitrogen	%	0.03	0.05	0.04	0.05	>0.1
Nitrate	mg/kg	0.7	0.5	0.5	1.2	>10

Note: 1. $CaCl_2$ is less subjective to seasonal variations

Background concentrations of heavy metals and pesticides in the 0-20 cm layer at both Site 2(a) and Site 2(b) are well below guidelines for urban backyards, as shown in Table 7 and Table 8, respectively. Compared with the aluminium and iron in the topsoil at Site 2(b), the compacted layer sampled at Site 2(a) is substantially higher (as would be expected as there is more clay in the soil) and some heavy metals are higher.

Table 7 Site 2(a) – metal and pesticide laboratory analysis results for the 0-20 cm layer

Metal	Guideline[1]	Site 2(a)	Pesticide	Guideline	Site 2(a)
Silver (mg/kg)	n/a	<1	DDT, DDE, DDD (mg/kg)	<60	<1
Arsenic (mg/kg)	<25	1	Aldrin and Dieldrin (mg/kg)	<2	<1
Lead (mg/kg)	<75	6	Chlordane (mg/kg)	<13	<1
Cadmium (mg/kg)	<5	<0.5	Endosulfan (mg/kg)	<68	<1
Chromium (mg/kg)	<25	20	Endrin (mg/kg)	<3	<1
Copper (mg/kg)	<1500	4	Heptachlor (mg/kg)	<2	<1
Manganese (mg/kg)	<950	100	HCB (mg/kg)	<3	<1
Nickel (mg/kg)	<100	6	Methoxychlor (mg/kg)	<75	<1
Selenium (mg/kg)	<50	1	Other organochlorine pesticides (mg/kg)		
Zinc (mg/kg)	<1850	25	PCBs (mg/kg)	<0.25	<1
Mercury (mg/kg)	<10	0.01			
Beryllium (mg/kg)	<15	<1			
Boron (mg/kg)	<1125	1			
Cobalt (mg/kg)	<25	1			
Iron (%)		2.26			
Aluminium (%)		1.56			

Note: 1. Residential with garden/accessible soil (home grown produce <10% fruit and vegetable intake (no poultry), also includes childcare centres, preschools and primary schools).

Table 8 Site 2(b) – metal and pesticide laboratory analysis results for the 0-20 cm layer

Metal	Guideline[1]	Site 2(b)	Pesticide	Guideline	Site 2(b)
Silver (mg/kg)	n/a	<1	DDT, DDE, DDD (mg/kg)	<60	<1
Arsenic (mg/kg)	<25	1	Aldrin and Dieldrin (mg/kg)	<2	<1
Lead (mg/kg)	<75	4	Chlordane (mg/kg)	<13	<1
Cadmium (mg/kg)	<5	<0.5	Endosulfan (mg/kg)	<68	<1
Chromium (mg/kg)	<25	6	Endrin (mg/kg)	<3	<1
Copper (mg/kg)	<1500	3	Heptachlor (mg/kg)	<2	<1
Manganese (mg/kg)	<950	80	HCB (mg/kg)	<3	<1
Nickel (mg/kg)	<100	5	Methoxychlor (mg/kg)	<75	<1

Metal	Guideline[1]	Site 2(b)	Pesticide	Guideline	Site 2(b)
Selenium (mg/kg)	<50	<1	Other organochlorine pesticides (mg/kg)		
Zinc (mg/kg)	<1850	11	PCBs (mg/kg)	<0.25	<1
Mercury (mg/kg)	<10	0.01			
Beryllium (mg/kg)	<15	<1			
Boron (mg/kg)	<1125	1			
Cobalt (mg/kg)	<25	2			
Iron (%)		0.75			
Aluminium (%)		0.19			

Note: 1. Residential with garden/accessible soil (home grown produce <10% fruit and vegetable intake (no poultry), also includes childcare centres, preschools and primary schools).

E5.2.2 Low lying areas

Sites 3 to 10 were selected on the basis that there was a potential future risk of salt accumulation from the use of slightly to moderately saline recycled water. The findings of the baseline monitoring at these sites are summarised in Table 9.

Table 9 Summary of soil properties of monitoring sites in low lying areas.

Site	Catchment	Field description	Soil parameters	Impact potential
3	Drainage plain on upper tributary of Montgomery Creek.	Dark brown sandy or silty loam overlying mottled sandy clay. Perched water table evident	Alkaline and sodic topsoil. High nitrogen, low phosporous. Metal concentrations well below guidelines for urban backyards.	In catchment of existing small rural holdings with onsite wastewater treatment. Unlikely to be impacted by Googong development.
4	Floodplain on upper tributary of Montgomery Creek downstream of Site 3.	Dark brown sandy loam overlying mottled sandy to medium clay. Perched water table evident	Slightly sodic topsoil. Low nitrogen and phosphorous. Metal concentrations well below guidelines for urban backyards.	Potential to be impacted from Googong West development.
5	Foot slope on upper tributary of Montgomery Creek downstream of Site 4.	Pale grey-brown sandy loam overlying bleached A2 then bright yellow clay.	Low nitrogen and phosphorous. Metal concentrations well below guidelines for urban backyards.	Potential to be impacted from Googong West development

Site	Catchment	Field description	Soil parameters	Impact potential
6	Lower slope on upper tributary of Montgomery Creek downstream of Site 5. Rocky outcrop nearby.	Sandy loam material overlying rock or weathering regolith.	Slightly sodic topsoil. Low nitrogen and phosphorous. Metal concentrations well below guidelines for urban backyards.	Potential to be impacted by residential development up slope.
7	Foot slope above Montgomery Creek downstream of Site 6. Rocky outcrop nearby.	Clayey sand material overlying rock.	Slightly sodic topsoil. Low nitrogen and phosphorous. Metal concentrations well below guidelines for urban backyards.	Potential to be impacted from Googong North development including Sporting Field 2.
8a	Foot slope above tributary of Googong Creek downstream of Club Googong.	Topsoil had recently been washed away. 0-25 cm of brown clay, sand gravel and stones.	Sodic topsoil. Low nitrogen and phosphorous. Metal concentrations well below guidelines for urban backyards., with the exception of chromium and manganese (which exceed the guidelines).	Potential to be impacted from Googong North development including Sporting field 1.
8b	Foot slope above tributary of Googong Creek downstream of Club Googong.	Light brown clay sand with gravel and small stones.	Low nitrogen and phosphorous. Metal concentrations well below guidelines for urban backyards., with the exception of chromium and manganese (which exceed the guidelines).	Potential to be impacted from Googong North development including Sporting field 1.
9	Drainage plain on upper tributary of Montgomery Creek below WRP. Rocky outcrop nearby.	Brown sandy loam overlying bleached layer the yellow brown mottled clay.	Low phosphorous. Metal concentrations well below guidelines for urban backyards.	Potential to be impacted from Googong North development including Sporting field 2.
10	Foot slope above upper tributary of Montgomery Creek below 'Bunyip' downstream of Site 5.	Brown or grey clayey sand overlying bleached layer then greyish or yellow brown sandy clay	Sodic soils, saline at depth. Low nitrogen and phosphorous. Metal concentrations well below guidelines for urban backyards.	Potential to be impacted from Googong Central development.

E6 Potential environmental risks and impacts

This section relates specifically to the 'off-site' risks associated with the use of recycled water as a water source from irrigation within the Googong township.

The EA and appended studies identified that the potential off-site risks associated with using recycled water primarily relate to the introduction of salt into the landscape and receiving waters as a result of garden and landscape irrigation and discharges from the WRP. More salt will be added to the soil (and potentially the groundwater) from recycled water irrigation than is currently the case, or if conventional potable water supplies were used.

During prolonged rainfall events, salt accumulated from recycled water irrigation has the potential to leach below the plant root zone and start to move to lower lying parts of the landscape. Soil salt levels downhill could increase, harming the growth of existing or future vegetation stands. At worst, salt scalds could develop in lower lying areas and soil erosion may subsequently occur where plant growth is impaired.

Salt stored in the landscape may also find its way via interflow or groundwater to streams in the catchment of the Queanbeyan River. However, discharges from these sources are likely to be generated in pulses following heavy and/or prolonged rain and/or erosion events. During high rainfall events the flow rate in perched groundwater tables, creeks and rivers is likely to be greater, consequently minimising the risk of adverse impacts.

A lesser risk is accumulation of other pollutants such as nitrogen that is also found in the recycled water.

To minimise risks to the Googong Dam catchment a section of the south-east corner of the Googong township (39.9 ha) will not be developed. It is zoned for environmental protection to avoid direct impact on the Googong Foreshores.

E6.1 Potential off-site risks

E6.1.1 Runoff and seepage

Applying more water than can be absorbed by the soil when irrigating will lead to runoff or seepage of recycled water. Risks will be mitigated by irrigation scheduling as detailed in SOP4.

Irrigation within individual houses poses fewer risks (from a recycled water perspective) as the water to be irrigated will be diluted with rainwater. However households are likely to use garden fertiliser. Excessive use could influence measurements at monitoring sites.

