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Beverley Park water reuse plant: getting the salt just right

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ABSTRACT

The extraction type wastewater recycling systems are those where wastewater is taken from the collection system en route to the central treatment plant. This paper discusses a case study of Sydney's first ever extraction type scheme, the Beverley Park water reuse scheme. Primary applications of recycled water from this case study site include: parks and ovals, green-belt and golf course irrigation. Given the plant's location on a major interceptor sewer along Kogarah Bay, tidal influx posed a significant challenge due to high salt levels. Salt sensitive grass on golf course greens meant that treated water had to meet stringent quality requirements with regards to salt. The design involved modelling the process of diurnal fluctuations in salt levels and to provide an optimised process design. A non-membrane, design based solution was also chosen to resolve this high salinity challenge. This Case Study highlights the significant challenges in planning, design and commissioning of water reuse plant intercepting sewer carriers prone to salt water intrusion. The study provides valuable knowledge that will assist in providing viable extraction type water reuse schemes for tidal impacted areas.

Keywords: Sewer mining; Water reuse; Salinity; Tidal intrusion; Diurnal

1. Introduction

Decentralised water reuse schemes have been categorised into three main types, as illustrated in Fig. 1 [1,2].

Upstream type: The upstream type of systems typically is used to treat wastewater generated at the outskirts of a centralised collection system, where opportunities for reusing the reclaimed water exists due to large suburban parks, or golf course or median strip irrigation [1]. Typically, this type of reuse scheme is associated with new housing developments and new commercial centres on the outskirts of the city. As shown in Fig. 1, an example of this type of reuse is currently being implemented in South Sydney at Discovery Point Development, in Tempe.

Extraction type: Wastewater to be recycled in the extraction type of systems is taken literally mined from the collection system en route to the central treatment plant [2]. The case study project that is the focus of this paper is in fact an extraction type scheme as per this classification, and it is therefore commonly referred as water "mining" scheme. Typical applications of extraction type satellite systems include: park or green-belt irrigation, water reuse in commercial centres and cooling tower applications.

Interception type: The interception type systems are those, in which wastewater is intercepted before reaching the collection system [1]. Intercepted

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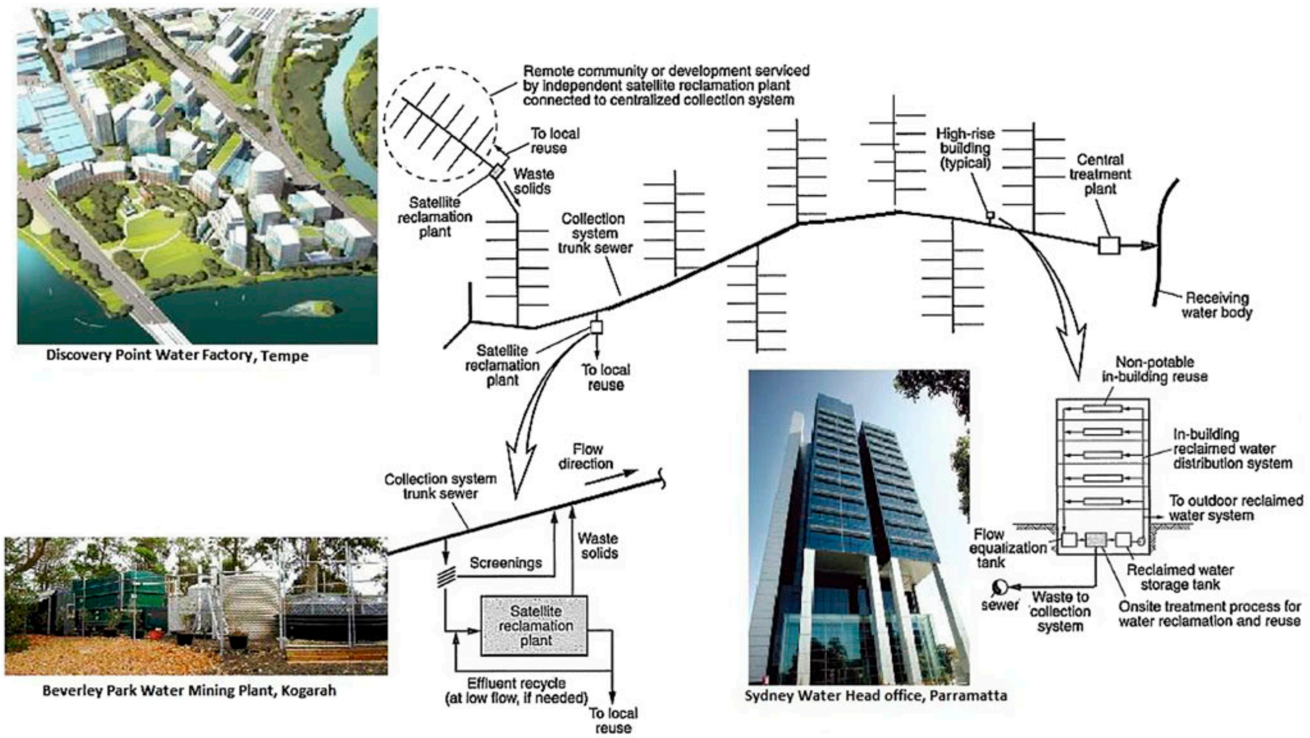

