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BUILDING A WATER RESILIENT TOWN

INTEGRATED WATER CYCLE SAVES WATER AT GOOGONG

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EXECUTIVE SUMMARY

In the 2000s, Australia experienced the Millennium Drought which affected water supply for most of the major cities. In the midst of the drought, the new town of Googong was being planned in the inland area of Queanbeyan, south west of Canberra. In order to be more resilient to variable water supply, the town was master planned to have an integrated water cycle (IWC) which aims to reduce potable water consumption by some 60%.

At the infrastructure level, the IWC includes a state-of-the-art water recycling plant, dual reticulation system for recycled water and potable water (including dual reservoirs), bulk water supply, three sewage pumping stations, and WSUD (water sensitive urban design) to treat stormwater runoff in the township. At the household level, the Googong Building Design Guide mandates a residential BASIX (Building and Sustainability Index) score of 60 that enforces installation of water efficient fixtures, rainwater tank, and connection to recycled water supply. These mean that recycled water and rainwater will be used in place of precious potable water for open space irrigation, flushing toilets, watering gardens, washing machines and firefighting.

Googong IWC is unique as it is a purpose built, 100% developer-led project. This paper reports on the key challenges and lessons learnt from planning, design and delivery of the project. It also describes ongoing works to verify project assumptions, to facilitate better design and timing for the delivery of future assets. Today Googong is a thriving town of some 2,000 people. Preliminary analysis suggests that the township is well on its way to attain its original stated goal – for a township of 18,000 people to use the same amount of water that 6,500 normally would.

INTRODUCTION

For many inland townships in Australia, having a sustainable supply of water is paramount to the livelihood of the communities. Unlike coastal towns where water supply could potentially be augmented via desalination of seawater, such choices do not exist for the inland townships. To ensure survival, water conservation is often an essential part of life inland.

In early 2000s, Canberra Investment Corporation (CIC) embarked on a major new town project south of the New South Wales (NSW) town of Queanbeyan, adjacent to the ACT. Located close to the Googong Dam, the new township of Googong will have approximately 6,000 homes, housing some 18,000 people. Covering a greenfield area of about 784 hectares, the new town will be developed over a horizon of some 25 years.

Planning for the new town coincided with the Millennium Drought, which affected water supply across most parts of Australia, especially the eastern states where Googong is located. To drought proof the new town of Googong, the town was master planned to have an integrated water cycle (IWC), which aims to reduce water consumption by up to 60%.

Based on the IWC concepts, the project was granted concept and project approvals as a state significant project by the NSW Department of Planning in 2010. CIC (now Peet) subsequently formed a 50/50 share joint venture entity (namely Googong Township Pty Ltd or GTPL) with Mirvac to deliver the project. Since 2010, GTPL has delivered the entire Stage 1 (4,700 EP capacity) of the IWC infrastructure. The assets were then gifted to the local utilities, Queanbeyan-Palerang Regional Council (QPRC) and Icon Water.

Today Googong is a thriving town with about 2,000 residents and some 1,000 houses either constructed or under construction. This paper reports on the challenges and lessons learnt from the project to date.

PLANNING TO BE WATER RESILIENT

From the outset, Googong was designed to be a water resilient town. This is achieved by having an integrated water cycle (IWC) that aims to cut potable water consumption by some 60%. Key features of the IWC include:

- The use of reticulated recycled water as source substitution
- Demand reduction through:
  - Water efficient designed landscaping
  - Mandated water efficient appliances
  - Rainwater tanks
  - Water sensitive urban design (WSUD) employed within the overall subdivision design

The IWC consists of a series of water and wastewater infrastructures for the new township, which is depicted in Figure 1.

Potable Water Supply

Googong sources its potable water supply from a DN1800 water main operated by Icon Water between the two major water treatment plants in the Canberra region. In 2013, an offtake was constructed to draw water from the DN1800 water main, which connects to a new bulk water pumping station (BWPS). From the BWPS, potable water is pumped to a high level reservoir before it gravitates to supply the new township.