To minimise these risks management of the Googong township should make home gardeners aware of the recycled water quality on a regular basis (e.g. 3-monthly). If the concentrations of nitrogen and potassium are significant (or other constituents) then management should make home gardeners aware of what this means in terms of quantity of 'added' conventional fertilisers. The use of plants that are salt tolerant with low fertiliser needs should be encouraged by Googong township managers.

Additionally, ongoing soil monitoring of the 10 sampling sites will identify whether further action is required.

E6.1.2 Groundwater contamination (off-site)

There is the possibility of leaching of soluble salts (including nutrients) into the groundwater for the same reasons as described in Section E6.1.1 above.

Risks are reduced by the same methods described in E6.1. Groundwater quality within the Googong township will be monitored as described in the Groundwater Monitoring Program (GWMP) (WMP Appendix B).

E6.1.3 Spray drift

Drift can occur from sprinklers, particularly on windy days. This could result in salt and nutrients directly entering water bodies although the impacts are likely to be very small. A more significant risk is air-borne pathogens, however the very highly treated and disinfected recycled water also reduces this risk to a low level.

Risks are more significant from high-pressure guns on travelling irrigators. These will not be used within the Googong township. Furthermore moderate pressure ‘pop up’ irrigators on sports fields will be switched off automatically in high winds (i.e. greater than 15 km/hr).

All other irrigation of open space areas and within home gardens will be low pressure micro-sprays.

E7 Overview of irrigation management of open space areas

E7.1 Responsibilities

The various personnel responsible for the sustainable operation of the IWC Project are identified in Figure 4 and Figure 5. Roles and responsibilities will initially lie with GTPL personnel (Figure 4), but as irrigation areas are transferred to Queanbeyan City Council (QCC) these will transfer to QCC personnel (Figure 5).

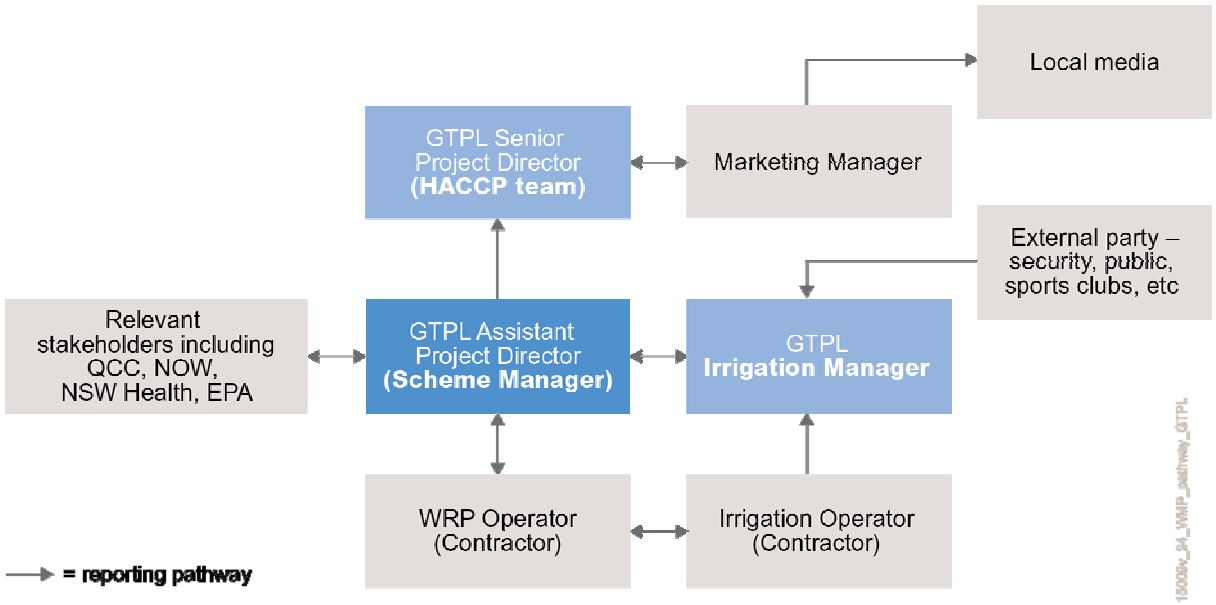


Figure 4 GTPL personnel responsible for recycled water irrigation (bolded titles indicate how these positions are referred to in the IMP)

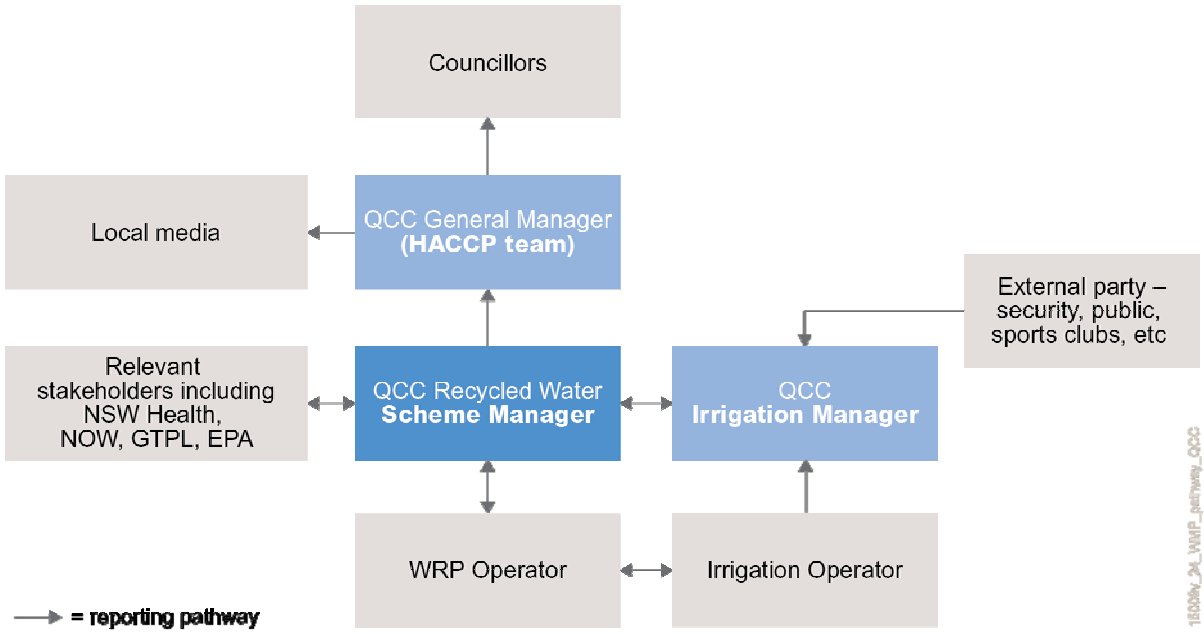


Figure 5 QCC personnel responsible for recycled water irrigation (bolded titles indicate how these positions are referred to in the IMP)

The SOPs, work practices, maintenance, monitoring and reporting requirements for managers and staff responsible for irrigating and monitoring the sports fields are outlined in Section E9 of this IMP.

The SOPs, work practices, maintenance, monitoring, reporting and auditing requirements for the operation of the IWC Project are provided in the Essential Sewage and Recycled Water Quality Management Plan (RWQMP) and the WMP.

E7.2 Management overview

Recycled water delivered to the sports fields, and other areas for irrigation, will be treated and monitored to ensure that:

- It meets *Australian Guidelines for Water Recycling: Managing Health and Environmental Risks (Phase 1)* (AGWR) (National Resource Management Ministerial Council, Environment Protection and Heritage Council and Australian Health Ministers' Conference 2006) for irrigation of household gardens.
- The load of potential pollutants in recycled water (nitrogen, phosphorus and salts) can be immobilised by the plant soil ecosystem.

The quality of the recycled water will be monitored so that the Irrigation Manager is aware of the quality of the water and can adjust management practices accordingly as outlined in the SOPs. The Irrigation Manager will practice irrigation scheduling to ensure that they do not irrigate more water than can be taken up by the growing plant. Furthermore, a soil moisture deficit should be maintained after irrigation to minimise the risk that subsequent rainfalls leach recent fertiliser applications.

A number of preventative measures (or barriers) will be in place including the use of Australian recycled water standards for colour coding of pipes and installation of Australian standard signage to advise customers and the public that recycled water is being used for irrigation. The monitoring of recycled water quality as well as the drainage water leaving the two sports fields will provide important input into the assessment of the sustainability of irrigation practices. This is because recycled water contains plant fertilisers that will need to be taken into account when undertaking fertiliser programs. If too much fertiliser is applied, excess nutrients may enter the drainage that leaves the two sports fields.

Monitoring programs for recycled water quality, surface water and groundwater quality are not detailed within this IMP. Details of these monitoring programs can be found in the RWQMP and relevant sub-plans of the WMP. It will be important that the irrigation managers are advised of the results of these monitoring schemes in a timely manner.

E7.3 How to use this IMP

This Plan is based on the Hazard Analysis and Critical Control Point (HACCP) methods advocated by the AGWR. The method comprises 12 elements that fall into four main categories:

1. Commitment to responsible use and management of recycled water.
2. System analysis and management.
3. Supporting requirements (e.g. employee training, community involvement, research and development, validation, and documentation and reporting systems).
4. Review (e.g. evaluation and audit processes).

The 12 elements are identified in more detail in the RWQMP.

