A New Dawn for Decentralised Sewerage

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Abstract

Sunrise at 1770 is a sustainable sub-division of 172 lots located on the coast of Central Queensland. Sunrise is a high-end development being a gated community where an economic premium is placed upon the environment. It is completely off-the-grid in regards to its water network and has implemented an integrated decentralised system. Each house has a minimum of 48 000 L of rainwater tank storage to provide the potable supply. Supplementary potable supply is available from a nearby aquifer. Recycled water is provided to each house for toilet flushing and external water usage through a dedicated purple pipe system. Recycled water is also used to irrigate a large (200 000 seedling) endemic native plant nursery used for revegetation, a community car-wash, and in emergencies fire-fighting water. The decentralised network provides the fire-fighting water for the development primarily through the aquifer and for localised bush-fire fighting the rainwater tanks. The decentralised water system has successfully provided the water requirements for the development throughout 4 years of drought without the need to bring in water from external sources. In 2007 Sunrise at 1770 won the most sustainable development in Queensland from the Urban Development Institute of Australia (UDIA), won Australia's most sustainable development (UDIA) in 2008, and made the finals in the United Nations Australian 2008 World Environment Day Awards for Water Design.

Keywords

Eco-development, fire-fighting, off-the-grid, rainwater, recycled water, scoria and zeolite

Introduction

Eco-development has come a long way since the United Nations Environment Programme described the process as a an irrational use of resources in the late 1970's (UNEPStaff 1977; UNEPStaff 1978). Environmentally responsible design principles used in civil construction have prompted the creation of not only single houses, but entire sustainable sub-divisions (Beal, Hood et al. 2008). Sustainability and environmental engineering as 'new' fields of science have wide appeal but relatively little consensus as to what it is exactly that makes one structure/s an eco-development and another not (Painter 2003). This debate has created a new term called 'green washing'; where environmentally beneficial claims are made in the absence of scientific based evidence (Karliner 2001). This issue can be further confused when one sustainability measure has unexpected environmental consequence in another area. For example, connecting rainwater tanks to the inside of a dwelling can have stormwater reuse benefits but selecting wrong pump can cause a substantial increase in energy requirements (Kele, Hoffman et al. 2006; Beal, Hood et al. 2008). Holistic sustainable designs are hard to achieve and face potential impediments from economics and traditional modes of thinking in civil engineers, town planners, and associated regulatory authorities. Sunrise at 1770 has implanted a holistic eco-development with a decentralised water system as an integral component.

The Sunrise at 1770 development is located south of the dual townships of Agnes Waters and 1770 in Queensland, Australia. This part of Queensland is called the 'Discovery Coast' and is a popular seaside tourist destination. Sunrise at 1770 is a gated community with a 172 house lots, two community clubs, and various sporting facilities. The development has been constructed to suit the requirements of the high-end of the market; with an understanding that many of the dwellings will be holiday homes. The fluctuation in usage patterns can make sustainability more difficult to achieve in tourist infrastructure (Rigall-I-Torrent 2008). A concerted effort to make the development holistically sustainable has been made through interlocking design features.

Sustainable Design Features

The developers obtained 628 hectares of land in a process which involved the sterilisation of sand mining leases. Only 2.5% of this land is to be developed (including all buildings, roadways, etc). Over 75% of the land was donated to the Australian Bush Heritage Fund to form the Reedy Creek Nature Refuge; this is the largest donation private land to a conservation group in Queensland. Land was also donated to the indigenous owners the Goreng Goreng people. The dwellings in Sunrise are covered by a legally binding covenant, which has been enforced, that limits the building size and form, and the materials used. Building designs are examined by an expert committee to ensure that mandatory sustainable design practices are incorporated.

In terms of civil construction, roadways are narrow, and each lot is surrounded by wildlife corridors, with fences being banned to ensure unimpeded travel. Due to the proximity of turtle nesting beaches a dark sky policy, resulting in minimal artificial lighting visible from the coastline, has been implemented. An endemic native plant nursery has been established and the entire site (628 hectares) is being revegetated with local species.

Sunrise at 1770 has its own autonomous water supply, wastewater treatment, and water recycling system. Relatively few large eco-developments go completely off-the-grid with no access to local government ‘top-up’ reticulated water supplies in case of emergency. The need to guarantee water supply to the development has resulted in a fully integrated decentralised water plan.

Methodology

To ensure the adequate and safe supply and treatment of water to Sunrise at 1770 a decentralised water plan has been constructed with a number of back-ups in case of infrastructure failure.

Stormwater Treatment

Stormwater treatment is divided into two categories: ground runoff and roof runoff. Water sensitive urban design principles have been used in regards to ground runoff. All carparks are made of porous material, the amount of impervious surfaces has been minimised, the sides of the roads have rock swales, and gross pollutant traps and filters have been installed to catch particulate matter. Ground runoff water is directed into vegetation rehabilitation areas (at a reduced velocity) as an irrigation mechanism.