Wastewater Collection, Treatment and Recycling

Wastewater is collected in two dedicated sewage pumping stations (SPSs) before it is pumped for treatment. At the heart of the recycled water system is a state-of-the-art Water Recycling Plant (WRP) that treats all the wastewater, and produces fit-for-purpose recycled water. Depending on seasonal variation in water balances, excess water will be discharged to the local creek.

The treatment processes at the WRP include:

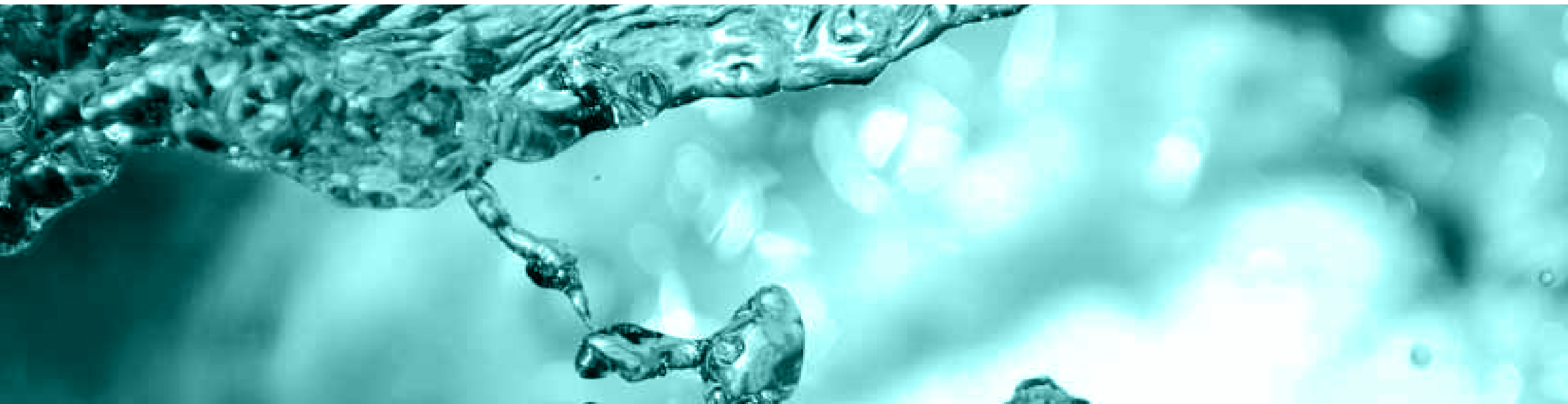
- Inlet works for preliminary treatment
- Membrane bioreactor (MBR) for wastewater treatment
- Tertiary phosphorus removal
- UV light disinfection
- Chlorine disinfection.

The MBR was designed to remove the wastewater organics and nitrogen. As part of the biological treatment process, some residual nitrate will be in the effluent. Phosphorus is removed both biologically and chemically using ferric salts and alum. The MBR was designed to be operated in both four-stage and five--stage mode. The five-stage operation will facilitate the biological phenomenon of enhanced biological phosphorus removal (EBPR), which could minimise the amount of chemical addition required to remove phosphorus. To further minimise chemical consumption, alum is dosed to the MBR filtrate before the precipitates are removed by banks of ultrafiltration membranes.

The WRP is also provided with a sludge treatment system that employs stabilisation and dewatering to produce biosolids that can be beneficially reused.

Recycled Water Supply & Rainwater Harvesting

Pre-validated technologies are employed at the WRP to produce the recycled water. These include the MBR membranes, and UV light disinfection reactors, which were sourced via a competitive Expression of Interest (EOI) and Request for Proposal (RFP) process.