An important feature of the HACCP approach is identifying critical control points (i.e. an activity, procedure or process where control can be applied, and that is essential for preventing hazards that represent high

risks or reducing them to acceptable levels) and preventative measures, as well as the use of multiple barriers to control hazards, meaning that if one measure fails, other measures continue to provide control.

Section E8 of this Plan identifies the critical control points (CCPs), critical limits and preventative measures downstream of the point of connection with recycled water.

Section E9 identifies the operational and maintenance requirements in the form of SOPs that are specific to recycled water irrigation.

Section E10 details the verification procedures to be undertaken when any irrigation scheme is commissioned. **An irrigation scheme cannot commence or continue operating until there is monitoring evidence to show that all processes are working according to target criteria.**

Section E11 details the ongoing monitoring and reporting requirements associated with this IMP.

E8 Critical control points, critical limits and preventative measures

E8.1 Critical control points (CCPs)

Critical control points require:

- Operational parameters that can be measured in real time, and for which critical limits can be set to define effectiveness (e.g. chlorine residuals for disinfection).
- Operational parameters that can be monitored sufficiently frequently to reveal any failures in a timely manner.
- Procedures for corrective action that can be implemented in response to deviation from critical limits.

CCPs for the recycled water that is delivered to individual households are measured at the WRP and recycled water reservoir and a detailed discussion of these is provided in the RWQMP.

CCPs for the irrigation of sports fields and irrigated open space areas can be different as there is:

- a lower water quality requirement with regard to pathogens due to the provision of a number of 'barriers' or 'preventative measures' at these sites compared with individual household sites; and
- Some constituents in recycled water can be at a higher concentration (e.g. nitrogen and phosphorus) as the plant/soil system can immobilise these before they reach any surface or groundwater body.

CCPs will prevent poor quality recycled water from being sent to the irrigation sites. CCPs at the WRP are monitored continuously and if any critical parameters, primarily disinfection limits, are outside of specification the recycled water distribution system can be disconnected to irrigation sites.

Sports fields and other open-space irrigation sites will have limits set for other parameters that ensure the irrigation system operates sustainably. These limits are important for maintaining the health of users and workers as well as risks to surface water and groundwater associated with the leaching or runoff of nutrients and salt. These limits are monitored over time by the Irrigation Manager and will be reviewed periodically.

A monitoring point can be installed at the irrigation tanks/reservoirs. Reservoir monitoring points will be measured for chlorine residual during the verification period and randomly on an ongoing basis or if there is concern that pathogen standards are not being met.

It will be important that pH, nitrogen, phosphorous. potassium and salt load are monitored in these reservoirs.

E8.2 Preventative measures and critical limits for irrigation of sports fields and public open spaces

Available preventative measures that reduce the hazard of end-user exposure to pathogens on sports fields and in other public open space areas include the following:

- Automated irrigation systems on sports fields that allow field to be accessed only when the turf is dry.
- Soil moisture monitors, rainfall and wind sensors that automatically stop irrigation under specified conditions.
- 180-degree inward throwing sprays at boundaries of sports fields.
- Micro-sprays in other open-space areas.

- Irrigation scheduling (see SOP4).
- Ability to isolate supply of recycled water delivered to irrigation tanks.
- Recycled water filtered before delivered to irrigation system.
- Town water supply isolated from recycled water supply.
- NSW Health approved signage and colour coding of above and below ground irrigation infrastructure.
- Special practices identified in Safe Work Method Statements for irrigation workers.
- Identification of an appropriately qualified staff responsible for training of site operators.

These preventative measures allow the CCPs for the irrigation recycled water to be less stringent than the recycled water delivered to individual households within the Googong township.

A critical limit is a prescribed tolerance that distinguishes acceptable from unacceptable performance. When a process that represents a CCP is operating within critical limits, performance in terms of hazard removal is regarded as being acceptable. However, deviation from a critical limit represents loss of control of a process and indicates that there may be an unacceptable health or environmental risk. Corrective actions should be instituted immediately to resume control of the process, and the health or environmental regulator may need to be notified.

Critical limits for the irrigation of the irrigation sites with recycled water are shown in Table 10 and Table 11.

Table 10 Critical limits for irrigation sites to reduce the hazard of end-user exposure to pathogens

Potential critical control point	Critical limits	Monitoring frequency	Sampling procedure	Responsibility for identifying and solving sampling/ reporting failure	Corrective action	Responsibility for action at irrigation site
Recycled water quality delivered to the irrigation reservoirs	Measurable chlorine residual	Continuous	Chlorine analyser	Scheme Manager	Identify problem to be corrected. Until corrected direct recycled water to bulk storage	Scheme Manager
	Turbidity measurement	Continuous	Turbidity analyser	Scheme Manager	As above	Scheme Manager
Time of irrigation	Irrigation must cease so that the field is dry when a use commences	Daily	Staff to check before event	Irrigation Manager		Irrigation Manager
Weather station	Rainfall less than 10 mm over previous two days	Daily	Automated or manual	Irrigation Manager	Stop irrigation until there is a significant soil moisture deficit	Irrigation Manager
Spray drift	No use of pop-up spray irrigation in windy conditions (i.e. greater than 15 km/hr)	Automated sensor or daily observations	Automated sensor or daily observations	Irrigation Operator	Stop irrigation	Irrigation Manager
Potable water supply lines	No cross connections with recycled water supply	Whenever plumbing works are undertaken at irrigation sites	Sample all potable water outlets after plumbing works	Scheme Manager	Investigate and identify cross connection	Scheme Manager

Table 11 Critical limits at irrigation sites that address the hazard of groundwater and surface water contamination

Potential critical control point	Target critical limits	Monitoring frequency	Sampling procedure	Responsibility for identifying and solving sampling/ reporting failure	Corrective action	Responsibility for action at irrigation site
Irrigation system scheduling	15mm soil moisture deficit prior to an irrigation event	Daily when irrigation is occurring	Soil moisture monitors and/or manual moisture probes.	Irrigation Manager	Change irrigation schedule.	Irrigation Manager
	5 mm soil moisture buffer after irrigation event		Visual observation (e.g. no puddles after irrigation). Soil moisture monitors and/or manual moisture probes.			
Recycled water quality	N < 18.5 mg/L[1]	Monthly	Sampled at irrigation reservoir	Irrigation Manager	If levels over a 12 month period exceed target limits clippings and cuttings should be removed from irrigation site on a regular basis.	Irrigation Manager
	P < 2 mg/L[1]	Monthly	Sampled at irrigation reservoir	Irrigation Manager	If levels over a 12 month period exceed target limits clippings and cuttings should be removed from irrigation site on a regular basis.	Irrigation Manager

Potential critical control point	Target critical limits	Monitoring frequency	Sampling procedure	Responsibility for identifying and solving sampling/ reporting failure	Corrective action	Responsibility for action at irrigation site
	pH 6.5 – 7.5	Monthly	Sampled at irrigation reservoir	Irrigation Manager	Investigate problem and correct if possible. If outside target range check soil pH. If soil pH out of range ameliorate with lime or sulphate as required.	Irrigation Manager
	Salt (TDS) >1,500 mg/L[1,2]	Monthly	Sampled at irrigation reservoir	Irrigation Manager	Check for source of salinity (WRP or closed storage) and investigate cause.	Scheme Manager

Note: 1. Taken from nutrient budgets undertaken for fairways at Young (Agsol 2012).

2. This is an average value. The relative dryness of the climate will determine salinity impacts. In a dry year a value greater than 1500 ppm could have significant. However in wet years much higher salinities could be tolerated (up to 2500 ppm).

E9 Standard operating procedures (SOPs)

The following SOPs identify the tasks to be carried out by various personnel to minimise risks associated with the irrigation of recycled water and to ensure that preventative measures are in place and that actions are taken if critical limits are exceeded.

This document only addresses those operational procedures for recycled water produced at the WRP commencing at the irrigation reservoirs (refer to Figure 1). Operational procedures upstream of this point as well as downstream of the irrigation sites are contained elsewhere in the RWQMP and WMP.

It should also be noted that many of the procedures (such as irrigation scheduling arrangements, maintenance of irrigation related equipment, turf management, etc.) required for the sustainable operation of the recycled water irrigation scheme are standard practices irrespective of the source of water. Hence these procedures focus on special operational procedures directly related to the use of recycled water.

E9.1 SOP1 Protection of human and environmental health

This operating procedure is aimed at protecting the health of the site users, the public and the environment from irrigating with recycled water. A separate SOP7 is for protection of health of irrigation workers.

Timely knowledge of the quality of the irrigation water is essential to the sustainable operation of the recycled water irrigation scheme.

E9.1.1 Hazards addressed

- End-user exposure to pathogens.
- Potential contamination of surface and ground waters.

E9.1.2 Preventative measures

It is noted that recycled water will normally achieve a standard that is superior to AGWR 2006 guidelines for irrigation of sports fields with ‘barriers’ or ‘preventative measures.

The following preventative measures will be used to reduce health and environmental hazards. These are:

- Potential to close some sites (e.g. sports fields) from public access.
- Colour coding of surface and sub-surface infrastructure.
- Signage alerting irrigation workers, customers and the general public to the use of recycled water.
- Appropriate signage providing relevant contact information to customers and the general public.
- Monitoring of CCPs at the WRP will allow delivery of recycled water to cease if water quality fails to meet targets for human health.
- Inward throwing low pressure sprays at the boundaries of irrigation sites.