Fig. 1. Types of decentralised reuse scheme (modified from [2]).

wastewater is in fact diverted to a satellite (decentralised) system for treatment and reused locally. Typical applications for this type of treatment systems are for water reuse in high-rise commercial buildings. A good example of interception type water reuse scheme is located at the Sydney Water Corporation's head-office building in Parramatta.

Beverley Park Water Mining was based on extraction type wastewater reuse scheme where in the raw sewage was extracted from the collection system (Ramsgate Sewer Carrier) and then treated to irrigation standards for re-use in Beverley Park Golf course. The details of the scheme are discussed in the Section 2.

2. Planning issues

2.1. Beverley Park Water Mining case study

All water mining projects typically go through six phases as outlined in Fig. 2 [3].

At the preliminary exploration stage, a first-round assessment is made whether water mining meets the project objectives, a potential market for reclaimed water is identified, rough costs are estimated and possible location is selected [4]. No detailed investigations occur at this point in the planning cycle, but *"a preliminary indication is made whether water mining lies within the realm of possibility"*.

For Beverley Park Water Mining Project, the scope of this pre-feasibility report included:

- A preliminary supply and demand analysis to ensure that sufficient recycled water will be available to meet the projected demand.
- The proposed capacity of the plant, which was based on the projected peak demand.
- A list of potential partners who could participate in the project as potential users of the recycled water. The preliminary list included in the report, identified the Beverley Park Golf Club as well as the St George Rugby League Club as viable partners.
- In addition to proposing a plant capacity, the report also listed a number of technological options available for this project, along with their projected costs.
- Lastly, identification of possible plant locations. The report recommended that the plant should be located in close proximity to major users. This recommendation essentially shortlisted the golf course as the most likely location.

The location of the proposed water mining facility with respect to the sewer trunk lines, as well as the flow variations within each trunk line are important selection criteria. To minimise the capital costs, the water mining plant should be as closed to the sewer trunk line as possible [5]. The sewer trunk selected