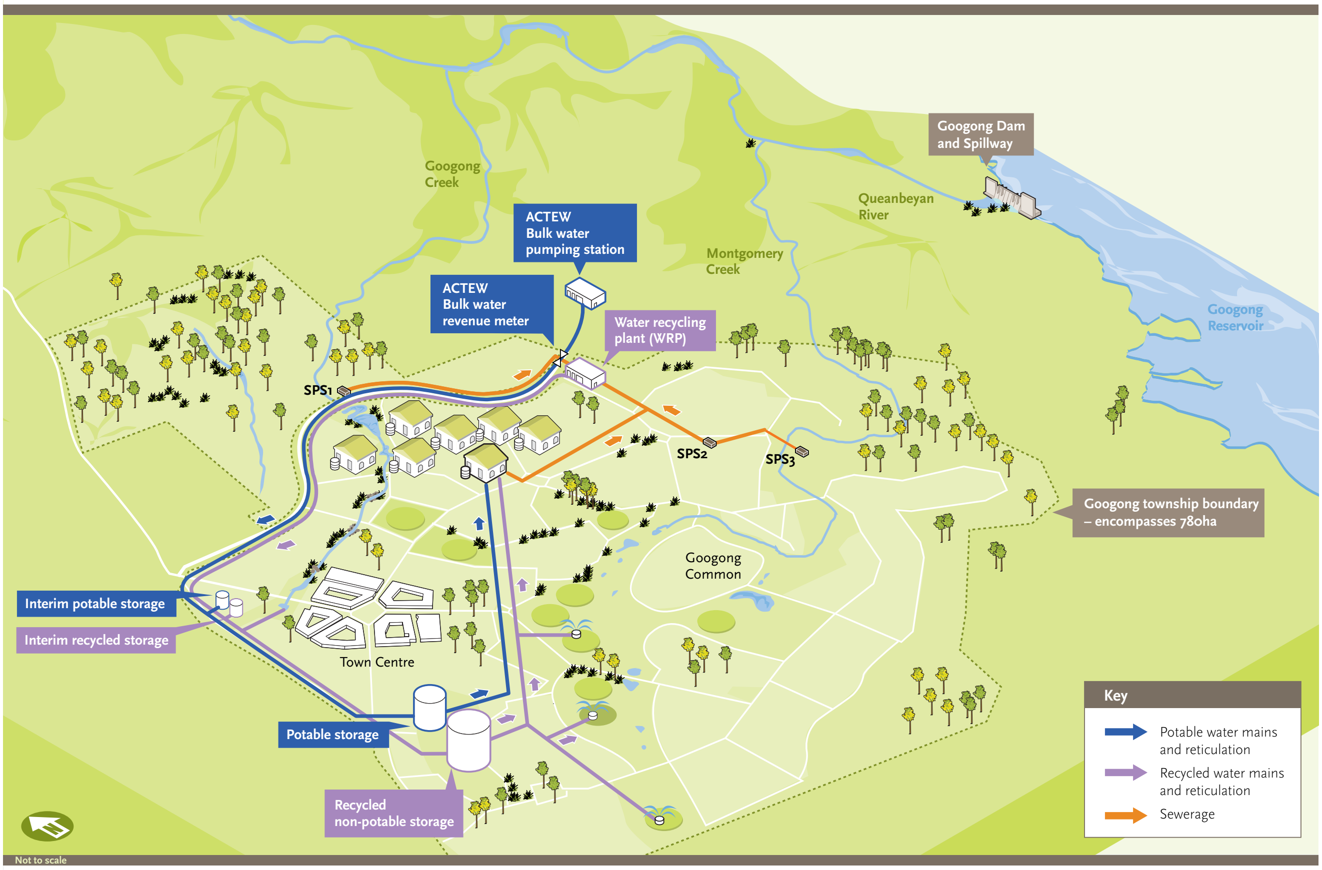


Figure 1. Googong Integrated Water Cycle Schematics

The pre-validated equipment was then nominated to the main construction contract for implementation. With this procurement model, the project was safeguarded against the use of non-validated equipment. Another key process for the production of recycled water is chlorine disinfection. A purpose built large diameter buried pipe was designed and constructed. The long length to diameter ratio (in excess of 90:1) was tracer tested and demonstrated to have excellent plug flow characteristics, an essential feature to achieve the required virus kill. For the production of recycled water, a series of critical control points (CCPs) are monitored to ensure integrity of the pathogen reduction barriers.

The recycled water is then transferred to a high level recycled water reservoir, before it is distributed to the township in parallel with the potable water reticulation network. At Googong, recycled water is connected to toilets for flushing and outdoor taps for gardening. This is illustrated in Figure 2, which shows how non-potable waters are used at a household level.

In addition to the recycled water, each household also has a rainwater tank, which supply to the washing machine.

DEALING WITH CHALLENGES

An innovative project brings its own set of challenges. For Googong, the following describes some of the key challenges faced and lessons learnt from the project.