E9.1.3 Operational procedures

This procedure involves:

1. Not irrigating if recycled water quality is outside critical limits unless additional preventative measures are put in place.
2. Scheduling irrigation to avoid overwatering the site.
3. Judicious use of fertiliser based on established standards for sporting fields, parks and landscaping but taking into account fertiliser supplied in recycled water.
4. Irrigation Manager and workers to alert the Scheme Manager of any unusual appearance or smell in the recycled water.
5. Use of existing IWC Project complaints/incident protocols by management, nearby residents or passers-by.

E9.1.4 Responsibilities and authorities

The responsibilities are as follows:

1. The Scheme Manager must notify the Irrigation Manager as soon as the recycled water by the WRP is known to exceed any critical limit e.g. salt or pathogens or (more unlikely) excessive nitrogen and phosphorus concentrations.
2. The Irrigation Manager will undertake regular monitoring of nitrogen, phosphorus, pH and salinity as outlined in Table 11.
3. In the event of a human health based critical limit being exceeded and based on the estimated risks associated with the exceedance, the Irrigation Manager will inform the Scheme Manager. The Scheme Manager will then be responsible for any action which could involve:
    - Stopping supply; or
    - Consulting with the Irrigation Manager and recommend another action (e.g. enforce a longer withholding period before the sports field can be used) .
4. The Irrigation Manager is responsible for reporting any significant incidents that could be related to recycled water to the Scheme Manager who will work to a resolution as appropriate.
5. The Scheme Manager and Irrigation Manager together will communicate with the affected stakeholders which could include (depending on the severity of the incident) NSW Health, Workcover, emergency personnel, players and spectators using the site and the general public.
6. Irrigation operators are required to follow instructions given by the Irrigation Manager in all matters relating to recycled water.
7. The Irrigation Manager is to advise (immediately by personal contact if possible) the Scheme Manager of any unusual appearance or smell as well any complaints from end users.
8. Complaints from users or the public about the irrigation system smell or colour are to be forwarded by the Irrigation Manager immediately to the Scheme Manager.
9. The Scheme Manager will keep a record of significant incidents, outcomes of any discussions and resolutions.
10. At the end of each year the results of documented records are to be summarised by the Scheme Manager and discussed with the sports field management and the HACCP team.

11. Any changes to the procedure will require an appropriate update of this IMP by the Scheme Manager.

E9.1.5 Documentation

- Records of the quality of recycled water.
- Standard incident/complaint reporting forms.
- All documentation to be recorded in a manner that makes its accessible to the HACCP team, Scheme Manager and Irrigation Manager.

E9.2 SOP2 Use of data generated from a weather station

A weather station located within the township will provide necessary data to assist with irrigation scheduling (SOP4).

E9.2.1 Hazards addressed

- Potential contamination of surface and ground waters due to irrigation during inappropriate weather conditions.

E9.2.2 Preventative measures

The availability of preventative measures to reduce environmental hazards associated with irrigation after or during rain or during other unsuitable weather conditions may include the following:

- Irrigation not undertaken in wet weather.
- Irrigation scheduling arrangements.
- Automated anemometers, rainfall gauges and soil moisture recorders connected to an automated irrigation system.

E9.2.3 Operational procedures

This procedure involves:

1. Regular review and maintenance of the weather station or weather monitors associated with the automated irrigation system.
2. Communication of data to managers and operators of the irrigation system.

E9.2.4 Responsibilities and authorities

The responsibilities are as follows:

1. The Scheme Manager must regularly review and maintain the weather station.
2. The Scheme Manager must communicate data collected to the Irrigation Operator in a timely manner.
3. The Irrigation Manager maintains any automated monitoring equipment (e.g. rain gauges, soil moisture monitors or anemometers) and modifies irrigation scheduling arrangements accordingly.

E9.2.5 Operational parameters

1. No irrigation if more than 10 millimetres of rainfall has been received during the previous two days.
2. No irrigation when wind speeds exceed 15 km/hr.
3. No irrigation if soil is at filed capacity.

E9.2.6 Documentation

- Rainfall, wind and temperature records.
- Evidence that preceding rainfall events, seasonal temperatures and wind events are taken into account when scheduling irrigation.

E9.3 SOP3 Maintenance of good quality turf cover

Good quality turf cover is essential to ensure that the water, nutrients and pollutants in recycled water are being immobilised by the plant/soil system.

E9.3.1 Need for fertiliser

The sporting fields will be mown regularly. Mowing returns the grass clippings with their nutrient content to the soil. As the mown grass breaks down volatile nitrogen compounds may be released, but other nutrients will stay in the soil until they are dissolved in water and are taken up by plant roots or leached. Ammonia, nitrate and nitrites as well as sulphur and chlorine compounds and potassium are relatively soluble and will leach if too much water is applied. Phosphorus compounds are less soluble and a significant proportion will potentially be adsorbed to the soil particles and unavailable for plant growth. When establishing a turf there is a significant need for phosphorus applications but over time this lessens as the grass clippings are recycled. For this reason the main fertiliser needs on established turfed irrigation sites are nitrogen followed by potassium.

The soils tests at Sports Field 1 suggested that sufficient phosphorus was already present in the soil and it is possible that irrigation with recycled water will provide all future phosphorus needs.

Well managed sporting fields are fertilised every four to six weeks throughout the growing season. As shown in 0 some nitrogen, phosphorus, potassium and trace elements will be potentially available in recycled water produced at the WRP. These will be delivered every time there is an irrigation event. The forms of nitrogen in recycled water will vary throughout the year.

Table 12 Fertiliser recommendations for sporting fields at Googong assuming irrigation with recycled water

Element	Total amount required to establish grass	Quantity likely to be supplied in recycled water	Additional quantity likely to be required	Seasonal application	Comment
Lime/calcium	Nil	Not known	Only apply if pH $CaCl_2$ drops below 5.5	Autumn	Fields are currently alkaline.
Total nitrogen	180 kg/ha/annum	25-35 kg/ha	145-155 kg/ha	Fast release in early spring and autumn, Slow release varieties in other months.	Use of ammonia sulphate initially will lower high pH.
Phosphorous as (P_2O_5)	180 kg/ha (initial application)	1.25-1.75 kg/ha	Only in response to soil tests (Bray P drops below 25 mg/kg)	Initial applications to bring topsoil Bray P to above 25 mg/kg.	Site 1 already has sufficient phosphorous.
Potassium	75 kg/ha	75 kg/ha	5-25 kg	With every irrigation.	Any additional potassium needs could be applied in autumn.
Sulphur			Unknown		Sufficient amount likely to be supplied in recycled water.
Iron			Unknown		Imported sandy topsoils likely to be deficient in iron.

Parks and landscaping areas are unlikely to be fertilised as much as playing fields and recycled water is likely to provide sufficient fertiliser except for nitrogen.

Nitrogen

Turf nitrogen fertilizers are usually classified as quick release or slow release. Quick-release sources are water-soluble (e. g., ammonium nitrate, urea, ammonium sulphate); they will release nitrogen into the soil solution rapidly with rainfall or irrigation. They produce a relatively short-lived flush of growth and can burn the grass leaves if applied incorrectly (e.g. on hot dry windy days). Slow-release forms of nitrogen will release nitrogen over longer periods potentially reducing the risk of nitrogen leaching to groundwater after a significant rainfall event.

Too much nitrogen can result in Pythium blight, patch and leaf spot diseases; thatch production; increased water usage; and the need for increased mowing. Some problems that are not so obvious include reduced root, rhizome, tiller, and stolon growth, as well as reduced heat and drought tolerance.

Turfs deficient in nitrogen will exhibit characteristic symptoms including:

- Older leaves become light green then yellow then darker yellow-brown.
- Turf becoming less dense, encouraging weed encroachment (e.g. clovers).
- Diseases such as ‘dollar spot’ or ‘red thread’ occur.
- Slow growth.

Phosphorus

The greatest growth response to phosphorus is usually observed with new turf grass seedlings. Phosphorus deficiencies are rarely observed in established turf, unless the phosphorus level in the soil is extremely low or an unfavourable soil pH exists. Where a deficiency does occur, turf plants may suffer from reduced growth, dark or reddish leaf colour, or narrow leaf blades. Soil tests should be made before new turf is seeded, and every few years on established turf, to make sure the available soil phosphorus is present in adequate amounts.

Potassium

Potassium plays a vital role in healthy turf grass growth and development and is second to nitrogen in the amounts required for turf growth. Physiologically, potassium is involved in cellular metabolism, environmental stress resistance, disease incidence, internal water management, and wear tolerance.

Where clippings are not removed, the potassium requirement is 80 to 100 kg/ha/year. Potassium reserves are more difficult to build up in sandy soils than in those having a greater storage capacity for this element. Thus, smaller and more frequent applications of potassium (as would be the case if potassium rich recycled water is used) are ideal.

Iron

Under normal turf grass-growing conditions, it is common to observe a colour response in turf grass after an iron application, especially if the turf grass is growing on a soil of neutral or alkaline pH. For the most part, turf grasses are sensitive to iron levels and an application of iron generally imparts a darker green colour to the turf grass.

