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Ref No: J-0710-283 TA

Thursday 25th October, 2007

Satori Resorts
Level 6, 244 Queen Street
Brisbane, Queensland, 4001

Attn: Paul Sparshott

REVIEW OF MASTER PLANED DEVELOPMENT SEWAGE SYSTEM PROPOSAL

Dear Paul

1.0 Introduction

Simmonds & Bristow have been engaged by Satori Resorts to review the proposed Sewage Treatment system and the usage options for recycled water for the EIS (Environmental Impact Statement) stage proposal for the Master Planned Community development at Ella Bay in Northern Queensland.

2.0 Proposed Sewage Treatment System

The system proposed consists of sewage treatment to an advanced tertiary level using an Membrane Bioreactor (MBR) type system, with further treatment to obtain the required effluent concentrations for A+ class recycled water through Reverse Osmosis (RO), as per the Queensland Water Recycling Guidelines.

This A+ Class water is intended to then be used for irrigation of the Golf Course and garden bed areas, made available for non-potable reuse to the residents, for use as fire-fighting water, wash down water and other non-potable reuse.

The irrigation system proposed includes a wet weather storage (WWS) facility, with an estimated size of approximately 4000kL, although no disposal area has been determined at this stage.

The current sewage treatment system has been proposed to meet the following effluent criteria:

Table 1: Preliminary Design Effluent Quality

Parameter	Unit	Requirements		
		Minimum	Median*	Maximum
Suspended Solids	mg/L			<1
Turbidity	NTU			<2.0
5-Day Biochemical Oxygen Demand (BOD5)	mg/L			<10
Total Nitrogen	mg/L			<10
Total Phosphorous	mg/L			<1
Faecal (Thermotolerant) Coliforms	CFU/100mL		<10	
pH	Unitless	6.5		8.5
Dissolved Oxygen	mg/L	2.0		

* Median of 5 samples of final effluent, taken at least 30 mins apart.

This effluent quality was drafted for the Little Cove development, in 2005, before the *Queensland Recycled Water Guidelines* were released. Hence, this standard was based upon the *National Water Quality Management Straegy, Guidelines for Sewerage Systems, Use of Reclaimed Water.* These guidelines differ slightly from the *Queesland Recycled Water Guidelines*.

To conform with the A Class requirements listed in the *Queensland Recycled Water Guidelines* a maximum limit of 1600 uS/cm for Conductivity (EC) needs to be included. Additionally, monitoring for E.Coli will need to be conducted, with a median limit of <10 cfu/100mL, as for Faecal Coliforms.

The remaining effluent quality listed in Table 1 conform with the requirements for A Class recycled water

The following section outlines the Queensland Recycled Water Guidelines limits for A Class and A+ Class recycled water.

3.0 WATER QUALITY REQUIREMENTS FOR DISPOSAL AND RECYCLING

For disposal as irrigation water, the effluent produced by the sewage treatment process needs to be A Class. As stated in the last section the water quality listed in Table 1 conforms with A Class requirements, but requires the addition of a maximum conductivity limit of 1600 uS/cm.

Compliance with this conductivity limit may be obtained by the addition of a Reverse Osmosis system. The addition of Reverse Osmosis will likely produce A+ Class quality water, although this will require the validation testing listed in the following sections.

For Recycling for urban non-potable reuse (garden watering, toilet flushing, etc) the recycled water will need to reach A+ Class.

A Class and A+ Class requirements are listed in the following sections.

4.0 QUEENSLAND RECYCLED WATER GUIDELINE REQUIREMENTS

The *Queensland Water Recycling Guidelines, December 2005*, gives a number of classes of recycled water. These range from A+ Class to D Class recycled waters.

