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Selecting Sanitation Options: A Case Study of South Can Tho

TECHNICAL REPORT

September 2010

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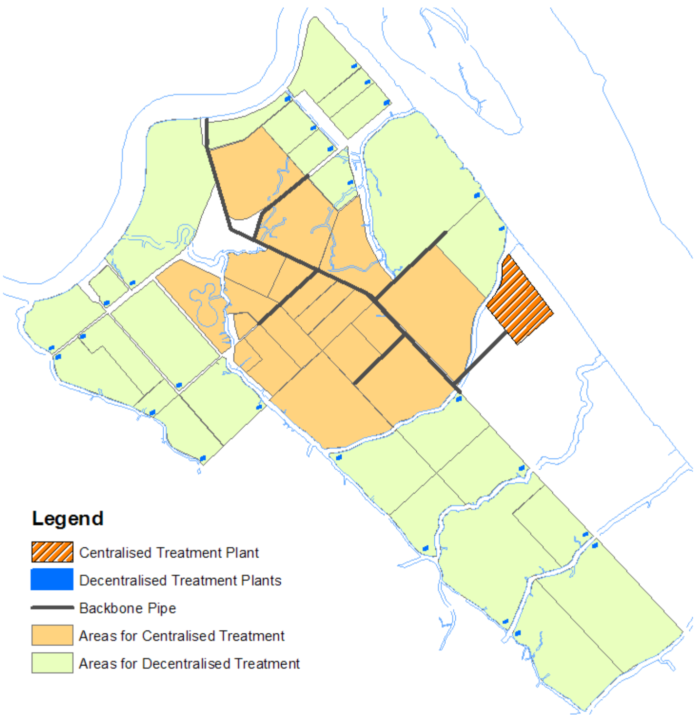
Executive Summary

The Institute for Sustainable Futures (ISF), from the University of Technology Sydney, in collaboration with Can Tho University (CTU) and Can Tho Water Supply and Sewerage Company (WSSC) completed a 2-year collaborative research project assessing the wastewater infrastructure options for Can Tho City. The comparison of alternatives was made on the basis of cost-effectiveness and on the relative sustainability of the options, as determined through a participatory stakeholder sustainability assessment process with several government agencies in Can Tho.

The study compared four wastewater management alternatives for the new urban area of South Can Tho with an area of 2080 hectares and likely to house more than 250,000 people in the future. The intent was to examine the applicability of recent innovations and international trends in wastewater management. Alternatives considered include centralised treatment (Option 1), decentralised treatment at the scale of several hundred households (Option 2), a combination of centralised and decentralised (Option 3, as shown below) and an option with resource recovery in decentralised areas (Option 4). The resource recovery option involves urine diversion and storage for use as fertiliser in nearby agricultural areas.

Layout of Option 3 – Centralised and Decentralised Treatment



Analysis of demographics, water-use and wastewater quality characteristics informed modelling of wastewater and nutrient flows. A collaborative process and various detailed contextual analyses informed the choice of wastewater technologies and the spatial configuration of each option. A technical design process for each option was conducted, including designing the requisite pipe network, pumping stations and treatment plant units. In terms of treatment technologies, the centralised treatment in Option 1 and 2 was a trickling filter, and the decentralised component in Options 2 and 3 used a sequence of anaerobic baffled reactor, anaerobic filter and a planted horizontal gravel filter. Option 4 used a recirculating sand-filter in decentralised areas with urine storage and transportation. All options included ultra-violet disinfection in order to meet national water quality discharge standards.

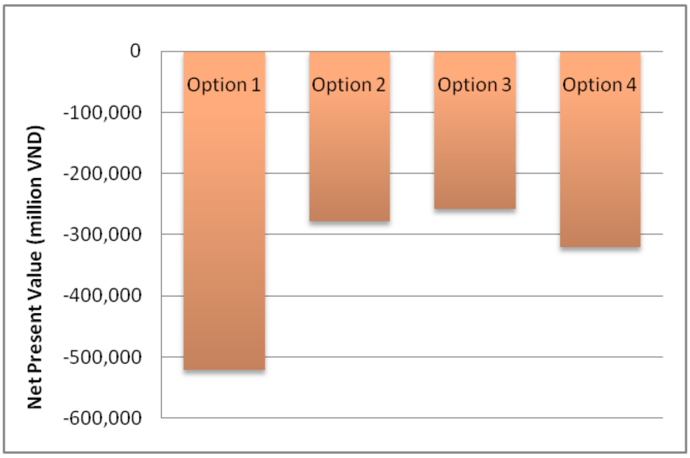
A **cost-effectiveness analysis** of four options was conducted that took into account the staging of developments in the new urban area. All capital and operation and maintenance costs were included (including energy, labour and equipment/asset replacement) over a 30 year period of analysis. A discount rate of 8% was applied to determine the net present value for each option.