E9.3.2 Hazards addressed

- Poor quality turf.
- Potential contamination of surface and ground waters.

E9.3.3 Preventative measures

The following preventative measures are available to reduce hazards associated with poor turf cover:

- Use of robust salt tolerant grass species over most of the irrigated area (in this case couch and rye grass).
- Availability of irrigation.
- Good quality ‘topsoil’.
- Superior management (including a regular program of visual inspection, targeted soil testing and soil management).

E9.3.4 Operational procedures

This procedure involves:

1. Irrigation operators (under the supervision of the Irrigation Manager) maintain turf cover through regular mowing, irrigation scheduling (see SOP4) application of suitable fertilisers and chemicals to reduce weeds.
2. Regular monitoring by the Irrigation Manager of the water in the irrigation reservoirs on its fertiliser and salt content.
3. Monitoring of turf condition by the Irrigation Manager.
4. Undertaking a targeted soil testing program in response to deteriorating turf quality and rectification of problem as appropriate e.g. lime and/or fertiliser applications, changing irrigation scheduling, use of chemicals etc.
5. In the event of a specific recycled water issue appropriate rectification of the WRP.
6. Monitoring of drainage leaving sports fields as part of the groundwater /surface monitoring program.

E9.3.5 Responsibilities and authorities

The responsibilities are as follows:

1. The Irrigation Manager must monitor regularly the amount of fertiliser (nutrients) and salt and pH in recycled water.
2. The Irrigation Manager must take into account of the properties of recycled water when adjusting the fertiliser program.
3. If salt levels exceed 2.5 dS/m in recycled water for the previous month then the Irrigation Manager may consider using a leaching irrigation, particularly if the weather is hot and there has been little recent rain.
4. The Irrigation Manager is to investigate any deterioration in turf quality.
5. If there is evidence of salt impacting on turf quality available other water supplies could be considered.
6. If the deteriorations are potentially related to recycled water quality, then the Scheme Manager should be advised to determine whether changes are needed at the WRP.
7. Authorities responsible for monitoring drainage from the sports filed are to alert the Scheme Manager if concentrations of nitrogen and phosphorus are unacceptable. The Scheme Manager is then responsible for alerting the Irrigation Manager at the sports fields to change fertiliser practices.
8. An annual summary of recycled water quality and quantity delivered to the various irrigation sites with incidents and their resolutions is to be provided to the HACCP team by the Scheme Manager.

E9.3.6 Operational parameters

- Turf covering at least 95 per cent on sports field and acceptable grass and tree appearance elsewhere.
- Minimal weed infestation, yellowing or other signs of disease.
- Appearance of the turf.
- Visual appraisal of turf.
- Any regular topsoil test results.
- Results of any groundwater/surface water monitoring downstream of irrigated areas.

E9.3.7 Documentation

All the following documentation will be kept by the Irrigation Manager.

- Date and volume of water applied after each irrigation.
- Date and quantity and type of fertiliser applied.
- Date, time and quantity of any other rectification (e.g. weed or pest control) or sowing of a winter grass species.

All the following documentation will be kept by the Scheme Manager.

- Any significant deterioration in turf quality incident reports that involved the intervention of the Scheme Manager.
- Unacceptable ground/surface water monitoring results.
- Updates to this SOP in any future IMP by HACCP team in consultation with the scheme management as appropriate.

E9.4 SOP4 Irrigation scheduling

Irrigation scheduling arrangements determine the rate and volume of irrigation water delivered to the site. If the rate and volume are too great runoff/ponding may occur (creating a health risk to end users and potentially contaminating surface waters) or leaching to groundwater (potentially contaminating this resource) may occur. If the volume delivered is too low, turf growth may be adversely impacted.

Recommended irrigation depths for the different land uses within the NH1A area have been estimated based on irrigation of these areas to date using potable water. The estimated volumes are based on three millimetres of water per 15 minutes of operation from the irrigation heads installed. The application rates are provided in Table 13, and compare to the mean annual average rainfall for the site of just less than 600 mm.

Table 13 Recommended annual irrigation water application depths

Land use	Irrigation depth (mm/annum)
Playing fields	560
Parks open space/verges	404
High value streetscapes/planter garden beds	372

Irrigation application rates are highest in the summer months and zero in the winter months. Estimated temporal patterns of irrigation application depths for the respective classes are provided in Table 14.

Table 14 Recommended monthly irrigation depths (mm)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Playing fields	72	72	56	48	20	12	12	20	48	56	72	72	560
Parks, OS/Verges	56	56	36	36	12	6	6	12	36	36	56	56	404
High value St-scape garden beds	56	56	32	24	12	6	6	12	24	32	56	56	372

The NSW Cricket Association Handbook (ISFM 2002) suggests watering of sports fields as follows:

- Summer - Four to five times per week depending on temperature, with 20 minute cycles.
- Winter - Three times per week with 10-minute cycles.

The climate data for Googong suggest this should be modified as follows:

- October to March – three to five times per week with 10 to 20 minute cycles taking into account temperature and rainfall events prior to any irrigation.
- September and April-May – three times per week with 10 to 20 minute cycles.
- June-August – twice a week with 10 minute cycle.
- During the establishment of ryegrass the handbook recommends watering be undertaken twice a day for the first eight days and then tapered off to normal irrigation frequency and cycles. In this case water should only operate on 10 minute cycles.

Notwithstanding the above the grass should be allowed to dry down to a moisture deficit of 15 mm and only 10 mm applied leaving a 5 mm soil moisture buffer (see Table 15). This scheduling arrangement ensures good root development and mitigates the risk of surface runoff should rainfall occur soon after an irrigation event.

It is expected that the amount of irrigation water required by the parks and landscaped areas would be less. In particular, once the landscape areas are established irrigation would cease except for drought events.

The timing of irrigation also affects the length of any withholding period between irrigation application and end users accessing the site. The following recommendations are based on the assumption that the grass dries more quickly in summer:

- Peak (Summer): available irrigation time 8pm to 5am – 9 hours.
- Shoulder (autumn and spring): available irrigation time 7.30 pm to 3.30 am – 8 hours.
- Winter: available irrigation time 7.30 pm to 2.30 am – 7 hours.

Table 15 Monitoring observations by site operator in relation to irrigation schedule

Item	Reason	Expected results	Results requiring corrective actions	Corrective action	Responsibility
Appearance of grass before an irrigation event	Needs irrigation	Dry or with dew only.	Wet grass or puddles, wet or moist soil to a depth greater than 10cm.	Stop irrigation and revise schedule.	Irrigation Manager
Appearance of grass after irrigation event.	Determine whether too much recycled water has been applied.	Wet turf but significant puddles not evident.	Significant puddles, sometimes a flowing channel.	Reset current irrigation scheduling arrangements.	Irrigation Manager

Item	Reason	Expected results	Results requiring corrective actions	Corrective action	Responsibility
Spray irrigation during irrigation event.	Determine whether application is even.	As above.	As above but located in 'patches'. On switching irrigation system on, observations of uneven spray patterns, irregular nozzle spray.	Identify problem and repair.	Irrigation Manager
Weather prior to irrigation.	Recycled water will runoff or leach to groundwater.	As above.	Winds >10 km/hr, significant rain.	Cease irrigation.	Irrigation Manager

E9.4.1 Hazards addressed

- End-user exposure to pathogens.
- Potential contamination of surface and ground waters.

E9.4.2 Preventative measures

The following preventative measures are available to reduce health and environmental hazards associated with irrigation scheduling includes:

- Constructed drainage system to avoid surface ponding.
- Automated system that allows night time irrigation.
- Automatic water pressure monitors that will switch off irrigation in the event of a leak.
- Installation of a Pressure Reducing Valve to guarantee maximum operating limits to avoid potential blow outs.
- Automated climate monitors that will switch off irrigation in high winds, or if significant rain falls

E9.4.3 Operational procedures

This procedure involves:

1. Reading or receiving automatic data from a flow meter from the irrigation reservoir that measures the rate of flow to the irrigator.
2. Establishing a suitable irrigation scheduling mechanism which takes account of:
    A. The timing of an irrigation event
    B. The infiltration capacity of the turf
    C. The rate at which individual sprinklers allow water to enter the soil

D. The spacing of irrigation nozzles or drippers.

3. Observing the state of the irrigation site prior to and at the completion of an irrigation event.
4. Ensuring the fields are not used for an established withholding period.
5. Extending the withholding period if an irrigation or rainfall event results in significant ponding.
6. Timely rectification of faults in irrigation infrastructure

The frequency of irrigation will depend on soil moisture conditions and ambient temperatures which control the growth rate of the turf. The need for irrigation can be measured directly using soil moisture monitors or through an irrigation schedule that takes account of prevailing weather conditions.