Minimising Odour Footprint and Visual Impacts

One of the key requirements for the WRP is to ensure that it blends in with the surrounding environment. This means that it needs to have a minimal odour footprint, as well as being aesthetically acceptable to the community.

To minimise the odour footprint, the MBR technology was chosen as it is compact, which enables the entire secondary treatment process to be covered. In fact, most parts of the WRP are covered to minimise fugitive release of odorous compounds.

Testing was also conducted as part of the commissioning works to verify tightness of the covers, and performance of the odour control system. Operational experience over the past two years confirmed performance within expected parameters, with no odour complaints having been received to date.

To minimise the visual impact, the project sought less intrusive, low structures which lead the project to the adoption of ultrafiltration membranes for tertiary phosphorus removal, instead of conventional dual media filters. Googong is one of the first projects where membranes are used for tertiary phosphorus removal. Again operational experience over the past two years has demonstrated that the combination of technologies adopted is capable of achieving low level of effluent phosphorus while minimising the use of chemicals.

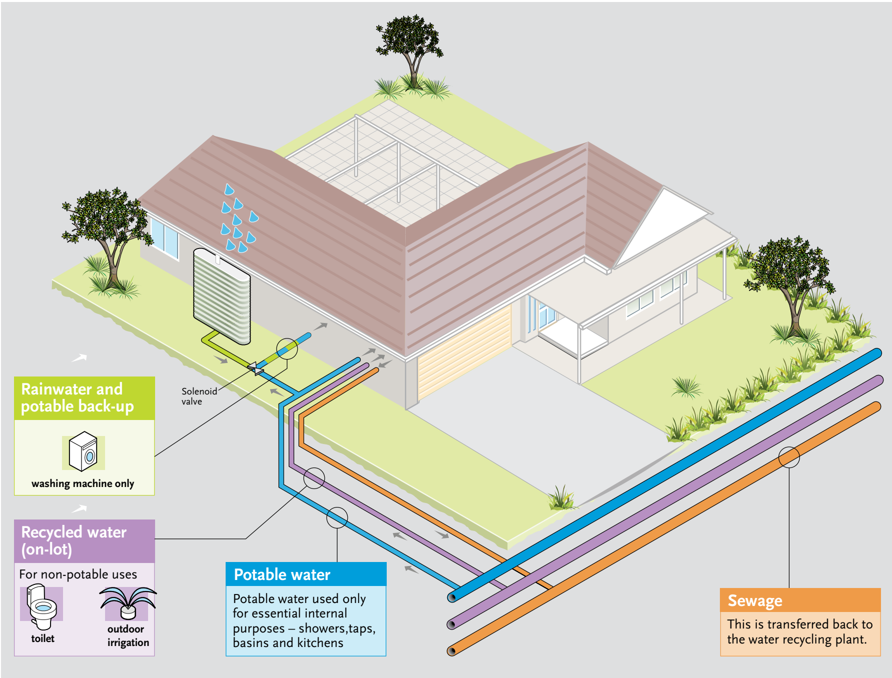


Figure 2. Water and wastewater plumbing at a household level

Minimise Accumulation of Total Dissolved Solids

At the planning level, one of the major challenges is to balance the competing effluent quality requirements for phosphorus and total dissolved solids (TDS). The Googong WRP is required to meet a combination of tight phosphorus limit of 0.5 mg-P/L and a total dissolved solids (TDS) limit of 700 mg/L, both on a 90 percentile basis).