Rainwater tanks are installed to capture the roof-runoff stormwater. A minimum of 48 000 L of rainwater capacity is required for each home. A first flush device is mandatory. If a pool or spa is installed at a dwelling additional rainwater tank storage is required equal to or greater than the volume of water in the pool or spa. The rainwater tanks provide the main source of potable water.

Potable Water Supply

The 48 000 L rainwater tank storage was modelled on what would be required to guarantee with 97% certainty all of the potable water supply requirements for a specific dwelling over a 100 year period. The assumptions for this model used the historical rainfall record and an average roof size of 400 m^2. Potable water supply is required for all household water usages excluding toilet flushing and outside taps which are supplied with recycled water. The cold-water taps in the laundry can be supplied with recycled water but this is currently not in operation.

A supplementary potable water supply from an aquifer is available. Three bores can supply water to the main infrastructure compound; where it is filtered, pH adjusted and disinfected. This treated water can be pumped to any lot in the development via a reticulated main that has an air-break connection (back-flow prevention) to each rainwater tank. A float system activates this top up facility. Rainwater tanks cannot receive more than 500 L of top-up water from the aquifer per day. The top-up potable water line is metered and residents are charged per kilolitre usage.

Wastewater Treatment

The wastewater treatment chain implemented at Sunrise at 1770 is summarised in Table 1. The treatment chain is designed to treat at a flow-rate of 3 L/sec and cope with a peak flow of 250 000 L per day.

Table 1 Treatment Chain at Sunrise at 1770

Sunrise at 1770 Treatment Chain
Dual septic tanks on each lot
250 kL holding tank with aerator & mixer
44 kL anoxic settlement tank (BNR)
44 kL zeolite & scoria filter tank
10 kL holding tank
Venturi aerator
30 kL holding tank
High velocity sonic disintegrator (HVSD)
Cell detention unit
2 x Pool filter filled with filter sand
2 x Wastewater filter with mixed media
Ultrafiltration
Reverse osmosis unit
Chloride disinfection unit
Recycled water tank

The dual septic tanks retain the majority of solids, thus making the development resemble a South Australian septic tank effluent disposal scheme (STEDS). A STED scheme is where the primary treated effluent from the septic tanks is piped away from the house block via gravity sewer mains, generally to a lagoon in South Australia, instead of being disposed of onsite (Crites and Tchobanoglous 1998). At Sunrise the primary treated effluent from the septic tanks is transported through a reticulated sewerage system to a 250 kL holding tank containing an Aspiro Plus aerator. This aerator also has a mixer unit and was sized to be able to turn-over (top-to-bottom and vice versa) the volume of water typically held within the tank. The Aspiro Plus was installed to enhance biological breakdown of solids and to aid in the nitrogen cycle transformations.

The effluent from the 250 kL tank now flows into two 22 kL tanks that are joined together to give a 44 kL capacity. The effluent within these tanks is allowed to go anoxic, thus aiding the denitrification process. The tanks also provide further settling capacity. Butterfly valves control the distribution of the effluent; it is designed for 10% of the flow to return to the 250 kL tank and the remaining 90% to be delivered to the zeolite and scoria tanks. The flow return to the 250 kL works as a very basic biological nutrient removal (BNR) stage. There are two 22 kL zeolite and scoria filter media tanks.

The zeolite and scoria tanks are a new treatment technology recently patented that have specialised treatment applications. Zeolites are hydrated alumino-silicate minerals with an open structure that can accommodate a wide variety of cations (Mumpton 1999). They can be natural (48 known types) or artificial (150+ known types). The major historical use of zeolite in the wastewater treatment industry is for the removal of ammonia and ammonium (Cejka, Bekkum et al. 2007). Scoria is the term used to describe macrovesicular volcanic rock ejecta, generally of basaltic or andesitic composition (Wenk and Bulakh 2004). Scoria is formed from the ‘froth’ of an eruption and has a crystalline structure that is very porous. Both scoria and zeolite can cation exchange contaminants of concern such as sodium and ammonia. Research conducted at Sunrise at 1770 in conjunction with the Central Queensland University has shown that the particular blend of zeolite and scoria used can reduce ammonia to below detection and maintain the sodium adsorption ratio (SAR) below 4. The volcanic rock filtration is a natural process and does not require the high energy requirements of other treatment technologies that remove these cations of concern.