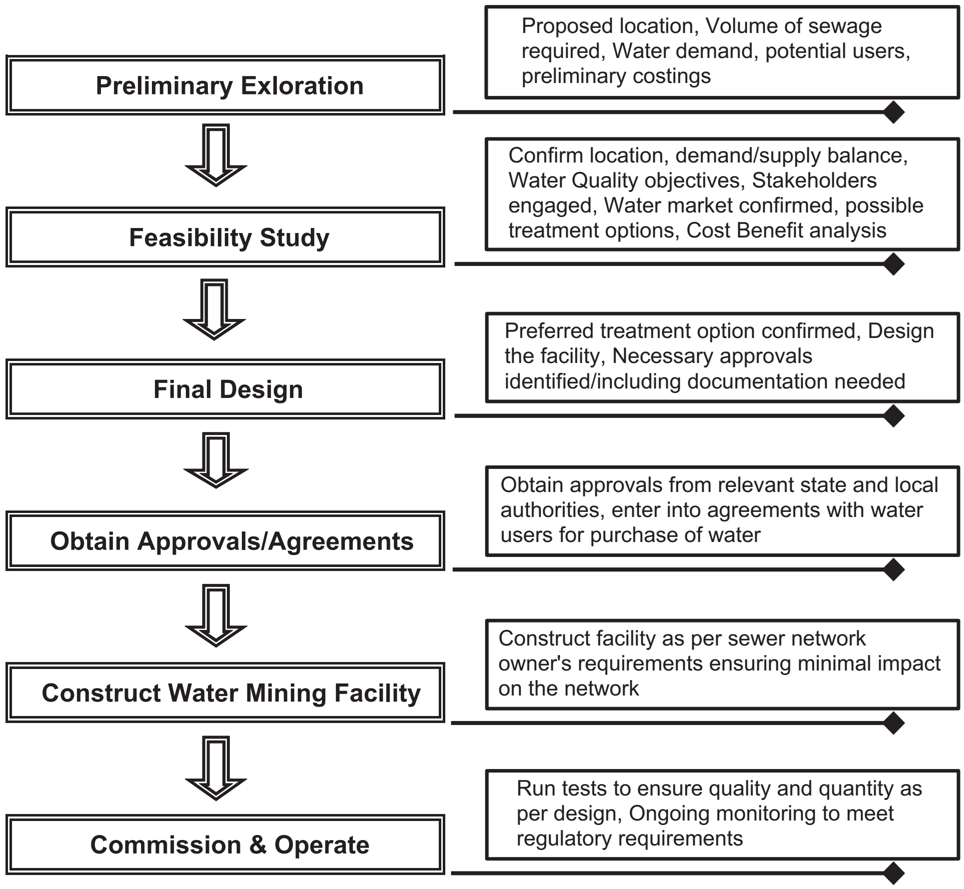

Fig. 2. Planning & Implementing Water Mining Project [3].

for water mining should have sufficient flows to meet the projected demands. This paper further discusses, in Section 2.2, the ramifications and subsequent design challenges that resulted from the decision about plant location. As shown in Fig. 3, selection of an appropriate site for the Beverley Park Water Mining plant closely followed in the key consideration as suggested by Rimer et al. [5].

2.2. Location of plant

The location for the plant along the Ramsgate Road was recommended for the following reasons:

(i) The Ramsgate Road sewer carrier traverses Beverley Park golf club boundary on the southern end. It is a large box carrier, 1.06 m wide × 1.06 m deep. It carries waste water from Sans Souci area traversing along that Kogarah Bay to the sewage pumping station near Beverley Park golf club. The capacity of the sewer was estimated at approximately 1.14 kL/s, with sufficient flow to provide the estimated demand from the proposed recycling plant.

(ii) For the purpose of the relevant statutory planning conditions, the selected site was owned by Kogarah Council and was zoned as Open space 6(A). Locating the plant on the site meant that the plant could be constructed under the NSW *Local Government Act*, which at the time of constructing the Beverley Park plant was a well-defined process when compared to as yet undefined legislative framework of constructing a wastewater treatment plant in Sydney that is not owned by Sydney Water Corporation.

(iii) The area required for the proposed plant footprint, there was sufficient land available at this site. Appropriate consultation with the golf club ensured that plant design was integrated with the golf course.

(iv) Another advantage of locating the plant along the Ramsgate Road was the easy access for delivery trucks and operational vehicles. Ramsgate Road being an arterial road already had