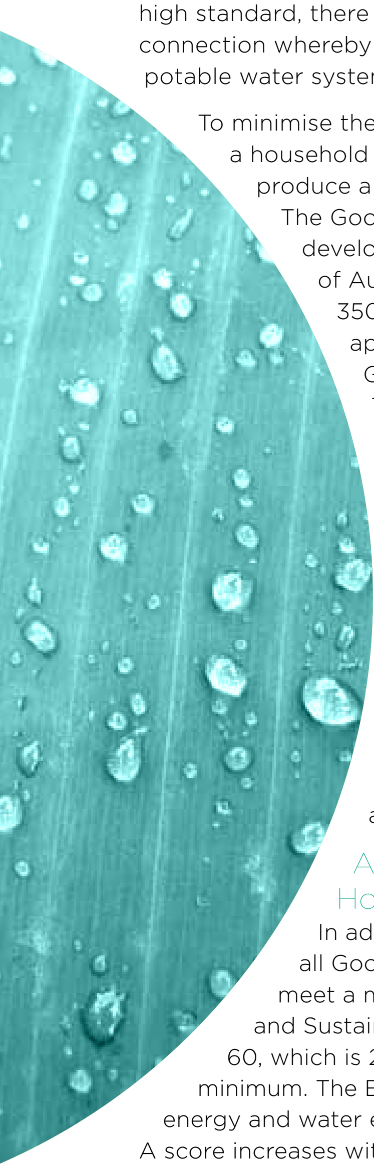
While 700 mg/L TDS is not a particularly low limit, it was recognised from the outset that non-biodegradable compounds (e.g. TDS) will accumulate in a semi-closed water cycle unless it is adequately managed. It is also recognised that while household contributions of TDS (e.g. the use of detergents) could not be changed, opportunities exist to minimise chemicals added for wastewater treatment. In addition, recycled water end uses could be modified to minimise accumulation of TDS.

To quantify the challenges, dynamic models for water and TDS balances were set up to elucidate impacts of wastewater treatment technology, types and quantity of end uses on the competing objectives of low effluent phosphorus and TDS. The models are based on a 40-year time series water balance model, and simulate the fate of TDS as chemicals are introduced at the households as well as for odour control, disinfection and phosphorus removal at the WRP. Sensitivity analyses were then conducted to examine the impact of different phosphorus removal technologies, different combinations of recycled water and rainwater end uses, and different development mixes.

Key outcomes from the study include selection of phosphorus removal technology, modifying recycled water end uses and appropriate development lot sizing to maximise direct irrigation onto land. For example, it was recognised that development mixes that limit irrigation (e.g. apartment blocks) are less desirable from a TDS accumulation perspective. In addition, the modelling work suggested that it is beneficial to have direct application of recycled water for irrigation, instead of the original approach of using rainwater for irrigation in the first place.

Avoiding Cross Connection

One of the key concerns for Googong, or any recycled water scheme, is the occurrence of cross connections between the potable and recycled water systems – at both a network and household level.



Even though the recycled water is treated to a very high standard, there are high consequences of a cross connection whereby recycled water is delivered to the potable water system.

To minimise the risk of cross connections at a household level, GTPL engaged MWH to produce a Googong Plumbing Standard. The Googong Plumbing Standard was developed, based on The Plumbing Code of Australia and Australian Standard 3500 Plumbing and Drainage, and applying them to the specific Googong water supply system. The mandatory standard has been written as a user-friendly guide to make it accessible to all new Googong residents. The Googong Plumbing Standard has been adopted by the local council and is issued to all new Googong residents and plumbers. All household plumbing in Googong must comply with this standard. Cross connection audits were also conducted by Council to verify the absence of cross connections.

Achieving Efficiency at the Household Level

In addition to the mandatory standards, all Googong home owners are required to meet a minimum NSW residential Building and Sustainability Index (BASIX) score of 60, which is 20 points above the NSW state minimum. The BASIX score is related to both energy and water efficiency of new developments. A score increases with the more energy and water efficient mechanisms being applied in a new dwelling. The high BASIX requirements mean that houses in Googong must have rainwater tanks and water efficient fixtures, and be connected to recycled water supply. As an aside; Googong also mandates a minimum 40 energy usage reduction points, higher than the standard BASIX minimum of 25.

Engaging the Community

Googong is a recycled water township. For this to work, it needs buy-in from everyone in the community - from the operators of the assets, to the community in Googong which is using the water. The Googong community does not just consist of residents, but it also includes visitors, workers, school children and local sports teams. To complement the mandatory plumbing guidelines, GTPL and QPRC created an ongoing Googong community education initiative. The initiative aims to encourage commitment to water sustainability by the entire Googong community. The initiative also aims to introduce new residents to the concept of recycled water by educating them about the full life cycle of recycled water - where it comes from, how it is made, the correct use of recycled water and responding to the frequently asked questions – like "Can my dog drink recycled water?"