Results of the cost-effectiveness analysis are detailed below. For South Can Tho, Option 3 (combination of centralised and decentralised) was found to have the lowest overall cost, both in terms of capital costs and operational costs. Option 1 (centralised) was found to have costs almost double that of Options 2 and 3. The lower cost of the options involving decentralised treatment is in part due to matching the timing of investments with the demand for the sanitation service, as the new urban area develops over time. The resource recovery option (Option 4) was found to offer significant benefits in terms of potential revenue from sales of fertiliser that far out-weighed the operation and maintenance costs for this option.

RESULTS OF THE COST ANALYSIS OF SANITATION OPTIONS

Cost of option in present value million VND (2010)	**Option 1 Fully centralised**	**Option 2 Fully decentralised**	**Option 3 Centralised / decentralised**	**Option 4 Centralised / decentralised with resource recovery in decentralised areas**
Present Value Capital Cost	517,000 (27m USD)	276,000 (14m USD)	256,000 (13m USD)	330,000 (17m USD)
Present Value Operation and Maintenance Cost	4,000	1,900	2,200	2,300
Present Value Revenue from Fertiliser Sales	-	-	-	11,800
Net Present Value	-521,000 (-27m USD)	-278,000 (-14m USD)	-258,000 (-13m USD)	-321,000 (-18m USD)
Levelised cost per household	20 (1,000 USD)	11 (600 USD)	10 (500 USD)	13 (700 USD)
Levelised cost per m^3 water consumed	0.064 (3.4 USD)	0.030 (1.6 USD)	0.029 (1.6 USD)	0.036 (1.9 USD)

NET PRESENT VALUE OF SANITATION OPTIONS



A participatory **sustainability assessment process** was conducted with project partners and seven government departments to consider the wider implications of each option. Criteria were developed collaboratively for five broad areas of concern: technical and risk, social, environmental, economic and financial, and finally, city future. Stakeholders engaged with relevant information about the options and made judgements of performance against the various criteria.

The conclusion of the sustainability assessment was that the most beneficial option would be Option 3 – a combination of centralised treatment for the area of densest population and close proximity to existing infrastructure, and decentralised treatment elsewhere. Technically, this option involves a small-scale capacity upgrade to the centralised treatment plant and use of a proven decentralised technology for less dense areas likely to be developed in the future. Socially, public health would be protected and affordability is ensured through relatively low operation and maintenance costs (which are the basis for setting tariffs). Environmentally, the energy requirement for pumping (and hence greenhouse gas emissions) is significantly less for Option 3 than for a fully centralised system, and the proposed treatment would contribute markedly to improved surface and groundwater quality. Financially, this option has the lowest net present value and levelised unit cost. Finally, in terms of Can Tho's future, this option was considered to contribute to innovation and demonstration of a new, tailored approach to wastewater planning that provides flexibility and adaptability to uncertainties such as the rate of urbanisation and potential climate change impacts.

The second preference was for Option 4 (urine diversion and use as fertiliser), with strong interest in this option for future wastewater planning. The costs of this resource recovery option demonstrated that the revenue stream from fertiliser sales was significantly larger than the operational costs of the wastewater system. Option 1 (fully centralised) was the least favoured option as it had the highest overall cost and lowest performance against environmental criteria.

Overall, city stakeholders in Can Tho demonstrated strong interest in the study and its findings. For a rapidly growing urban area such as South Can Tho, understanding the cost and sustainability implications of alternative sanitation infrastructure scenarios provides a much needed evidence base to assist government agencies in determining how best to invest and provide services. Can Tho city leaders have indicated that the results of the study will be taken into account in the next stages of infrastructure planning in South Can Tho.

More generally, often the technological solution for wastewater in urban areas in developing countries is assumed to be large-scale systems. The findings of this study challenge that premise. The study shows decentralised systems to be a valuable component in developing cost-effective, sustainable wastewater solutions, particularly in the face of uncertain rates of urbanisation and the context of climate change mitigation and adaptation.