E9.4.4 Responsibilities and authorities

The responsibilities are as follows:

1. The Irrigation Manager is responsible for reading the meter and maintaining records showing the amount and timing of recycled water delivered from the irrigation reservoir to the irrigation system for each irrigation event.
2. Where the above conditions are not met the Irrigation Manager (in consultation with the Scheme Manager) is to determine the reason and identify appropriate action.
3. The Irrigation Manager is responsible for monitoring the effectiveness of the irrigation scheduling arrangements.
4. The Irrigation Manager is responsible for reporting all complaints and incidents to the Scheme Manager as appropriate and will maintain all notifications of complaints and incidents.
5. The Irrigation Manager is responsible for rectifying any incidents as soon as possible.
6. Once a year the results of documented records are to be summarised by the Irrigation Manager and discussed with the HACCP team and Scheme Manager.
7. Any changes to the procedure will require an appropriate update of this SOP.

E9.4.5 Documentation

- Reports of recycled water irrigated and time of irrigation kept on irrigation schedule computer.
- Daily records of water delivered from the irrigation reservoir to the irrigation sites kept on flow meter computer maintained by the Scheme Manager.
- Observational monitoring/complaints reports kept by the Irrigation Manager when a problem is detected.
- Notifications to the Scheme Manager in response to a significant complaint or incident.
- Annual summary and discussion of results (including significant incidents and complaints) of amount of recycled water used for presentation to the HACCP team.
- Any updates to the IMP triggered by a change in this SOP.

E9.5 SOP5 Maintenance of equipment

Maintenance and repair of irrigation infrastructure operational procedures would occur irrespective of the source of water. For this reason this section is of a general nature only.

E9.5.1 Operational procedures

1. Maintaining an irrigation infrastructure inventory e.g. Table 16.
2. Routine (preventative) maintenance to be carried out on all items as per manufacturers' instructions.
3. Corrective actions/repairs will be taken as identified from unexpected observations and measurements.
4. Documentation of significant incidents and corrective actions undertaken.

Table 16 Example equipment inventory to be maintained

Site	Number	Spare part location	Supplier and contact details	Frequency of routine maintenance	Comment
Irrigation area (ha)		n/a	n/a	n/a	
Automated flow meter					
Computerised control/ read-out					
Pumps					
Timing mechanism on irrigator					
Main-Lines					
Nozzles					
Calibration of measurement equipment					

E9.5.2 Hazards addressed

- End-user exposure to pathogens.
- Potential contamination of surface and ground waters.

E9.5.3 Preventative measures

It is noted that recycled water will normally achieve a standard that meets the AGWR for irrigation of sports fields. However, the following preventative measures are available to reduce health and environmental hazards associated with irrigation equipment maintenance includes:

- Audits of irrigation site equipment.
- Appropriate site operator training.
- Routine maintenance schedules for each piece of significant equipment.

E9.5.4 Operational procedures

This procedure involves:

1. Regular maintenance and calibration (if required) of each piece of significant irrigation equipment according to manufacturer's instructions.
2. Timely replacement of equipment close to the end of its life cycle.
3. Identifying malfunctioning equipment in a timely manner.
4. Undertaking repairs of malfunctioning equipment in a timely manner.
5. Reporting of complaints, significant incidents and emergencies.
6. Notifying the Scheme Manager of any significant incidents.
7. Summarising relevant actions in annual reports to the HACCP team.

E9.5.5 Responsibilities

1. The Irrigation Manager is responsible for the identifying maintenance activities for all identified equipment.
2. The Irrigation Manager is responsible for auditing and the programming of routine maintenance activities for all identified equipment.
3. The Irrigation Manager is responsible for carrying out routine inspections, preventative maintenance and identifying and responding to breakdowns and emergencies.
4. Individual Irrigation Operators are to advise the Irrigation Manager in the event of an emergency (e.g. black-outs, vandalism) or incident (such as a breakdown, unavailability of spare parts, etc.).
5. In the event of a significant incident that may be related to recycled water irrigation, the Irrigation Manager is to prepare incident reports for the Scheme Manager.
6. The Scheme Manager is to summarise significant events for the HACCP team.

E9.5.6 Documentation

- Lists of equipment to be maintained.
- Regular inspection/maintenance activity reports.
- Spare part inventories.
- Incident/follow up action reports.
- As appropriate inclusion in summary papers by the scheme manager to the HACCP team.

E9.6 SOP6 Prevention of cross connections

A human health hazard at the site is related to the possibility of cross connections between the potable water supplies to the site and the recycled water supply. Accidental cross connections could occur whenever maintenance is undertaken on recycled water or potable water supply lines.

E9.6.1 Hazards addressed

- End-user exposure to pathogens.

E9.6.2 Preventative measures

It is noted that recycled water will normally achieve a standard that meets the AGWR for irrigation of sports fields. However, the following preventative measures are available to reduce health and environmental hazards should there be a concern regarding the quality of the water. These are:

- Site auditing during the verification and validation stages and after subsequent onsite works are undertaken.
- Use of qualified and trained plumbers or approved contractors.
- All above ground infrastructure at sites with existing irrigation will be colour coded according to Australian Standards.
- All new irrigation subsurface installations will be colour coded according to the Australian standard for recycled water.
- Implementation of a cross-connection inspection protocol for new properties and ongoing auditing, as outlined in the RWQMP.

E9.6.3 Operational procedures

This procedure involves:

1. Education and training of plumbers for works involving recycled water.
2. Use of qualified plumbers.
3. Identifying the location of potable water and recycled water supply lines and connections.
4. Use of Australian Standards for colour coding and signposting all recycled water and potable water surface infrastructure.
5. Use of Australian Standard for plumbing work carried out, including the testing of cross connections between the recycled water and potable water supply.
6. When replacing subsurface infrastructure use of Australian standard procedures (colour codes, pipe size, etc.).

E9.6.4 Responsibilities

1. The Scheme Manager will be responsible for identifying and mapping the recycled water pipelines and potable water pipelines located in their vicinity.
2. A copy is to be provided to the Irrigation Manager.
3. The Scheme Manager is responsible for alerting/training all contractors and staff who maintain or repair water supply infrastructure at the irrigation sites of the locations of both water supplies.
4. Any work carried out on water infrastructure will be inspected by the Scheme Manager, as soon as it is completed, to ensure no cross connections have occurred.
5. The Scheme Manager will provide appropriate documentation (including significant incident reports) to the HACCP team.

E9.6.5 Documentation

- Records of work and audits undertaken on water supply infrastructure near the pipeline or within the recycled water irrigation areas.
- Annual reports of any relevant works to be available for the HACCP review team.

E9.7 SOP7 Irrigation worker health and safety

Despite the very high level of treatment of the recycled water it is possible that it still contains bacteria, funguses, parasites, and viruses that can cause intestinal, lung, and other infections. Appropriate equipment, work practices and personal protective equipment (PPE) are required to minimise risks to the health and safety of irrigation workers. Irrigation workers are the most exposed end-user to potential hazards in recycled water.

E9.7.1 Hazards addressed

- End-user exposure to pathogens.

E9.7.2 Preventative measures

It is noted that recycled water will normally achieve a standard that meets the AGWR for irrigation of sports fields. However, the following preventative measures are available to reduce health and environmental hazards should there be a concern regarding the quality of the water. These are:

1. Training and education regarding the potential hazards of irrigating with recycled water (see SOP8).
2. Use of standard signage to alert workers of hazards and appropriate work safe practices in the staff rooms and at all sites where exposure to recycled water is possible.
3. Inclusion of operational procedures in Work Safe Manuals.
4. A place onsite with clean water for washing hands.
5. A place to wash and clean up after work.
6. Maintaining a supply of disposable gloves.
7. Clean areas set aside for eating and smoking.
8. Cleaning facilities or services for clothing (e.g. if clothing is contaminated with recycled water, it should be changed for clean clothing prior to the worker leaving the site).
9. Up to date inoculations including tetanus and hepatitis.

E9.7.3 Operational procedures

This procedure involves:

1. Irrigation Operators to wash hands well with clean water and soap before eating or smoking and after work.
2. Irrigation Operators should not touch their noses, mouths, eyes, or ears with their hands, unless they have just washed with potable water.
3. Irrigation Operators to keep fingernails short and to use a stiff soapy brush to clean under nails.

4. Irrigation Operators to wear waterproof gloves when handling any equipment associated with recycled water. In particular gloves to be worn when hands are cut, chapped or burned.
5. Irrigation Operators to shower and change out of work clothes before leaving work.
6. Irrigation Operators should not keep soiled work clothes with other clothes.
7. Irrigation workers to report any injury or illness that could be related to the use of recycled water to the Irrigation Manager.
8. In the event of illness, irrigation workers to advise their doctor that they work with recycled water.
9. Recording and documentation of incidents by Irrigation Manager.

E9.7.4 Responsibilities

1. The Scheme Manager will be responsible for training all irrigation workers in the operational practices described above.
2. The Irrigation Manager is responsible for updating the current Work Safe document taking into account the procedures described above.
3. The affected irrigation worker is responsible for advising the Irrigation Manager of any illness potentially caused by the recycled water.
4. The Irrigation Manager is responsible for reporting such incidents to the Scheme Manager.
5. The Irrigation Manager is responsible for reporting any relevant Work Safe incident.
6. The Scheme Manager will be responsible for incorporating a summary of any activities/incidents associated with this SOP into an annual report for the HACCP team

E9.7.5 Documentation

- Updates to Work Safe manuals.
- Incident reports.
- Annual summary reports of relevant incidents to be available for the HACCP review team.

E9.8 SOP8 Training procedures

Appropriate operator and user training will be provided by the Scheme Manager as per the RWQMP.