The community education has been completed using several media for distributing information, in order to capture the widest possible audience. This has included community information sessions, the production and distribution of key fact sheets to all residents, the use of social media to provide updates and information about the water recycling plant, township wide emails and letterbox drops, sustainability workshops, town-wide signage about recycled water, regular meetings with interested community members and a WRP site tour is planned for the future.

The community has been receptive and interested in the water recycling scheme, and it was one of the reasons for choosing to purchase a lot in the township. From this contact with the community, ideas for further engagement in the recycled water scheme have actually been brought to us by the community. For example, when some residents learned that the WRP is capable of producing high grade biosolids, they suggested that we could investigate the use of biosolids as fertiliser on the Googong community garden that was under construction.

This idea has received a positive reaction from the community and this is something that we are still looking to get off the ground.

Through community education, two negative issues – sewage and water shortage – are turned into something positive – aided by terminology in that "Water Recycling Plant" (WRP) has been consistently used rather than the more traditional 'Sewage Treatment Plant" (STP). The people of Googong have been enabled to gain their own sense of ownership of the WRP and achievement.

Project Staging & Implementation

Googong is a developer led project, with GTPL being responsible for delivery all the IWC assets. With the exception of bulk water supply assets which were gifted to Icon Water, the rest of the IWC infrastructures were gifted to the local council (QPRC) for ongoing operation and maintenance.

The nature of private business means that the delivery timeframe has to match the overall business objectives, which ties closely to lot sales and subsequent land/lot development. From a lot sales perspective, Googong has been a highly successful project. The master planned nature of the township is a major drawcard to prospective residents, and lot sales have exceeded the original targets. This had two major effects:

- The number of delivery stages has to be combined as the originally planned stages became too close to each other. As an example, the original plan has the WRP delivered over seven stages. Currently the WRP will be delivered in just three stages.
- It is critical to deliver each of the Stage 1 assets on time to meet the development needs. In a short period of six years since project approval was granted, the entire Stage 1 assets have been delivered, which include two sewage pumping stations (SPSs), two interim potable and recycled water reservoirs, a fully functional WRP, and all related reticulation infrastructure.

The speed of delivery often means that an asset is planned, concept and detail designed, constructed, commissioned and handed over in a short time frame of three to four years. The interim water reservoirs and SPS1 were constructed in 2013 to enable the first residents to move into the town in early 2014.
For the initial stage, the small volumes of wastewater produced was collected and tankered away for disposal at a regional sewage treatment plant. In late 2015, the WRP was commissioned to treat the wastewater, enabling cessation of the tankering services.

This coincided with the sewage flow being approximately 150 kL/day, just sufficient for the commissioning of the 1 ML/day rated WRP.

VALIDATING PERFORMANCE & ASSUMPTIONS

Staged delivery of IWC assets enables key design assumptions to be monitored and verified prior to the next stage of asset delivery. The project has adopted a proactive approach to monitoring performance of the IWC assets. Such monitoring enables better estimates in terms of:

- Sizing of assets
- Timing for asset delivery.

Flow Monitoring

Monitoring of water and wastewater flows was conducted to understand a number of key design assumptions:

- Potable and recycled water consumption rates, which facilitate sizing of potable and recycled water reservoirs
- Wastewater generation rate (e.g. daily generation of wastewater per equivalent population), which facilitates sizing of the WRP
- Lag time between lot sales and occupancy, which is a key parameter in terms of predicting timeline for asset delivery.

Monitoring of flows (both waters and wastewater) is complemented by regular "garbage bin" surveys which is a tool used to estimate the number of occupied households. The use of garbage bins on collection days is considered to be the most reliable measure of occupied households. As an example, Figure 3 depicts the predicted and actual population increases with time. It is clear that, since mid-2015, the actual population consistently lagged behind the predicted population – not unexpected in that a conservative (faster) occupancy rate was needed to manage the risk of demand outstripping infrastructure capacity in a new area. As of the end of 2016, the lag time has been approximately four months. Overall the lag time between lot sales and occupation is about 18 months.

Overall proactive monitoring of the township population and corresponding flows enables the project to better size the assets and schedule delivery. This has a significant benefit in terms of right sizing the project as well as managing the cash flows.