The filtered effluent is gravity fed into the 14 kL tank. The effluent is then pumped, aerated by a venturi, and stored in a 30 KL tank. From there the effluent is pumped into a treatment shed where it undergoes high level treatment (see Figure 1). It first goes through the high velocity sonic disintegrator (HSVD), which has been contained in a soundproof structure, and put under pressure. The HVSD uses sound waves to break the cell membrane of microorganisms, whether they are bacteria, viruses or protozoa, and then killing the organisms by putting the cell membrane under pressure and causing it to rupture. An oxidising agent, such as chlorine dioxide is used as additional disinfection, at this stage. The effluent then flows through to sand-filters (pool-filters), two mixed media filters (containing activated carbon, zeolite, sand and agates), a micro-fine bag-filter, and then has the option of going through the ultrafiltration unit and the reverse osmosis unit if further treatment is required. The treated effluent is stored in a 150 kL recycled water tank in which a chlorine dosing arrangement keeps the residual chlorine between 1-3 mg/L

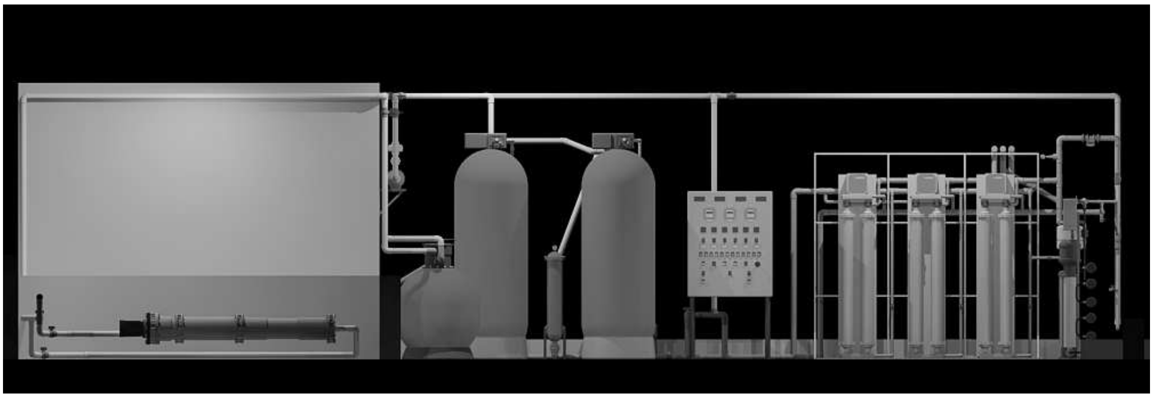

Figure 1: Layout of the High Level Treatment Stages

The aim of the treatment chain is to create Class A+ recycled water of the quality outlined in Table 2.

Table 2: Licence Conditions for the Sunrise at 1770 Sewerage Treatment Plant

Quality Characteristics	Minimum	Maximum
BOD_5		5 mg/L
Suspended Solids		5 mg/L
Ammonia as Nitrogen		0.4 mg/L
Total Nitrogen		1.5 mg/L
Total Phosphorus		0.2 mg/L
pH	6.5	8.5
Residual Chlorine	1 mg/L	3 mg/L
Faecal Coliforms		1 cfu/500 ml
Viruses/Protozoa		Log 5 removal (influent)
Turbidity		2 NTU

Water Recycling

100% of the recycled water produced at Sunrise at 1770 is recycled. The native plant nursery is the main user of the recycled water with approximately 200 000 seedlings currently under cultivation (Figure 2). Australian native plant species can be sensitive to certain constituents of water, in particular sodium and phosphorus (Bond 1998). The water operators liaise closely with the botanists on staff to ensure that there are no plant health issues in regards to the recycled water. The plants raised in this nursery have a special meaning to Australians as the majority of them were first identified by the botanist Sir Joseph Banks in 1770.

Figure 2: The Native Plant Nursery

Recycled water is also available for all outside irrigation requirements throughout the development through a dedicated purple pipe network. The purple pipe also supplies recycled water for toilet flushing. A community car wash has been constructed and uses recycled water. If insufficient recycled water is available for use it can be supplemented with additional water from the aquifer. In an emergency the recycled water can supplement the fire fighting supply.

Fire-fighting

Sunrise at 1770 is located in a high risk bush fire area. Some of the sustainable design features actually increase fire fighting concerns; most notably the revegetation program (increasing the potential fuel load) and the narrow roadways (reducing their effectiveness as fire-breaks). The water volume needed to fight fires is actually higher than the potable and recycled water requirements combined. The model used requires 15 L/sec for a minimum of 6 hours to be available; this enables more than one fire to be fought at once. Purpose built fire fighting tanks are kept supplied with treated water from the aquifer. All rainwater tanks (including those used to offset pools and spas) have fire fighting connections and the recycled water storage tanks can be linked to the fire fighting supply. A traditional triple bottom line analysis would typically state that 48 000 L of rainwater tank storage is not economically viable (Hatton-MacDonald 2003; Beatty, O'Brien et al. 2005). However, in a decentralised water network that is completely off-the-grid; the dispersed nature of the rainwater tanks and their size make them an excellent supply of fire fighting water in this high risk bush fire area, as well as economically sustainable.