CONTENTS

1 Introduction

1.1 Study purpose

The Institute for Sustainable Futures (ISF), from the University of Technology Sydney, in collaboration with Can Tho University (CTU) and Can Tho Water Supply and Sewerage Company (WSSC) completed a 2-year research project assessing the cost-effectiveness and sustainability of wastewater infrastructure options for Can Tho City. The Can Tho People's Committee approved the City's cooperation in May 2009 and the project was supported by an AusAID Australian Development Research Award grant.

The aim of the study was to undertake a collaborative, analytical, and robust decision-making process to select the most context-appropriate, fit-for-purpose, cost-effective and sustainable sanitation infrastructure solution for a case study area in Can Tho City. In doing so, the study tests the applicability of recent international changes and innovations in wastewater management to the context of Can Tho.

Importance was placed on strong collaboration between the UTS research team, CTWSSC and CTU. The process also engaged other city stakeholders including government departments, to foster a sense of ownership of outcomes and ensure the findings were realistic and applicable to the city of Can Tho.

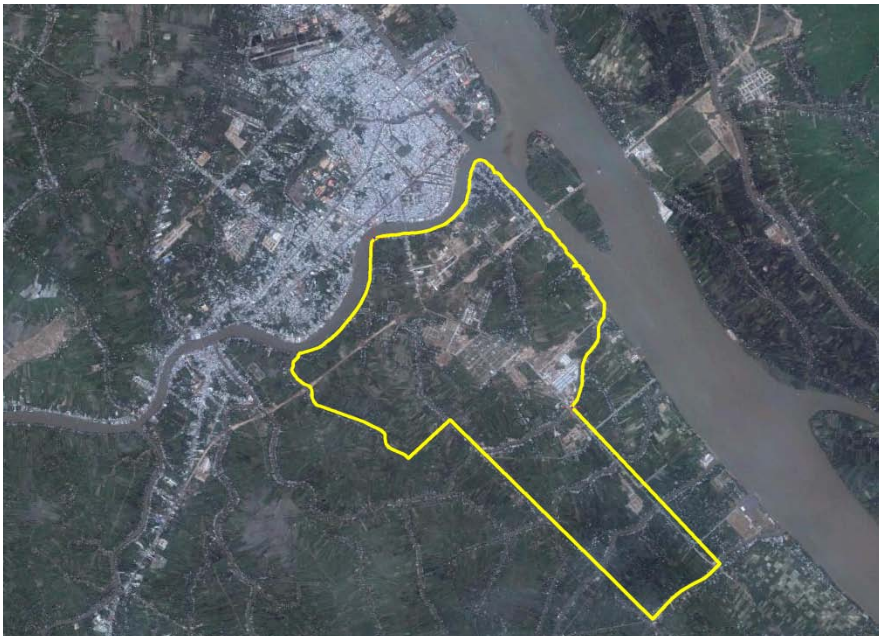
Specifically, the study developed and compared a set of four wastewater management alternatives which include centralised, decentralised and resource recovery options for the new urban area of South Can Tho. The comparison of alternatives was made on the basis of cost-effectiveness and on the relative sustainability of the four options as determined through a participatory sustainability assessment process.

1.2 Background

Wastewater challenges in Can Tho

Can Tho, a Class 1 city (a city with provincial status) in the Mekong, is facing rapid urbanisation. This study focused on South Can Tho and specifically on four wards in Cái Răng District: Hưng Phú, Hưng Thạnh, Phú Thứ and Tân Phú (Figure 1). This area of South Can Tho is a newly urbanising part of the city, mainly comprising new developments on green field sites without established infrastructure. Construction master plans for this area indicate a total population of 150,000 people, representing an increase from around 47,000. However if developments go ahead as currently planned by investors, then the analysis conducted for this research suggest that this population could reach as many as 278,000. The 1:2000 spatial plan of South Can Tho urban area was approved by the former provincial People's Committee by Decision No. 90/2002/QD-UB dated 04/10/2002 and 2207/QD-UB dated 02/07/2003 with a total area of 2,080 Ha.