Effluent Phosphorus & TDS

As discussed earlier, phosphorus and TDS are key parameters in term of license compliance. These parameters were monitored extensively during commissioning of the WRP. As an example, Table 1 compares the assumed and actual wastewater TDS that are not biodegradable.
It is clear that the assumed values are very close to the actual values, justifying the initial estimates.

Table 2 compares the assumed and actual levels of TDS increases due to dosage of chemicals employed at the WRP. It was observed that the actual sulphate increase is less than the assumed value. This is due to the (approx.) 35% lower level of phosphorus observed in the wastewater (i.e. 10 mg-P/L instead of 14-16 mg-P/L), as well as better process performance of the WRP.

From a process performance perspective, the plant has been able to achieve very low level of effluent phosphorus (below 0.1 mg-P/L, and as low as 0.013 mg-P/L) on a consistent basis.

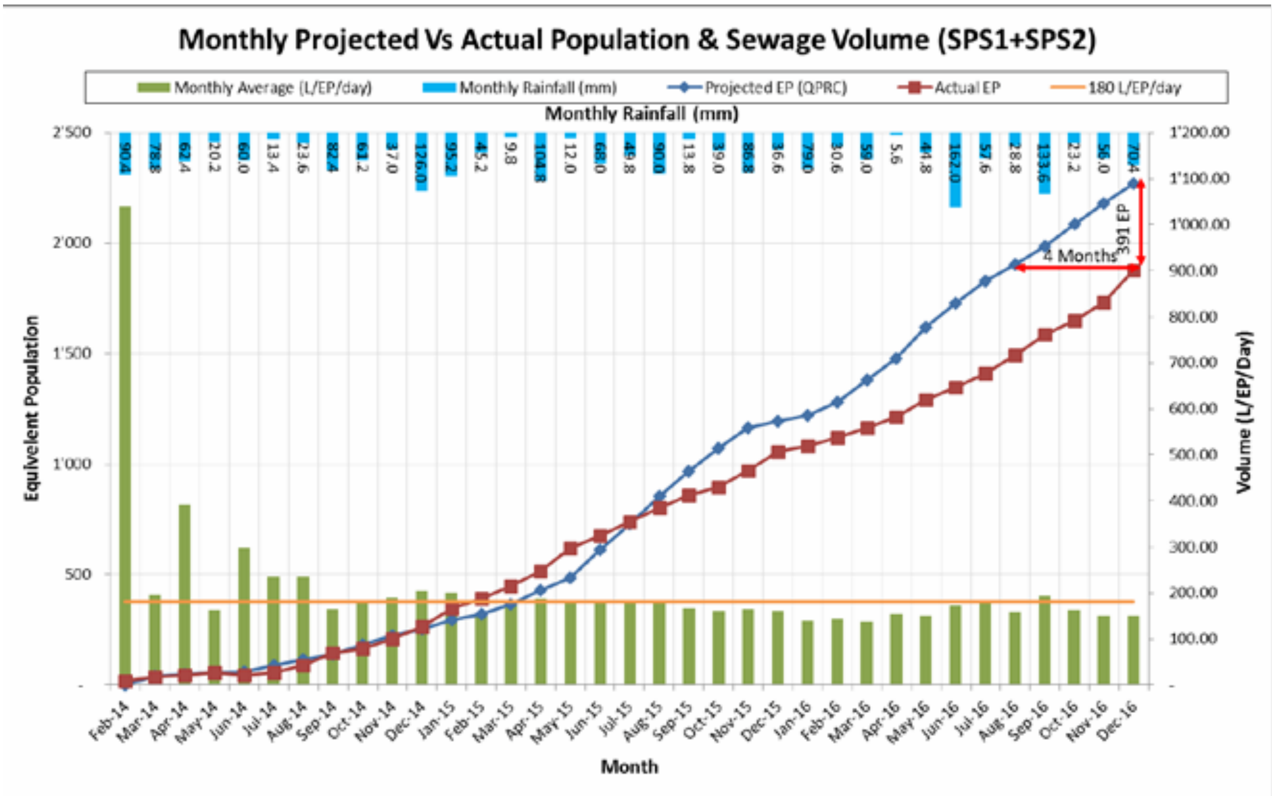


Figure 3. Monthly projected population, actual population and wastewater volume

Table 1. Assumed and actual source of wastewater non-biodegradable TDS

Parameter	Unit	Assumed Value	Actual Commissioning Value - Median
Dominant cations (i.e. sodium, potassium, calcium, magnesium)	mg/L	109	105
Dominant anions (i.e. sulphate, chloride)	mg/L	90	80
Soluble inert organics, silica	mg/L	40	20
Phosphorus	mg-P/L	12-16	10