E9.8.1 Hazards addressed

- Operator and end-user exposure to pathogens.
- Potential contamination of surface and ground waters.

E9.8.2 Preventative measures

It is noted that recycled water will normally achieve a standard that meets the AGWR for irrigation of sports fields. However, the following preventative measures are available to reduce health and environmental hazards should there be a concern regarding the quality of the water. These are:

- Operator training program.
- End user awareness program (Community Education Strategy).
- Appropriate signage.

E9.8.3 Operational procedures

This procedure involves:

1. The Irrigation Manager must have appropriate training and experience in the operation of an irrigation scheme.
2. The Scheme Manager will provide training (as needed) to the Irrigation Manager covering the issues set out in the RWQMP and WMP.
3. The end users (e.g. sporting club members, park users and local residents) and general public will be educated through a Community Education Strategy.
4. The Scheme Manager will report the results of the training program to the HACCP team once per year with information including but not limited to:
    A. who was trained and made aware
    B. details of newspaper articles about the scheme
    C. any incidents, emergencies or complaints that arose because of lack of appropriate training
    D. recommendations on future training, awareness programs.

E9.8.4 Responsibilities

1. The Irrigation Manager is responsible for ensuring all staff who will work or are potentially exposed by the recycled water irrigation scheme are trained as per the RWQMP and WMP.
2. The Scheme Manager is responsible for preparing suitable training programs, awareness campaigns and press releases to players, club members, local residents and the general public.
3. The Scheme Manager is responsible via the annual report to describe training and awareness programs that have been undertaken, who attended and outcomes including the need to change any aspects of the program.

E9.8.5 Documentation

- Lists of staff holding various positions affected by the recycled water scheme.
- Lists of other potentially affected end users (e.g. sporting club members, park users and local residents).
- Written training and awareness programs.
- Incidents and emergencies arising and follow up actions.
- Annual report to HACCP team.

E10 Onsite verification procedures

E10.1 Overview

This section discusses onsite verification procedures for the irrigated areas. The recycled water irrigation scheme should not commence until the verification process demonstrates that the scheme is in a condition where it does not pose unacceptable risks to human health or the environment.

A summary of the verification locations and monitoring processes are shown in Table 17 and Table 18.

A soil monitoring 'baseline' has been established to characterise the soil fertility of the topsoil (the main root zone) and the playability of the turf at Rockley Oval (Sports Field 1) and Duncan Fields (Sports Field 2). When investigating any future failures in turf performance, this baseline can be used to establish the nature of changes in soil as a result of recycled water irrigation (or fertiliser use). These changes may have contributed to any deterioration in turf quality.

E10.2 Verification of turf condition

The following observations are to be made on turf condition prior to the recycled water irrigation commencing. It will be important to note the time of year as turf condition will change with the seasons.

1. Grass height before and immediately after mowing.
2. Grass uniformity and density.
3. Turf type.
4. Incidence of bare ground.
5. Location and likely cause of wear patterns.
6. Weeds – percent and types.
7. Rooting depth.
8. Condition of thatch or mat.

E10.2.1 Responsibilities

The responsibility for turf condition observations lies with the Irrigation Manager. Operational staff may carry out the observations as described above.

E10.2.2 Documentation

Results of turf and any corrective actions are to be documented by the Irrigation Manager.

Table 17 Verification procedures that address the hazard of end-user exposure to pathogens

Potential critical control point	Target critical limits or item	Monitoring frequency	Sampling procedure	Responsibility for identifying and solving sampling/ reporting failure	Corrective action	Responsibility for action at irrigation site
Recycled water quality and quantity at point of connection to irrigation system	Chlorine residual > 0.5 mg/L	Daily for 4 weeks	Chlorine analyser	Scheme Manager	Scheme Manager	Irrigation Manager
Irrigation system	Irrigation must cease four hours before public access.	Daily	Visual inspection	Site operator	Site operator	Irrigation Manager
Weather station	Rainfall, temperature and wind speeds	Daily	Visual inspection	Site operator	Site operator	Feedback by site operator to Scheme Manager if fault noticed
Signage, recycled water taps, free from cross connections, colour coding, labelling	Signage installed. No cross connections between recycled water and potable water supply. Recycled water taps quality as per guidelines.	Prior to irrigation commencing with recycled water. Before and after plumbing works to ensure recycled water supply is isolated from potable water supply.	Visual inspection	Scheme Manager	Scheme Manager	Scheme Manager
Work-safe manual	Work safe manual updated with special practices for handling recycled water irrigation.	Once during verification period	Updated manual check	Irrigation Manager	Update manual	Irrigation Manager

Table 18 Verification procedures that address the hazard of groundwater and surface water contamination

Potential critical control point	Target critical limits or item	Monitoring frequency	Sampling procedure	Responsibility for identifying and solving sampling/reporting failure	Corrective action	Responsibility for action at irrigation site
Recycled water quality at point of connection to irrigation system	N <18.5 mg/L	Five samples during verification period of 4 weeks.	For each sample, collect sample from 5 separate nozzles from irrigation system and combine.	Scheme Manager	Note that in terms of hazard short term exceedances of nitrogen are not a problem provided the average over a 12 month period is less than 18.5. Actual values will establish a guide for future fertiliser programs.	Scheme Manager
	P <3.5 mg/L	Five samples during verification period of 4 weeks.	For each sample, collect sample from 5 separate nozzles from irrigation system and combine.	Scheme Manager	Note that in terms of hazard short term exceedances are not a problem provided the average over a 12 month period is less than 3.5. Actual values will establish a guide for future fertiliser programs.	Scheme Manager

Potential critical control point	Target critical limits or item	Monitoring frequency	Sampling procedure	Responsibility for identifying and solving sampling/reporting failure	Corrective action	Responsibility for action at irrigation site
	pH 6.5-7.5 (in water)	Five samples during verification period of 4 weeks.	For each sample, collect sample from 5 separate nozzles (do not combine).	Scheme Manager	Note that in terms of hazard short term exceedances are not a problem provided the average over a 12 month period is within the target range.	Scheme Manager
	Potassium (no target)	Five samples during verification period of 4 weeks.	Collect sample from 5 separate nozzles and combine.	Irrigation Manager	Establish level to guide future fertiliser programs.	Irrigation Manager
	Salt concentration in recycled water <2.5 dS/m^2	Five samples during verification period of 4 weeks.	For each sample, collect sample from 5 separate nozzles (do not combine).	Scheme Manager	High salt may indicate a need to review phosphorous removal at WRP. Only likely to be a problem in unusually dry periods. Corrective action can include leaching irrigation but will be incident specific and based on soil salinity testing.	Irrigation Manager

Potential critical control point	Target critical limits or item	Monitoring frequency	Sampling procedure	Responsibility for identifying and solving sampling/reporting failure	Corrective action	Responsibility for action at irrigation site
Turf condition	Turf cover 95-100% on sports fields. Acceptable conditions in other areas. No yellow grass.	Weekly	Visual inspection	Irrigation Manager	Establish pre-irrigation turf conditions	Irrigation Manager
Irrigation system scheduling	Flow meter calibration at Sports Field sites.	3 tests over a 2-week period.	Sample (volume over set time period) to check flow meter is calibrated.	Irrigation Manager	Verify automated flow reading is correct. Identify problem and repair.	Irrigation Manager
Soil moisture meters if used	Soil moisture meter	Prior to each irrigation.	Establish water content in top 20 cm from standard testing measurement (e.g. recommended by manufacturer).	Irrigation Manager	Establish a baseline to check workability of soil moisture meters.	Irrigation Manager
Irrigation system components	Measurements as per manufacturer's instructions for optimal performance of the irrigation system.	At each irrigation during the verification period.	Once irrigation system is verified check performance of scheduling by observations after.	Irrigation Manager	Identify problem and repair.	Irrigation Manager

Potential critical control point	Target critical limits or item	Monitoring frequency	Sampling procedure	Responsibility for identifying and solving sampling/reporting failure	Corrective action	Responsibility for action at irrigation site
Automatic cut-offs on irrigation system (if relevant)	Rainfall >5 mm in any one irrigation event. Wind speed >15 km/hr during irrigation.	At each irrigation during the verification period.	Comparison with WRP weather station results.	Irrigation Manager	Identify problem and repair.	Irrigation Manager

E10.3 Verification of irrigation system

The pop-up spray irrigation system (or other irrigation systems as appropriate) need to be verified to determine effective delivery (rate and 'evenness' of application). Failure to have an even application will result in ponding and surface run-off, poor performing turf and at worst potentially creating runoff or leaching to surface water or groundwater.