4.1 A Class - D Class Recycled Water Requirements

The following table lists the requirements for A Class through D Class recycled waters, and has been drawn in full from the Queensland Water Recycling Guidelines. (*Ref Table 6.2b, Page 48, Queensland Water Recycling Guidelines, December 2005*)

Table 2: Recommended Quality specifications for A-D Class Recycled Water[1]

Class	**E.Coli** cfu/100mL[2] median	**BOD5** mg/L median	**Turbidity** NTU 95%ile (max)	**Suspended Solids** mg/L median	**TDS**, mg/L **OR** **EC**, uS/cm Median TDS/EC[3]	**pH**
A	<10	20	2 (5)[4]	5	1000/1600	6-8.5
B	<100	20	NR	30	1000/1600	6-8.5
C	<1 000	20	NR	30	1000/1600	6-8.5
D	<10 000	NR	NR	NR	1000/1600	6-8.5

1 Use of any of these classes of recycled water should involve development and implementation of a Recycled Water Management Plan incorporating risk management. The location of the sampling point for these parameters will depend on the outcome of the Recycled Water Management Plan (see Chapter 4 of these guidelines).
2 As these values are medians, for each of these guideline values a response value should be set (e.g. 50% above the guideline value). If the response value is exceeded, another sample should be immediately taken. If this exceeds the response value again, the supply of recycled water should be suspended, and the non-conformance and corrective action process implemented, with supply not being re-established until conforming product can be guaranteed
3 For sustainable irrigation, salinity should be kept as low as possible. For example, if TDS 1000 mg/L or EC >1600 µS/cm, a salinity reduction program should be implemented. However, there may be some uses where salinity reduction is not required, or where other salinity management options are more practical. This should be determined during the risk assessment.
4 Turbidity would generally be measured before the disinfection point at the treatment plant as this is the point at which low turbidity is essential. Monitoring at the treatment plant should be continuous with an alarm activated at an NTU of 2, and automatic shut-off of supply at an NTU of 5. If disinfection of Class A recycled water is achieved partly through processes that are less dependent on turbidity, an indicator other than turbidity should be used. For example, extended lagooning would use detention time in the storage as the critical limit (typically 40 days), rather than turbidity. Ozonation may use an oxidation-reduction potential (ORP) sensor, with the critical limit (in millivolts) determined by the quality of the feedwater.

To be classified as A Class recycled water, the water must meet the concentration criteria set out in the previous table. A Class water is also suitable for use in activities that only require B, C or D Class water.

4.2 A+ Class Recycled Water

A+ Class recycled water must meet all the physical criteria required for A Class, and has further requirements primarily aimed at; proven reduction in bacteriological and virological pathogen concentrations, process validation and risk assessment.

Process system validation for A+ Class water requires a Recycled Water Management Plan (RWMP) with HACCP (Hazard analysis & Critical Control Point) style risk assessment.

The following lists the requirements for A+ Class recycled water, and has been drawn from the Queensland Water Recycling Guidelines. (*Ref Table 6.2a, Page 47, Queensland Water Recycling Guidelines, December 2005*)

Microbiological Criteria

A+ Class recycled water must meet the following reduction in pathogens:

- Six log (99.999%) reduction of viruses (bacteriophages as indicators)
- Five log (99.99%) reduction of bacteria (E. coli as indicator)
- Five log (99.99%) reduction of protozoan parasites (Clostridium perfringens as indicator)
- For irrigation applications, compliance with trigger values for irrigation waters in Chapter 4 of the Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC and ARMCANZ 2000a)

A+ Class recycled water must meet the following microbiological criteria:

- E. coli <1 cfu/100mL (median); <10 cfu/100mL (95%ile)
- Clostridium perfringens <1 cfu/100mL (median); <10 cfu/100mL (95%ile)
- F-RNA bacteriophage: <1 pfu2/100mL (median); <10 pfu/100mL (95%ile)
- Somatic coliphage: <1 pfu/100mL (median); <10 pfu/100mL (95%ile)

Chemical and Physical Criteria

A+ Class recycled water must meet the following chemical and physical criteria:

- Turbidity <2 NTU (95%ile); 5 NTU (maximum)
- For dual reticulation systems, free chlorine residual 0.2-0.5 mg/L on delivery to customer. For other A+ Class uses, the need for a chlorine residual should be determined as part of the risk assessment.
- pH 6-8.5 (if disinfection relies predominantly on chlorine, but not chlorine dioxide) or 6-9.2 if other disinfection systems are used
- For sustainable irrigation, salinity should be kept as low as possible, e.g. if TDS >1000 mg/L or EC>1600 µS/cm, a salinity reduction program should be implemented

- Any other physical or chemical criteria that the risk assessment phase of the RWMP has identified as representing a risk to soil, crop or human health

Other Requirements

To qualify for A+ Class, recycled water requires a validation program consisting of 20 sampling events (with 3 replicate samples in each event) that demonstrate compliance with the above mentioned guidelines, before delivery to the point of use.

Further verification testing at weekly intervals (with 3 replicate samples taken each time) for the first year of operation, with monthly verification thereafter is also required.

It should be noted that this validation testing can be quite expensive, generally in the order of $80,000 for the full set of 20 sampling events. Additionally there are very few companies that are capable of providing the full suite of viral pathogen testing commercially within Australia.

Once the system is validated, All non-conformances will need to be reported to Queensland Health (this should be included in the contingency section of the Recycled Water Management Plan, RWMP).

5.0 TREATMENT TECHNOLOGY OPTIONS

The following section compares the two primary treatment options being considered, conventional activated sludge and the membrane bioreactor (MBR).

5.1 Activated Sludge System

A well operated and well maintained conventional activated sludge based sewage treatment system, equipped with deep bed sand (or multimedia) filters should be capable of producing a final effluent of the quality outlined in Table 1, section 2.0. A system of this nature was proposed for use in the Little Cove development.

However, for the production of A and A+ Class recycled water, the activated sludge process has a few drawbacks, primarily in viral pathogen and salt removal.

The addition of UV disinfection coupled with chlorine disinfection will likely give the pathogen removal required for A Class recycled water. However, to guarantee viral pathogen removal the addition of ultrafiltration membrane filtration units may be required.

As stated, increased viral pathogen removal can be achieved by the addition of ultrafiltration membrane modules to the back-end of the process. This essentially turns the activated sludge process into a form of Membrane Bioreactor (MBR) system. This is usually performed as a refit or retrofit to an existing plant, but does offer a few advantages, the primary of which being the production of a higher quality feedwater for the ultrafiltration process. Clarified and filtered effluent contains significantly less particulate matter. This results in reduced solids loading on the membrane, allowing for longer runs at higher flux rates, which can reduce backwash, enhanced cleaning (CIP or Clean in Place) requirements and pumping (transmembrane pressure) requirements. This, configuration, however, will increase the capital cost of the activated sludge system, and may be more operationally intensive than an dedicated MBR system.

5.2 Membrane Bioreactor (MBR)

The following section gives some information on MBR systems, their general configuration, some of their advantages and some of their drawbacks.

5.2.1 MBR Summary

A Membrane Bioreactor (MBR) system is based upon similar principles to an activated sludge system, but bypasses the use of clarification (although some designs retain clarification) and sand filtration, placing ultrafiltration membrane filtration units directly onto the back-end of the biological reaction tank (either internally to the tank or externally). An MBR generally runs a higher solids concentration than an activated sludge system (Activated sludge tends to run a mixed liquor solids concentration of between 4000mg/L to 6000mg/L, an MBR will run anywhere up to 10,000mg/L to 20,000mg/L to even higher).

The main benefits of this system are a reduction the footprint of the plant, as less process equipment (tankage) needs to be installed, and in some cases reduced operator attention requirements, from the combination of a high degree of automation and a possible reduction in the need for cleaning and maintaining clarifiers and sand filters. The higher solids content of the reactor tank may also allow for simplification of sludge wasting and disposal operations.