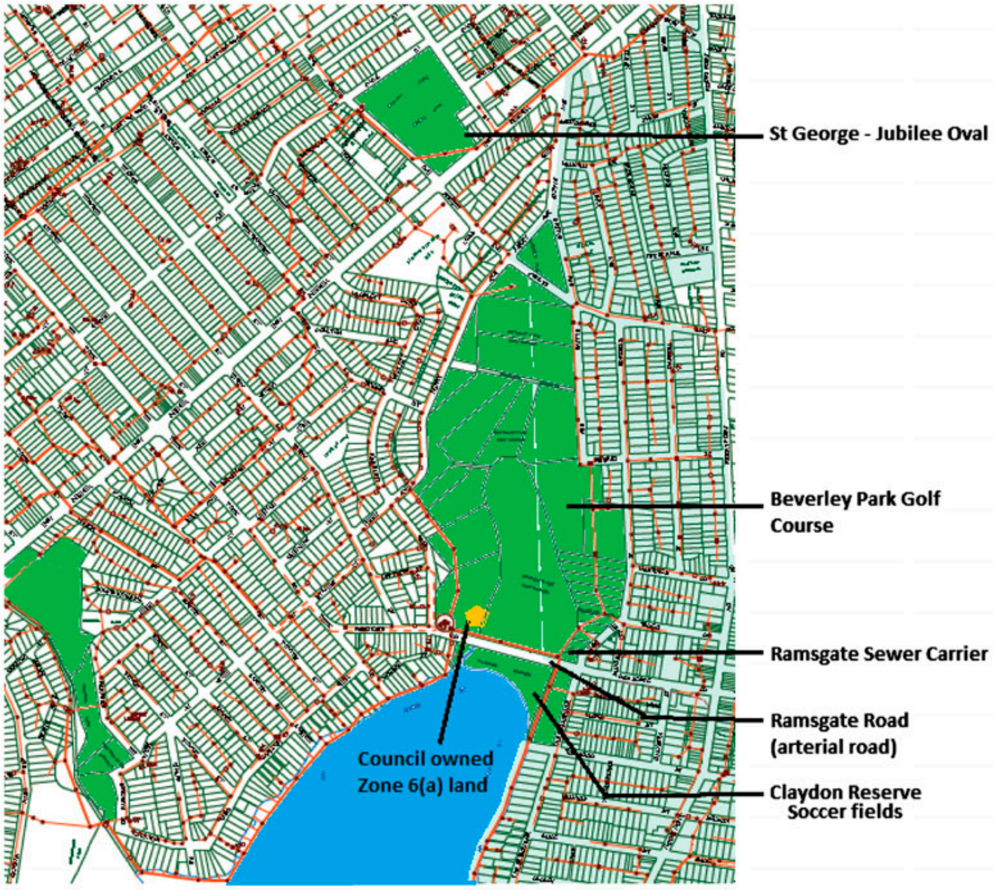

Fig. 3. Site selected for Beverley Park Water Mining Plant.

truck traffic on it and therefore the plant was not going to introduce truck traffic on an otherwise quiet neighbourhood street.

(v) The proposed location at the southern end of the Beverley Park golf course was also deemed suitable due to its minimal impact on the neighbourhood. The site is surrounded by the golf course on three sides and an arterial road on the fourth side. The nearest house is at some distance from the proposed plant location. Creative landscaping following the planned construction would ensure that there was no negative aesthetic impact on the neighbours.

(vi) The presence of power poles along the arterial road ensured that a power supply connection can be installed for the proposed recycling plant.

(vii) Finally, locating the plant within the Beverley Park golf course and across the road from Claydon Reserve ensured that two significant users of the recycled water were literally within a few metres from the plant. Furthermore, it would allow construction of a cost-effective supply line to the St George Jubilee oval using the existing stormwater channel that runs along the golf course all the way up to the St George Rugby League Club.

3. Design challenges

Despite the benefits of locating the plant at the southern end of the golf course discussed above, a significant design challenge emerged following sewage flow and quality analysis during the pilot plant phase. Given the site was accessing sewage from a large interceptor carrier along the Kogarah Bay, tidal influx in this carrier caused high TDS content in sewage as discussed below.

3.1. Design solution for diurnal fluctuations in sewage

A MaceHV Flo Doppler velocity metre/level sensor was used to gauge sewage flow in the Ramsgate sewer carrier [6]. This instrument transmits ultrasonic (sound) wave into the flow, which is reflected by acoustically reflective particles (e.g. air bubbles and suspended solids) and the instrument detects the reflected frequencies. The difference between the transmitted frequency and the received frequencies is directly proportional to the velocity of the stream flow [7].

Fig. 4 shows that diurnal pattern in the sewage flow within the Ramsgate sewer carrier, as observed between 15 September and 9 October 2006, during the project planning stage. The morning and afternoon peaks are clearly feasible in Fig. 4, with morning peaks around 10AM–11AM being greater of the two. During peak times, the discharge typically ranged above 100 L/s, with the lowest discharge typically hovering just above 20 L/s. The above figures confirmed that the Ramsgate sewer main had sufficient sewage volumes to supply wastewater to a water mining plant with peak demand of 750 kL/d.

Being a predominantly residential catchment, the sewage quality (Table 1) was reflective of this land use [8]. However, the salinity levels were atypical of residential sewage quality and posed a matter of concern. A major use of reclaimed water was going to be irrigation of golf course fairways and greens. Golf club however advised that the grass on their greens is particularly salt sensitive, and therefore the Club would not be interested in purchasing recycled water if total dissolved solids (TDS) content routinely exceeds 500 mg/L.