1. Irrigation controllers are to be checked during the verification program and at the beginning of every irrigation season.
2. First consult the manual for the controller.
3. Open the controller's cabinet and clean out any cobwebs, dirt, or debris, change the battery and check wiring for loose connections. Wire connections, including those for any rain sensor or soil moisture monitor.
4. The time and day showing on the controller should be checked and corrected if necessary.
5. An irrigation schedule should be checked to see if it inconsistent with the principles outlined in SOP4.
6. The sprinkler system includes valves, sprinkler heads, and emitters. Before running the system, remove the last sprinkler head in each line and let the water run for a few minutes to flush out any dirt and debris. Replace the sprinkler head and turn the system on, running one valve at a time.
7. Observe the spray patterns and position of the sprinklers for obvious problems such as clogged or misaligned heads.
8. Any sprinklers with built-in filter screens should be cleaned and replaced if necessary.
9. Leaks and misting from sprinkler heads may indicate high water pressure problems.
10. High pressure problems may be corrected by plumbing a pressure regulator into the sprinkler system. Pressure-regulating sprinkler heads are also available.
11. Adjustment and repair in order to apply the water as evenly as possible. The flow control on the valves may also be adjusted to fine-tune the system.
12. Turn the irrigation system on manually to make sure it is operating as programmed.

E10.3.1 Responsibilities

The responsibility for evaluation of the irrigation system lies with the Irrigation Manager. Operational staff may carry out the tests as described above.

E10.3.2 Documentation

Results of irrigation system tests and observations and any corrective actions are to be documented by the Irrigation Manager.

E10.4 Verification of soils

Methodology and background monitoring results from soils at Sports Field 1 and Sports Field 2 have already been established (Section E5). These show that nitrogen fertilisers are currently required. Potassium will also be needed until the recycled water is connected to the scheme.

Where recycled water irrigation of additional sports fields is proposed, background data on the topsoil will need to be collected, as outlined in Table 19. This should involve making a composite from 5 samples at

0-20cm and 20-40 cm using a 100mm Jarret augur. Samples should be taken in a five metre radius from a specified survey point.

Table 19 Soil tests (0-20cm) to be undertaken, expected results and contingency measures

Test	Expected result	Corrective actions	Comment
pH ($CaCl_2$)	6.0-7.0	pH<6.0 Incorporate agricultural lime at the rate of 2 tonnes/ha.	The expected slightly alkaline recycled water is likely to fix any acid pH conditions.
		pH>7.0 Add sulphate of iron, or sulphate of ammonia as well as the addition of decayed organic matter.	Sulphate of ammonia only to be used to the extent of any measured nitrogen deficiency in the soil. Recycling of grass clippings will return some fertiliser applied to the soil.
TN (sum of nitrate and ammonia nitrogen)	<0.11%	Nitrogen fertiliser required.	Take samples at the same time of year (preferably in spring). Where results are excessive or fertiliser is used samples should be collected again the following year.
	>0.11%	Do not fertilise unless grass appearance/soil testing (e.g. nitrate) indicate its necessity.	
Phosphorous sorption capacity	<150	Phosphorous fertiliser may be required.	Recycled water will supply a small amount of phosphorous.
Organic matter	1-3%		Organic matter improves soil water and nutrient holding capacity. Low levels indicate infertility. High values may impact on playability.
Soil salinity	<4 dS/m	Leaching irrigations of recycled water may be required.	Problem only likely to occur in very dry periods.
Soil sodicity	<6%	Calcium supplement required if topsoil contains significant quantities of clay.	Selection of calcium supplement will need to take account of the acidity of soil.
Texture (and % clay)	Sandy loam – sandy clay loam.	Irrigation strategies may need to change with very sandy soil (more frequent smaller irrigations) and very clay soils (less frequent longer irrigations).	Emerson Aggregate Test described below, relevant for sandy to sandy loam soils.
Soil structure	Emerson Aggregate Test (EAT) 3, 4, 5 or 6.	On topsoils with substantial clay concentrations low EATs (<3) indicate the likely need to apply a calcium supplement. EAT 7 may indicate too much organic matter and a soil wetting problem. EAT 8 indicates a hard setting soil requiring significant amelioration.	

E10.4.1 Responsibilities

The responsibility for soil tests lies with the Irrigation Manager. Operational staff may carry out the tests as described above.

E10.4.2 Documentation

Results of soil tests and any corrective actions are to be documented and kept by the Irrigation Manager. A copy should be provided to the Scheme Manager.

E10.5 Verification of groundwater/surface waters

Separate monitoring programs have been prepared to establish baseline characteristics of surface water and groundwater, and are provided as Appendix A and B of the WMP respectively.

E11 Ongoing monitoring and reporting

E11.1 Ongoing soil monitoring

E11.1.1 Irrigation areas

During operation of the WRP, ongoing monitoring at critical control points will occur, as outlined in Section E8.

Soil monitoring at the two established sites within the sports fields will occur on an annual basis, planned to commence in mid-2016 (following application of recycled water). The monitoring methodology will remain consistent with that outlined in Section E5.1 to enable an informed consideration of impacts.

At the end of the first year of WRP operation, a re-assessment of the analyte suite and trigger values should be completed. This would be undertaken as part of a review of the IMP, in consultation with the relevant stakeholders. Future changes that may be considered include the rationalisation of the soil monitoring to exclude metals and pesticides following the first two years of operation.

E11.1.2 Low lying areas

Impacts from the ongoing development of Googong township are not expected to be observed at the low lying sites in the short term, especially as recycled water will not be used within the township until mid-2016. Hence commencement of ongoing monitoring at these sites should be delayed until mid-2017. The monitoring methodology will remain consistent with that outlined in Section E5.1. The frequency and nature of future testing should be re-assessed based on the results obtained after the second monitoring round. Future changes that may be considered include the rationalisation of the soil monitoring to exclude metals and pesticides following the first two years of operation.

E11.2 Surface water monitoring

Refer to the Surface Water (and Aquatic Ecology) Monitoring Program (SWAEMP) (Appendix A of the WMP) for details regarding ongoing surface water monitoring.

E11.3 Groundwater monitoring

Refer to the GWMP (Appendix B of the WMP) for details regarding ongoing groundwater monitoring.

Specifically, two of the wells (GGW01s and GGW02s in Figure 1 of the GWMP) have been designed to intercept shallow groundwater perched above the interface with unweathered bedrock. As both are located at the down-gradient side of proposed irrigation areas, they will provide important information on the behaviour of salts and will enable early detection of any systemic change in groundwater conditions, particularly salinity, which may result from irrigation or other practices at the development.

Measurements of nitrogen and phosphorus will be undertaken six--monthly or in the event of an observed outbreak of algae in the Beltana Pond or increased concentrations of nitrogen or phosphorous in surface water bodies leaving the Googong township area.

In addition, data recorded by the groundwater level and EC loggers in key shallow bores will provide important ongoing information on the behaviour of salts. It will also enable early detection of any systemic changes in groundwater conditions through trend-based assessment that may be a result of the irrigation program or other practices within the development.

E11.4 Reporting

To aid the adaptive management processes prescribed for the IWC Project, the need to collate information generated through regular monitoring is required to improve future management.

Section 6.5 of the WMP states that reporting (which is to include the results and analysis of the soil monitoring), will be prepared annually. The reporting will include details of mitigation measures to minimise deleterious environmental impacts as a result of the operation of the IWC Project.

E11.5 Program reviews and adaptive management

The IMP will be an evolving document in response to management objectives, monitoring results and periodic feedback in the form of regular reporting. It will incorporate adaptive management outcomes with regard to regular reporting inputs and in consultation with the operator, relevant stakeholders, regulatory bodies and relevant experts.

A timeline of management objectives and actions to the end of year one of operation is detailed in Table 20. Ongoing management objectives at the end of year one will be evaluated at that time to consolidate monitoring results and consultative feedback to date.

Table 20 Proposed timeline of adaptive management processes in response to irrigation management objectives

Management Objective	Outcome	Action	Timeline
Baseline Monitoring (COMPLETED)	Inform the operational monitoring requirement of the IWC Project.	Dependent on results of baseline monitoring an annual report would recommend measures to mitigate adverse environmental impacts through the establishment of critical limits and SOPs.	Single monitoring round prior to proposed WRP operation.
Operational Monitoring	Collate operational monitoring on an annual (reporting) basis to document impacts upon specific environmental indicators.	Recommend mitigation measures to reduce detected impacts through modified water treatment objectives for the IWC Project.	Monitoring at critical control points as outlined in Section E8. Soil samples at irrigation sites - annually from mid-2016 (planned). Soil samples at low lying sites - annually from mid-2017 (planned). Report annually.
Ongoing update and review	Update and refine IMP on the basis of data collected to date in consultation with the regulator.	Consider impacts, control measures and SOPs implemented to date and refine the scope of the IMP accordingly.	Annual

E12 References

Agsol (2010). *Googong Residential Community - Recycled Water Irrigation Land Capability Assessment*. Prepared for CIC Australia.

Agsol (2015a). *Googong Township Stage 1 Irrigation Management Plan.* Prepared for GTPL.

Agsol (2015b). *Googong Soil Monitoring Program Report.* Prepared for GTPL.

Brown Consulting (2011). *Googong Township - An Irrigation Strategy Summary*. Prepared for CIC Australia.

DEC (2004). *Environmental Guidelines: Use of Effluent by Irrigation*, Department of Environment and Conservation.

ISFM Pty Limited (2002). *A Recommended Approach to Management of Turf Cricket Pitches and Outfields - a Curator's Handbook*. Prepared for the NSW Cricket Association.

NHMRC (2006) *Australian Guidelines for the Use of Recycled Water.* Natural Resource Management Ministerial Council, the Environment Protection and Heritage Council, and the National Health and Medical Research Council.