Cleaning requirements for the membrane units can be quite complex. Periodic chemically enhanced cleaning of the membrane filtration units is usually required in addition to normal backwashing. This is normally accomplished using a variety CIP systems (such as chemically enhanced backwashing), though in some instances the membrane modules can be removed and sent off-site for cleaning, although this would only be used in smaller plants where a full CIP system would be uneconomical.

Since the membrane replaces clarification, the feedwater tends to have much higher solids loading, which can lower flux rates. There are also some limitations on transmembrane pressure (the driving force across the membrane) due to the design of the units. The current interest in MBR based systems, however, has prompted companies to develop membrane modules capable of higher flux rates at lower transmembrane pressures.

5.2.2 Membrane Configuration

As mentioned in the first paragraph of this section, membrane contactors are placed at the back-end of the process. There are two primary locations, and a number of different methods of operating the membrane system. These methods will have some affect on capital costs, operational costs, noise, cleaning requirements, etc. The following section summarises the most common MBR configurations.

In-Tank Membrane Units

In this configuration the membrane is immersed within the bioreactor tank, with effluent being drawn through the membrane at low pressures by a suction pump. This configuration eliminates the need for pressure vessels for membrane containment, eliminates the need to liquids high in suspended, particulate, solids at high pressures and can simplify pumping and sometimes pipework arrangements.

This configuration has a number of drawbacks that need to be considered.

First of which is that the bioreactor tank requires energetic mixing in order to slough or sheer accumulated solids from the membrane surface. This forms part of the cleaning process, and is normally achieved by using a high-energy coarse bubble aeration system. This requires large blowers, which may be expensive to run and cause noise problems.

The second issue is the complex chemical cleaning arrangements, with either the entire membrane unit or sections of it needing to be lifted out of the tank and dipped into a CIP (Clean In Place) cleaning solution being one of the more common methods. This can increase operational complexity and OH&S risk issues considerably, and can require specialised labour for the changing of damaged membrane elements.

External Membrane Units

External membrane units are placed outside the bioreactor tank, with the mixed liquor being pumped (or moved via an airlift or similar system) through the membrane unit. These units require pressurised housings and more complicated pipework than in-tank systems, but backwashing and the complexity of cleaning requirements are generally reduced. The size of the aeration blowers required for the system may also be reduced, as excess mixing energy is not required for membrane cleaning. There are two primary configurations for external membrane units, these are 'side-stream' and 'dead-end', and are discussed in further detail later in this section.

It is also generally relatively simple to remove membrane elements from an external system, when compared to an internal system. These elements can then be sent offsite for repair, while being replaced with a self spare or similar. This may be a consideration considering Ella Bay's relatively isolated location.

Side-Stream Configuration

In a Side-Stream configuration a portion of the bioreactor tank contents is constantly pumped through a membrane contactor unit, with the filtrate being removed as effluent and the reject being passed back to the bioreactor tank.

Side Stream units benefit from having relatively long run times at relatively high flux rates. Many of these systems run high feedrates, which allow the membrane to be partially self cleaning, with the high feedwater flow sheering accumulated solids from the membrane surface. The membranes still require backwashing and chemical cleaning, but the requirements for both may be somewhat reduced.

These membranes, however, either require pumps that can both pump fairly concentrated solids solutions at high enough pressures to run the membrane, or require the use of other systems to provide transmembrae pressure for running the membrane. Recovery rates may be slightly lower per membrane unit, and more units may be required to achieve desired effluent flowrates, however the elongated run times should help to counter or reduce this problem.

Dead-End Configuration

Dead-End units pass the whole of the effluent flow through the membrane, until the membrane becomes sufficiently fouled as to require cleaning (this is the definition of a filter run). The membrane is then backwashed, with the backwash water either being dumped or being returned to the bioreactor. This configuration generates no reject stream.

Some units are constructed in a similar configuration to the activated sludge process refit mentioned in section 4.1. This uses a clarifier to capture the majority of the suspended solids, which is returned to biologically activate the bioreactor itself. This configuration reduces the solids load on the membranes, but will require a greater footprint and operator attention as a clarifier now has to be built and maintained.