The hybrid technology selected for the Beverley Park Water Mining plant utilises biological processes in conjunction with chemical and physical removal processes of coagulation and filtration [8]. Effluent from biological process is further polished through sand filter, and is disinfected by UV and/or chlorination.

As outlined in Fig. 5, the system involves following four key treatment steps:

- Chemically assisted fine solid separation (Chemical/Physical)—uses coagulation to remove fine solids;
- Submerged aerated filter (Biological)—enables biodegradable organic and nutrient removal.
- Fine sand or multimedia filter (Physical)—additional suspended solids removal.
- UV disinfection—the last step in the treatment process, commonly coupled with chlorination to meet the residual chlorine requirements.

Given the salt content of the raw sewage, the option of using reverse osmosis based water mining treatment was considered and ruled out due to high energy costs. Selected hybrid technology provided best life cycle costs when considering ongoing operations and maintenance costs, which are typically high

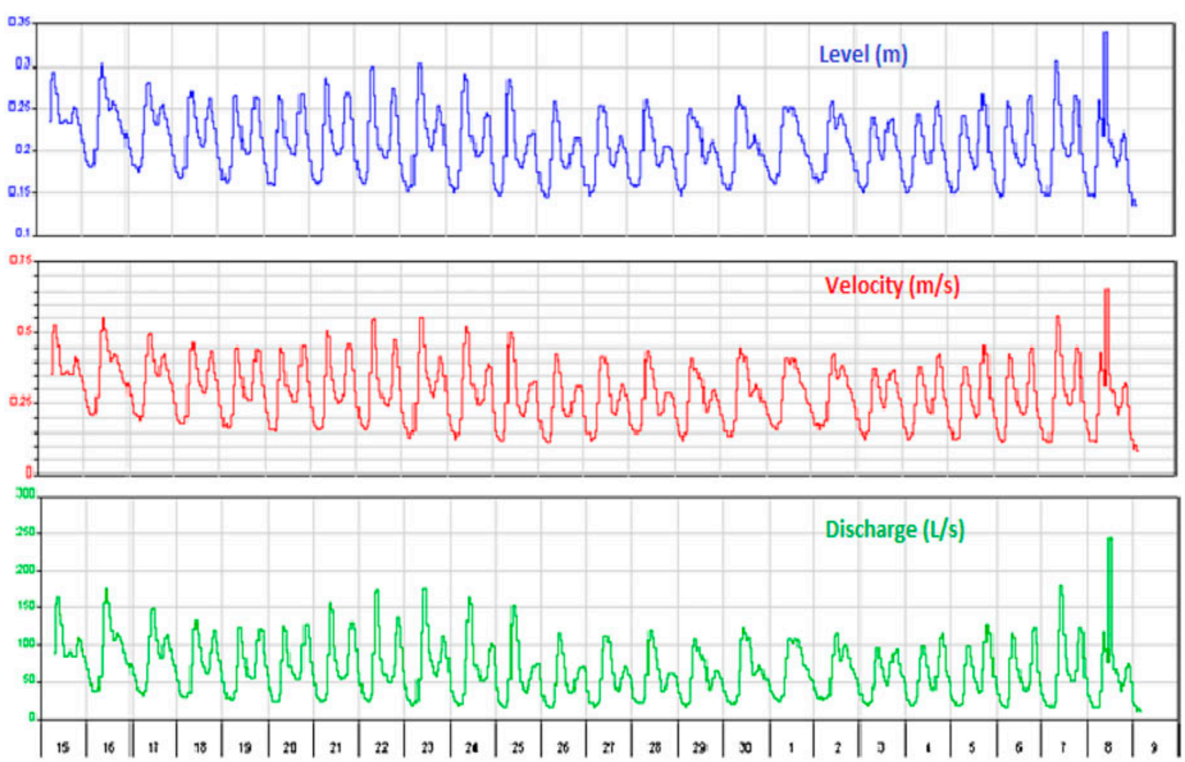

Fig. 4. Flow pattern from 15 September to 9 October 2006 in Ramsgate sewer carrier [6].