Figure 1: South Can Tho study area



According to local stakeholders and the CTWSSC, there are several challenges that must be addressed in considering wastewater solutions for South Can Tho. These include:

- the uncertain rate of urbanisation;
- ensuring connections between developer's wastewater collection systems and a primary collection system;
- the affordability of likely tariffs required for households and access to funding for the Can Tho Water and Sewerage Supply Company to manage sewage;
- the flat terrain which makes use of a gravity sewer difficult; and,
- the high water table, low lying land and susceptibility to the impacts of climate change.

The first wastewater treatment plant (WWTP) in Can Tho is currently being constructed with financial and institutional support from German development agencies GTZ, KfW and DED. This treatment plant is located at Cai Sau in South Can Tho, but under current plans will only treat wastewater from the existing urban centre in Ninh Kieu to the north of Can Tho River as it was not designed to accommodate wastewater from the new South Can Tho urban area. A capacity upgrade of this treatment plant is a potential option under consideration by CTWSSC and DoC for treating wastewater from South Can Tho, and is one of the options analysed in this study.

In addition to financing the Cai Sau WWTP, German development agencies are providing support to build the managerial, financial and organisational capacity of CTWSSC and to assist in the transition to new forms of costing and pricing for wastewater management.

Innovations and international trends in wastewater management

One of the purposes of this study was to examine the applicability of recent innovations and international trends in wastewater management in the context of rapidly developing cities such as Can Tho.

New drivers such as climate change impacts, concerns about energy use and uncertain rates of urbanisation have increased the need for flexibility, adaptability and low-impact solutions. In this context the use of both decentralised and centralised wastewater management technologies (and combinations of the two) is replacing the former traditional approach to large-scale urban wastewater infrastructure.

In addition, resource recovery is a growing concept in wastewater treatment, in which important nutrients such as nitrogen and phosphorus are recycled and sold as fertiliser. The approach is driven by concern about the loss of finite reserves of phosphorus for manufacturing commercial fertiliser and the damage created by introduction of excessive amounts of nutrients (nitrogen and phosphorus) from wastewater into waterways. It presents the possibility of an income stream from wastewater treatment. Technologies for separating wastewater streams and the use nutrients from wastewater as fertiliser have been tried and proven internationally, including in northern Europe and in Asia, for example in Beijing and also in Cagayan de Oro in the Philippines (see www.susana.org for case study information and fact sheets).

Development of the project through a consultative process

Consultative processes shaped each stage of the study. South Can Tho was proposed as the case study area by CTWSSC, and throughout the study project partners CTWSSC and CTU shaped the direction of the study, informing decisions relating to selection of options for analysis, choice of technologies for costing and analysis of sustainability considerations for each scenario.

The project was given official endorsement by the Can Tho People's Committee in May 2009. A range of government agencies were consulted in Can Tho on commencement of the study in June 2009, including the People's Committee, the Department of Planning and Investment, Department of Construction, Department of Natural Resources and Environment, South Can Tho Urban Administrative Authority and the Institute for Urban and Rural Planning and Architecture. Consultation with these agencies ensured all appropriate legal obligations were being taken into account and the various institutional perspectives on wastewater management were understood.