Table 2. Table 2: Assumed and actual TDS increases due to chemical dosage at WRP

Parameter	Unit	Assumed Value	Actual Commissioning Value – Median
Sulphate – due to ferric and alum dosing	mg/L	178 (Note 1)	127 (Note 2)
Chloride – due to disinfection	mg/L	10	12.3
Sodium – due to disinfection and alkalinity control	mg/L	44	17.5

Notes:

1. Sulfate increase to reduce phosphorus from 16 to 0.1 mg-P/L.
2. Sulfate increase as a result of reducing phosphorus from 10 to 0.013 mg-P/L.

Based on monitoring of effluent TDS, the treatment process is able to reduce 99.9% of phosphorus with a molar dose of 2.3:1, which is significantly better than the literature value of 4.5:1 (Metcalf & Eddy, 2004).

In fact, it is possible to further reduce the chemical dosage (and hence TDS increase) given that the observed effluent phosphorus concentration is significantly better than the limit.

The better process performance is attributed to the adopted designs (i.e. the use of membranes, secondary reuse of alum's residual precipitation power), which is reported in Wong et al. (2017).

The observed level of TDS increase due to disinfection is very close to the assumed increase in TDS. The level of sodium increase is lower as the need for alkalinity control is reduced; given that less ferric is needed to achieve the effluent phosphorus target.

Overall comparison of the assumed and observed levels of the non-biodegradable TDS compounds provides confidence in the original assessment conducted as well as the ability of the treatment process to meet the required performances.

CONCLUSIONS

This paper presents the journey of the Googong IWC project. Conceptualised in 2002, the project involved some 15 years of planning, design, approvals, and asset delivery. To date, the Stage 1 IWC assets have been fully delivered. This has enabled Googong to be a thriving town of some 2,000 people after a short period of three years since the first residents moved in. Preliminary flow monitoring analyses suggest that the town is well on its way of achieving its originally stated goal – to be a water resilient town where 18,000 people will use the same amount of water that 6,500 normally would.

ACKNOWLEDGEMENT

This paper represents a body of work conducted by a dedicated team of people over a 10-15 year period. The authors have been privileged to work with the collective team, and summarise the outcome of the project in this paper. At the corporate level, the project has involved the effort of a range of companies as well as utilities such as QPRC and Icon Water. The authors would like to acknowledge Paul Collins, Paul Phillips and Adam Joyner for their significant contributions to the original IWC concepts.

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Craig is the Assistant Project Director for the Googong Township project. Craig has led the Googong IWC project since its concept inception in early 2004, a role he took up after service in the Australian Army. A graduate of the Royal Military College Duntroon, Craig is a Civil Engineer with Master's Degrees in Project Management and Defence Studies. He has been the driving force behind the IWC Project, and is proud to call Googong home, where he and his charming wife Sally indulge their respective loves of English motor cars, and cooking.

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Katherine is civil engineer with experience in the water industry in both the public and private sectors. From 2013-2016, Kathrine was the Project Engineer for the Googong IWC project, overseeing delivery of a range of water infrastructures for the new township. Katherine is now with MWH in United Kingdom, with her most recent project being design of clean water networks for Thames Water. Whilst in the UK, Katherine has been indulging her love of travel, and adores that Britain allows dogs in pubs.

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Chiew is a practising engineer with 20 years experience in the water industry. For the past 13 years, he has been involved in a diverse range of wastewater treatment / water recycling projects. He is experienced with the full range of water recycling technologies, and has served a variety of roles in the project life cycle, from designer, tendering of work packages, contract supervision, commissioning, and providing operation advice.

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