Table 1
Observed water quality in the raw sewage upstream of the plant [8]

Faecal coliform, CFU/100 mL × 10^6	18	14	25	49
BOD_5, mg/L	220	200	220	210
Suspended solids, mg/L	320	340	290	280
Turbidity, NTU	110	640	130	110
Salinity, mg/L	1,340	4,200	8,970	
pH	8.1	8.2	7.2	7.6
Ammonia, mg/L	44	43	26	36
TKN, mg/L	68	47	34	55
Total nitrogen, mg/L	68	66	44	65
Phosphorus, mg/L	9.5	9.8	9.6	11

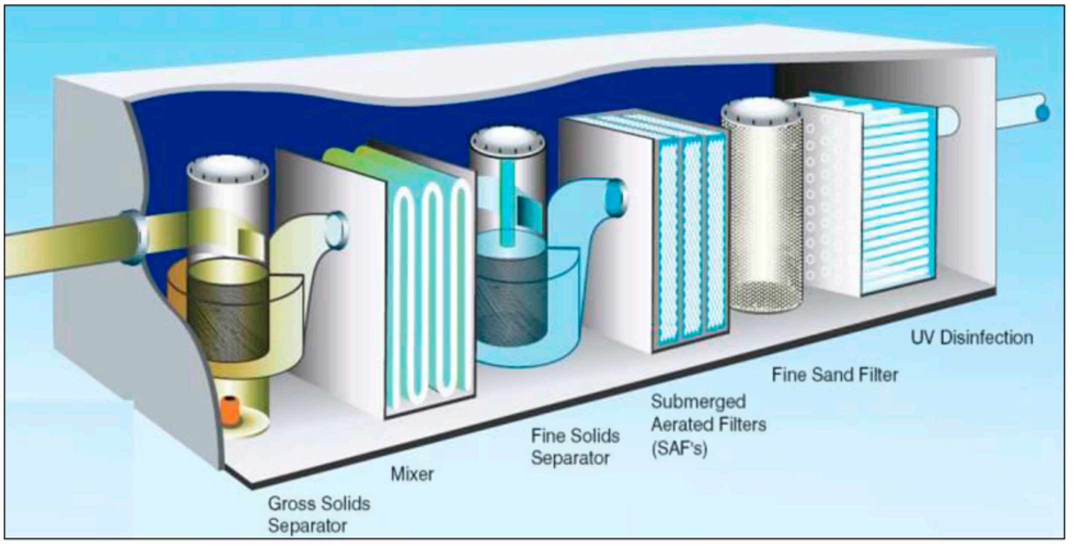

Fig. 5. Schematic of Water Mining treatment at Beverley Park Plant [8].

for membrane based options. It is important to note that none of the treatment processes included in the selected hybrid option have the ability to reduce the salt levels in the sewage. Salt content in the effluent would therefore largely remain unchanged from that found in the raw sewage. It was therefore critical to find a solution for this challenge in the design itself.

3.2. *Design solution for salinity*

Analysis of flow data with measured tidal levels showed appreciable tidal influx at 1.7 m Australian Height Datum (AHD) tide levels. In the absence of TDS observations in the sewer carrier, it was hard to assess the likely tidal impact. The Council therefore investigated the diurnal fluctuations of TDS in the sewage for viable operation of the proposed sewerage treatment plant.

Continuous monitoring (30 min time interval) of TDS, flow depths, temperature, dissolved oxygen and other chemical/bio-chemical constituents were undertaken in the sewer on 23 and 24 June 2005. Based on the results of sampling, the likely tidal influx and its impact on the sewer carrier were investigated. The flow depths were translated into flows in the carrier using hydraulic data available. The capacity of the sewer was estimated at approximately 1.14 KL/s. Plot of flow, TDS, measured Tide levels and flow depths in the carrier for a typical diurnal pattern are shown in Fig. 6.

TDS values in the sewer range from 615 to 19,100 mg/L. The impact of tide on TDS can be observed from a sharp rise in TDS 670–6,334 mg/L (afternoon at 16:30 h) when tide levels increase from 1.54 to 1.73 m. These observations concluded that tidal influx is dominant at about 1.7 m. Using simple mass