Discussion

Improvements to the decentralised water design can and are being made. An assessment of the energy requirements for the wastewater treatment plant is currently underway with the aim of placing sufficient solar panels (supplying back into the grid) on the roof of the treatment shed to make the facility carbon neutral.

Overall the decentralised water system has worked, considering below average rainfall has been recorded in 2004, 2005, 2006, and 2007 (average rainfall approximately 1130 mm) and the area was drought declared. To this point no completed house has required top-up water from the aquifer (note some of this water is used by the builders during the construction of the houses). In part this can be explained by the holiday nature of the homes equating to an overall smaller water demand. A small number of houses within the development are permanently occupied; with the largest single dwelling having a long-term occupancy rate of three adults and five children. Even the permanently occupied houses have not required top-up water. The water demands of the endemic plant nursery have required the use of treated aquifer water to top of the recycled water supply. No water from outside sources has been required to be bought in to supplement supply.

Economically the development has been very successful with an 80% increase in land values since the initial sale and over 97% of the lots sold. As close to 100 million dollars was invested in this eco-development, the risk has proved worthwhile.

The most interesting discussion point has occurred in relation to the local government's (first Miriam Vale Shire Council and then Gladstone Regional Council) reaction to the drought. The dual townships of Agnes Waters and 1770 have principally relied on groundwater sources for the majority of their water supply. The vast majority of the houses also have rainwater tanks although these were only recently compelled to have an internal connection; and this measure was not made retro-active. During the drought the level of the aquifer fell and it was thought by the council that the aquifer was not a reliable water supply for the towns. In late 2005 it was determined through a series of desk-top studies that a desalination plant was the only viable long-term solution to the water security of both towns. The plan that has been adopted by the local council in early 2008 is a traditional centralised option with a desalination plant at its core.

This plan has an initial 1.5 ML/day desalination plant that can be increased in size to a total of 12 ML/day as the water demand increases with population. A new Class A wastewater treatment facility is also going to be constructed. There is no doubt that this plan will provide water security and a supply of good quality water. However there are issues with this plan. The wastewater treatment facility will be located 9 km south of Agnes Waters and 14 km south of 1770 making the provision of Class A recycled water back to the townships economically unfeasible due to transportation expenses. There is no legal requirement for the treatment facility to be located so far away from both towns. The desktop studies conducted for council assumed that no additional savings in water demand could be made through the utilisation of rainwater or water efficiency. Environmental concerns have been raised in regards to the energy requirements of the desalination plant and its discharge of brine out into the Great Barrier Reef Marine Park and nearby turtle breeding beaches.

Arguably the largest concern is the cost of the centralised plan both in capital and in operation and maintenance. To construct the desalination plant and the wastewater treatment facility will require 43 million dollars for 700 residences. The operation and maintenance costs of these facilities will be substantially more than that of the current infrastructure which consists of a simple filtration, pH adjustment, and disinfection unit for the potable water and constructed wetlands for the wastewater. Agnes Waters and 1770 are already known to have very high costs for council rates; with a standard water connection fee of $340 and water charges per kL of $2.98 already in place. It has been acknowledged that the current desalination plan would require substantial growth in population (approximately double the current 2500 people) within seven years before the new infrastructure would be financially viable via the available rate-base. When the original economic assessment was conducted in 2005 high growth figures in population was forecast but the model failed to predict the impact of two floods in early 2008 and the dramatic drop in tourist numbers predominately caused by the increase in the price of oil. Instead of increasing substantially in 2008 it is now expected that the populations of the townships of Agnes Waters and 1770 may stagnant or even decrease. How the current rate-base of approximately 700 connections can support the operation and maintenance costs of the new centralised water infrastructure is of great concern to many residents in the local community.

A desk-top study was commissioned by the developers of Sunrise at 1770 to establish what the capital cost of installing, and in some sections retro-fitting, the decentralised option used at Sunrise throughout the townships of Agnes Waters and 1770. This desk-top study estimated that 19 million dollars would be required to upgrade the rainwater tanks, install water efficient household infrastructure, provide recycled water, and to install some additional bores to more equitably distribute the demand over the aquifer. Overall the decentralised option requires less than half the capital costs and has fewer environmental concerns to achieve the same levels of water security and water quality.

Conclusion

The opportunity to compare and contrast centralised and decentralised water infrastructure retro-fits for existing towns, both economically and sustainably, is relatively rare; especially in a set of circumstances where the decentralised option has already been installed locally and proven to be viable. It is somewhat disheartening that the council has chosen to install the more expensive centralised option. The local community has however formed a local action group and is campaigning strongly for a decentralised solution.

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