The filter runs for a dead-end configuration tend to be short, with the system being backwashed regularly, but the recovery rate can be higher, as more pressure is applied directly to the membrane. The pipework is somewhat simpler than the side-stream system, as the reject stream is no longer generated, eliminating the need for a return stream to the bioreactor.

Dead-End systems, however, require higher transmenbrane pressures, increased backwash frequency, both for chemically enhanced and non-chemically enhanced backwashing,

5.3 Ultra Filtration

As stated previously the MBR process is based upon ultrafiltration membrane units.

The water produced from an ultrafiltration process (either activated sludge with an ultrafiltration unit back-end or a more conventional MBR process) should meet the majority of guidelines required for both A Class and A+ Class quality recycled water, with many manufacturers claiming full removal of pathogenic bacteria and viruses, residual BOD, suspended solids and turbidity.

The ultrafiltration membrane itself is incapable of altering the pH of the feedwater, so the pH requirement needs to be addressed by either the proper operation of the biological treatment system or by pH adjustment before the membrane (which is usually required as the membrane elements can be sensitive to pH).

Ultrafiltration alone, however, will not reduce high salt (conductivity & TDS) concentrations, and in a coastal resort style community there is a high possibility that salt water infiltration (either by seawater infiltration or from other sources such as washing clothes soaked in seawater, etc) could increase the conductivity of the effluent above the 1600 uS/cm limit required in the guidelines. This requires the use of Reverse Osmosis (or similar) to remove residual salts.

Ultrafiltration is a pressure driven process, and hence will require power for generation of differential (transmembrane) pressures. Typical power consumption for ultrafiltration units is considered to be approximately 3 kWh/m3 of feedwater at a recovery rate of 70-85% (Metcalf & Eddy, 2002). Some MBR manufacturers claim large reductions in power requirements, with power draws down to 0.7 kWh/m3 feedwater (Norrit X-flow)

5.4 Reverse Osmosis

Reverse Osmosis is a membrane process that will essentially remove everything that isn't water from the feedwater. RO tends to require very high transmembrane pressures to work, and hence will tend to have high power requirements. Typical power requirements for an RO system are considered to be in the range of 18.2 kWh per m3 of feedwater, at a typical two-pass recovery rate of 70-85% (Metcalf & Eddy, 2002). Manufacturers are now producing 3-pass systems that can recover up to 90% of the feedwater. This produces a very salty reject stream that needs to be disposed.

The water produced by an RO process is so pure that it can corrode steel, attack concrete and leach salts, alkalinity and nutrients from whatever source is available to it. This requires that the water be conditioned (balanced) after production, usually by shandying (mixing) with a salt-containing water (this is achievable by running a bleed line around the RO unit, mixing the feedwater with the filtrate from the RO unit, assuming the feedwater is virus free, or by mixing with small amounts of seawater if the feedwater is unsuitable). This produces high quality recycled water, capable of reaching the A+ Class specifications.

6.0 EFFLUENT REUSE OPTIONS

Utilising membrane technology should allow for A Class water to be produced directly from the sewage treatment process.

This water, according to the guidelines, is considered suitable for irrigating public open spaces using above ground irrigation with uncontrolled access and in water features with no human contact. This includes golf courses & parks and in fountains or similar water features.

The Queensland Recycled Water Guidelines include a number of other applications for A Class water, but these are unlikely to be relevant, so they have not been covered here.

The addition of an RO system that guarantees the production of A+ Class recycled will allow the use of recycled water in a number of non-potable applications around the development. This includes watering household gardens, as wash down water, in household laundry, as fire fighting water, etc.

No specific comments on the use of recycled water for pool top-up has been made in either the *Queensland Water Recycling Guidelines, December 2006*, or the *National Water Quality Management Strategy Guidelines for Sewage Systems - Use of Reclaimed Water, November 2000.* Since this represents direct human contact reuse, it is likely that the final approval for this usage would be up to the Queensland EPA, and would depend heavily on appropriate risk assessments having been prepared.