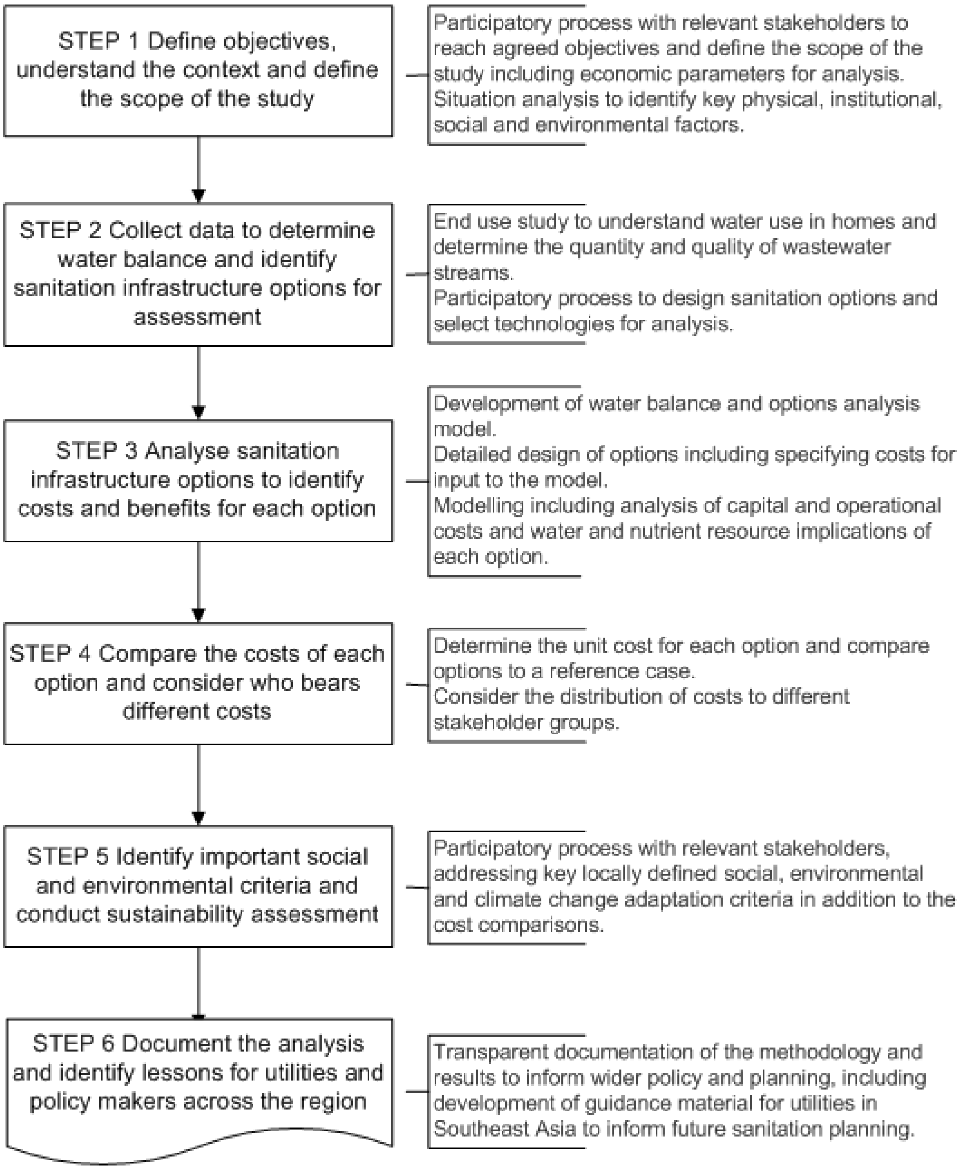
In June 2009 a set of wastewater configurations were identified and agreed upon in collaboration with CTWSSC. In October 2010 ISF hosted members of CTWSSC and CTU in Sydney and further work was completed focusing on the development process happening in South Can Tho.

In January 2010, in collaboration with CTWSSC, final decisions were made about the spatial planning of options and specific wastewater technologies most appropriate to the Can Tho context to include in the study. Following detailed research and analysis into the cost-effectiveness of each of the options, in July 2010 a sustainability assessment of the options was undertaken as a participatory process involving representatives from project partners and a range of city agencies.

2 METHODOLOGY

The cost-effectiveness of sanitation options was assessed drawing on an approach developed by the Institute for Sustainable Futures with five Australian water utilities and an environmental agency (see Mitchell et al., 2007). The sustainability assessment involved key stakeholders deliberating on a set of locally determined institutional, socio-economic, environmental and climate change adaptation criteria. Adapting the approach for the Can Tho context, the planning process included steps as described in Figure 2.

FIGURE 2: PROCESS FOR ASSESSING THE COST-EFFECTIVENESS AND SUSTAINABILITY OF SANITATION OPTIONS



Four different configurations for wastewater treatment were considered as part of the study and are detailed in Table 1 below.

TABLE 1: CONFIGURATIONS FOR WASTEWATER TREATMENT CONSIDERED IN THE STUDY

Option	Description
Option 1 Fully centralised	Connect all new developments to Cai Sau Wastewater Treatment Plant (WWTP) which is currently under construction and significantly upgrade the capacity of this treatment plant to accommodate the increased wastewater flows.
Option 2 Fully decentralised – separate systems for each development area	Install local decentralised wastewater treatment plants at all development lots. Each installation would service multiple households within development precincts.
Option 3 Combination of centralised system and decentralised systems	Connect selected new developments (determined by spatial analysis of a relevant parameters) to Cai Sau WWTP. Provide decentralised wastewater treatment technologies for other developments.
Option 4 Combination of centralised system and decentralised systems with urine separation for decentralised components	Connect selected new developments to Cai Sau WWTP (as for Option 3). Provide decentralised wastewater treatment technologies for other developments, including urine separating toilets. Collect and treat urine for agricultural reuse as fertiliser. This option builds on a pilot ecological sanitation project recently undertaken by Can Tho University.