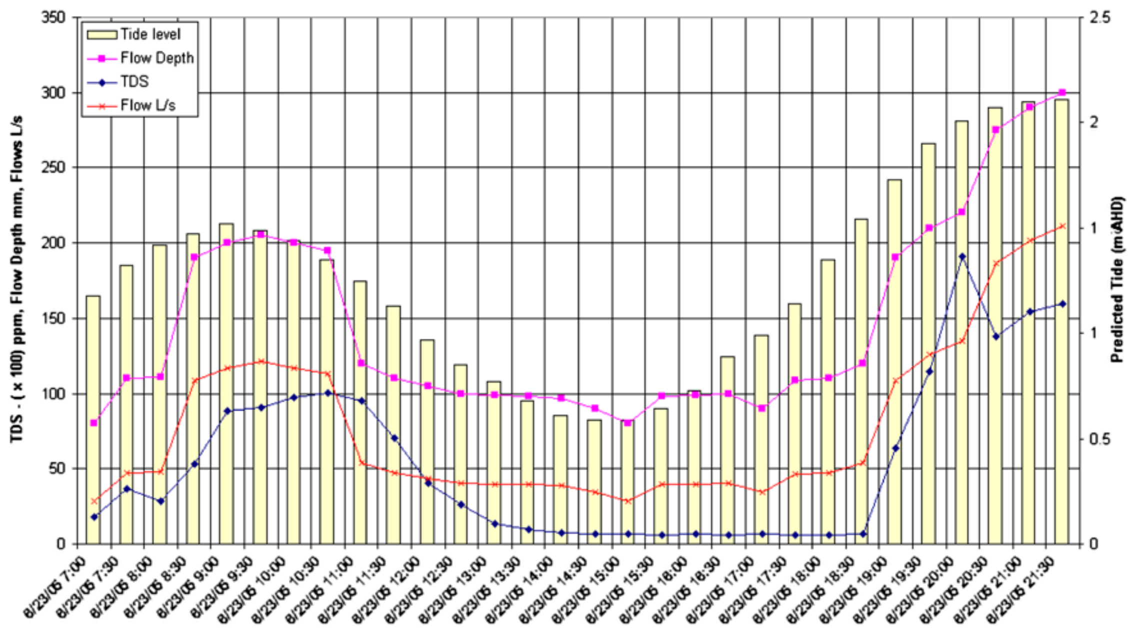

Fig. 6. Chart showing diurnal variation of flows, TDS and tide levels.

balance, with known concentration of TDS in seawater and typical domestic sewage, infiltration in the sewer was estimated shown in Fig. 7. It can be observed that there is a typical two-tiered infiltration inside the sewer pipe. The top tier, which is of relevance to plant design, is purely tidal influx that initiates when the tide reaches 1.7 m AHD. The lower tier of infiltration could be attributed to salt flushing below 1.7 m AHD or possibly a combination of groundwater influx and/or low-level tidal influx.

As highlighted in Fig. 7, a regression on the infiltration rates with tide levels show a trend (power) with good correlation (R^2 of 0.94) signifying that the infiltration from tidal influx is possibly the dominant process. This relationship was used to model the diurnal fluctuations in TDS loading in the sewer based on observed tide levels.

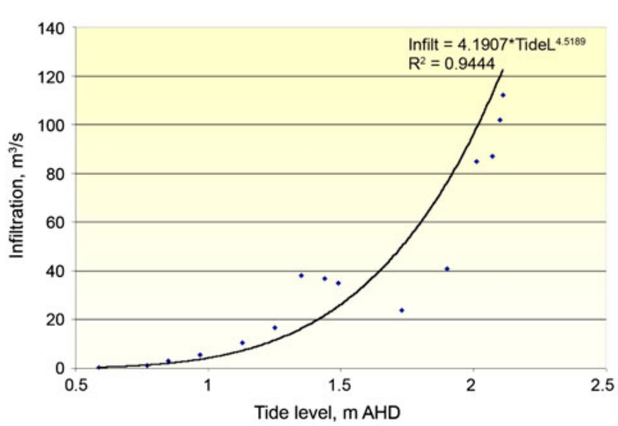

Fig. 7. Chart showing Infiltration rates in the sewer versus tide levels.

The above analysis indicated that there was a window of 4–5 h in the afternoons, during low sewerage flows, when the TDS is relatively low (<620 mg/L) in the carrier. This low salinity raw sewage can be pumped at 40 L/s to meet the peak water demand (750 KL/d). Process optimisation involved extensive modelling of sewer flows, TDS and process train to achieve the desired quality of effluent required for water reuse. The input process parameters were further validated by a demonstration plant that was commissioned to test the viability of the scheme prior to installation of the final treatment plant.