7.0 EFFLUENT DISPOSAL VIA IRRIGATION

While the water quality produced from an ultrafiltration system is very high, the normal requirements for Wet Weather Storage (WWS) and application rates still apply when disposing of effluent via land irrigation. These restrictions are primarily in place to prevent the runoff of irrigation water. Normally a large part of the focus of runoff effluent irrigation water tends to be nutrient contamination of environmental water. While increasing the purity of the irrigation water will reduce the risk of contamination of environmental water, there will remain concerns over erosion or soil damage from runoff irrigation water.

Due to this the requirement for wet weather storage is unchanged, irrespective of the quality of the water. However, higher quality recycled water could have a larger range of alternative uses (as outlined preciously). Since this demand still exists during high rainfall events, this reduces the volume that needs to be disposed of via irrigation, which may reduce the required size of the WWS facility.

Scale up of the wet weather storage facility from the Little Cove development also requires scale-up of the disposal area (this also runs into some difficulty with the enlargement of the catchment acting to catch more rain water).

Initial MEDLI modelling indicates that utilising 4000kL of WWS capacity, and about 70HA of irrigation area there is likely to be one (1) overtopping event per 10 years, with approximately 1000kL worth of overtop volume over a 5 day period.

This is with full disposal of effluent to land, not accounting for reductions in effluent flow due to recycling. It should also be noted that this overtop will occur only during periods of very high rainfall (the 10 year ARI event). This will result in significant dilutions of the overtop water. Calculations performed or the Little Cove project indicated that the level of dilution would reduce constituent levels well below those required in the GBRMPA standards.

7.0 SUMMARY AND CONCLUSION

In conclusion, the water quality presented in Table 1 of this report, which is equivalent to that proposed for the Little Cove project, is well within the requirements for A Class recycled water, but requires the addition of a maximum conductvity limit 1600 uS/cm to conform with A Class requirements..

This is capable of being achieved by an activated sludge system with sand filtration & UV disinfection, as was proposed for Little Cove.

It is also possible to achieve this effluent standard using an MBR system, which will serve to reduce the footprint of the plant, and can decrease the operator attention required for proper and efficient operation, with a high degree of automation being attainable.

Compliance with the required conductivity limit may requrie the addition of a Reverse Osmosis system. It is likely that the water produced from this system will conform wth Class A+ Requirements, but the validation listed in section 4.2 will need to be conducted to verify this. If required further virological reduction may be achieved with the addition of UV sterilisation.

Disosal of recyled effluent by land irrigation will require A Class recycled water. Recycling recycled water for use in urban non-potable use (flushing toilets, etc) will require A+ Class recycled water.

Further recycling options for A Class water revolve primarily around the watering of public green spaces. For the development this would mainly be the golf course and park/garden areas around the developments buildings. The use of A Class water eliminates setbacks that were once required for watering public areas using recycled water, and also allows for uncontrolled public access to the areas being watered.

Increasing treatment to A+ Class allows the water to be made available to residential or commercial dwellings around the development for use for watering gardens, as general washdown water, laundry washing, and for use as firefighting water.

However, the validation testing for A+ Class water is very costly, upwards of $80,000 for the full 20 validation sampling events required by the guidelines. This is primarily due to the low availability of some of the more specialised viral pathogen testing required under the guidelines.

The increase in water quality, does not allow for a reduction in wet-weather storage or disposal requirements. The focus moves from contamination of water bodies to problems with erosion caused by excessive runoff during rainfall events.

We trust this summary is suitable for your requirements. Please do not hesitate to contact the undersigned should you have any enquires, or if we can be of further assistance to you.

Yours Faithfully
SIMMONDS & BRISTOW PTY LTD

Terrence Allen BE*(Chem)*
Process Engineer