A further option that included separation of blackwater (toilet only) from greywater (remainder of domestic wastewater) was initially considered and then discarded at an early stage of analysis for two reasons. First, the dual pipe-work and pumping in flat terrain had a prohibitively high cost. Second, wastewater quality analysis demonstrated significant faecal coliforms in the greywater, meaning this stream would have required disinfection, negating any potential cost saving associated with separating the streams.

3 Findings of Contextual and Technical Analyses

In order to develop detailed design of wastewater options from the initial configurations, a series of contextual and technical analyses were conducted as detailed below.

3.1 Domestic wastewater treatment policy and legislation

Prime Ministerial Decision 758 (2008) on urban upgrading requires that 45% of sewerage in urban areas is collected and treated by 2020. Prime Ministerial Decree 88 (2007) requires that the drainage system in all newly developed areas must be designed to provide separate systems for stormwater and wastewater. Detailed requirements regarding wastewater network design are outlined in Standard TCVN 7957: 2008. The requirements for effluent quality after treatment of domestic wastewater are covered in the national regulation QCVN 14:2008/BTNMT – National technical regulation on domestic wastewater (Table 2). In South Can Tho, wastewater is required to be treated for discharge into Class A water bodies (water resources for domestic use).

Table 2 QCVN 14 National technical regulation on domestic wastewater

Parameter	Unit	Quality required for discharge to receiving water body CLASS A	Quality required for discharge to receiving water body CLASS B
pH	-	5-9	5-9
BOD	mg/l	30	50
TSS	mg/l	50	100
Dissolved solids	mg/l	500	1000
Sulfur	mg/l	1.0	4.0
Ammonia (as NH^+_4)	mg/l	5	10
Nitrate (as NO^-_3)	mg/l	30	50
Fat and oil	mg/l	10	20
Surfectants	mg/l	5	10
Phosphate	mg/l	6	10
Faecal Coliforms	MPN/100mL	3000	5000

3.2 Planning processes for infrastructure in new development areas

Oversight of planning and managing urban sanitation systems in Vietnam is spread across a number of agencies. For Can Tho (as a Class 1 City), city level masterplanning and construction plans requiring significant investment must be approved by national bodies, while planning for areas within the city is managed by city departments. Coordination between construction masterplanning, socio-economic development planning and development planning at the local level can be problematic, and local construction sometimes precedes finalisation of higher level plans.

At the national level, sanitation planning for urban areas is governed by the Ministry of Construction (MoC), which is also responsible for the Construction Master Plan (usually referred to simply as the Master Plan) for the City. A new City Master Plan is currently under preparation by national and international consultants for MoC. At the city level the Department of Construction (DoC) oversees construction masterplanning processes. DoC has commissioned a revised master plan for South Can Tho and this study has drawn on a number of drafts of this plan. At the local level, the South Can Tho Urban Administrative Authority (UAA, an authority appointed by the City) oversees the submission of 1:500 development scale plans from various public and private sector developers.

In principle, construction master plans are driven by overall socio-economic development plans (SEDPs). Socio-economic development planning and investment are led by the Ministry of Planning and Investment (MPI) with provincial and city level plans prepared on its behalf by the Hanoi-based Development Planning Institute (DPI).

Some aspects of water quality and environmental regulation sit with the national Ministry of Natural Resources and the Environment (MONRE) and the equivalent city level Department of Natural Resources and Environment (DoNRE).

Ultimate decision making on all these plans at the city level is the responsibility of the People’s Committee.

3.3 Analysis of wastewater generation and flows

The two sections below explain how the wastewater quantities were calculated, and include description of the results of a water end-use analysis followed by analysis of development plans in South Can Tho to provide a realistic population projection.