Fig. 8 shows the final optimised plant design that accommodates the high salinity in the raw sewage due to tidal influx. A 200 kL balance tank was included in the plant design after the fine and gross solid separation step, as shown in Fig. 8.

The introduction of a balancing tank into the plant layout to store low salinity primary treated effluent helped maximise the available window of low salinity water in the Ramsgate carrier. The rapid treatment capacity of the chemically assisted fine solid separation technology allowed the balancing tank to be placed after this primary treatment step [8]. Primary treated effluent from the balancing tank is subsequently sourced for further biological and other remaining treatment steps. Some operational controls

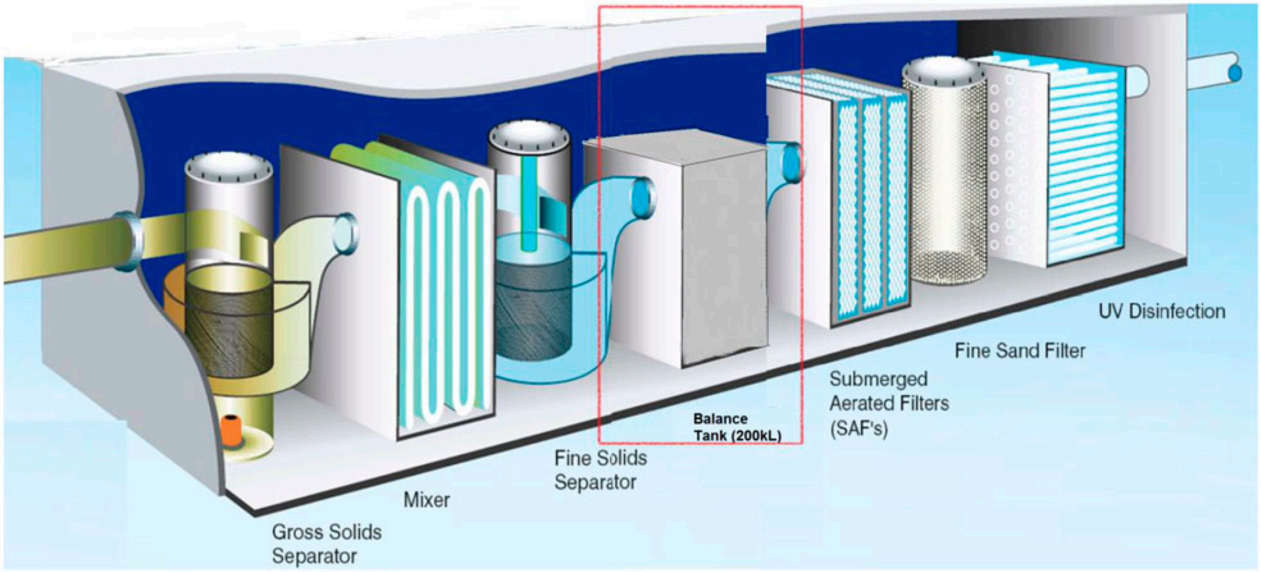

Fig. 8. Revised final schematic of Beverley Park Water Mining Plant.

were also introduced including online continuous monitoring of salinity that switches of the extraction pumps, in the event salt levels are found to be higher than the pre-set levels.

4. Conclusion

Given the climate change challenge facing by the planet and consequent emphasis on reducing carbon footprints, it is essential that our wastewater treatment technology options also address this important consideration. A membrane-based solution such as an RO filtration option to reduce salinity in the wastewater would typically consume between 3 and 6 kWh/kL of water treated. On the other hand the technology option chosen for the Beverley Park Water Mining plant uses between 0.5 and 0.75 kWh/kL of water treated for reuse. There is substantial savings in ongoing operational costs, as a result of the option selected.

This case study provides an optimised non-membrane design solution to treat the sewage to irrigation standards given high concentration of TDS in raw sewage. The study also provides the challenges in planning, design and commissioning of the water reuse plant intercepting sewer carriers prone to salt water intrusion. These sewer carriers are generally not considered as viable alternative given the quality of sewage and this study provides the valued knowledge that will assist in design of these schemes.

The innovative aspects of the Beverley Park Water Mining plant were acknowledged by the judges of the International Water Association's Project Innovation Awards. The project was selected as the winner of project innovation award for the Asia Pacific region in 2008.

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