Water end-use analysis

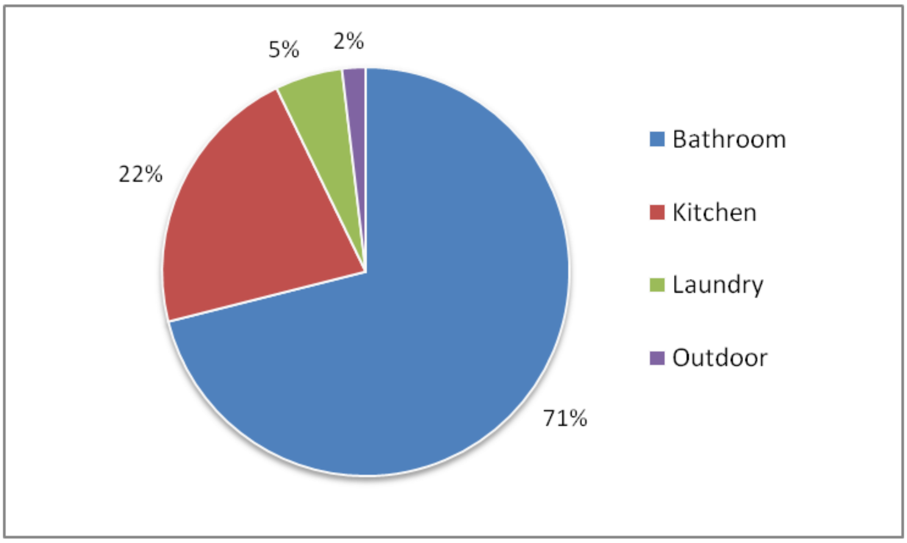
The standard approach in Vietnam for planning water and wastewater infrastructure is to utilise the Ministry of Construction Standard TCXDVN 33-2006 in which the norm for water supply for 2015 is 165 litres/capita/day, and for 2025 is 200 litres/capita/day. In this study an empirical approach was taken using an end-use analysis of actual water-use in 200 houses in South Can Tho, as well as analysis of samples of billing data for this and other parts of the city. This ‘bottom-up’ approach is consistent with international best practice in urban water planning in which actual water use is used as the basis for planning and design rather than broad standardised norms of consumption (Turner et al., 2008).

The ‘water end use study’ involved a survey of water use in 200 households in South Can Tho in December 2009 and was completed by staff and students from CTU in collaboration with CTWSSC. The study investigated how water is used in different types and sizes of households, including low income, middle income and high income.

Within each housing group, the study examined the range of different water uses, water-use technologies and the proportions of overall water consumption associated with each end-use. This information is critical for understanding realistic materials flows and how separation of different streams (for example grey water and black water) might work in practice.

Data analysis provided results that are different from standard end use assumptions in Australia, for example the bathroom appears to be the largest household water use and outdoor use is minimal (see Figure 3). This low proportion of outdoor use means that a significant portion of the water consumed will be translated into wastewater that requires treatment. There were no significant differences in water-use depending on the different numbers of floors of houses (which was seen to be indicative of socio-economic status). The data-set for stand-alone villas was too small to draw any conclusions, however it appeared likely that villas have higher overall water-use than row houses.

FIGURE 3: PROPORTION OF WATER USED FOR DIFFERENT END-USES BASED ON SOUTH CAN THO END-USE STUDY



Non-residential water-use intensities were calculated based on a small sample of billing data provided by CTWSSC. These varied from 0.001-0.045 m^3/m^2/day with restaurants and health-care facilities showing the highest water-use. These are in line with Australian figures on water use intensity in commercial and administrative buildings (for example see Bannister et al., 2005 and Stockland, 2009).

For residential areas, a wastewater factor of 95% was used (that is, an assumption that 95% of water consumed would become wastewater). This is higher than the norm of 80% which is used in calculations in Vietnam (as described by Decree 88), however is expected to be more accurate given the low proportion of outdoor water-use. For non-residential areas, it was assumed that 80% of the water consumed was released as wastewater.

These results underscore the need for local data collection and understanding of water supply practices as well as water use habits and norms. Although not included as part of the scope of this study, such end-use information would also be extremely useful for planning water conservation measures and programs. Demand-side interventions will be important in future years to reduce water and wastewater treatment costs and energy use, and in response to environmental pressures including climate change and saline intrusion.

Analysis of development plans and project populations

The total wastewater quantity for South Can Tho was calculated on the basis of projections for individual 'development lots' for which plans had already been submitted to the South Can Tho Urban Administrative Authority (UAA). The UAA has oversight of the development of the case study area. At the time of commencement of the study, detailed developer plans had been submitted to the UAA for 16 lots covering about half the land area.[1] These plans provided the basis for the calculations and cost-analysis conducted in this study. Overall, the South Can Tho area of 2,080 hectares has been divided into approximately 40 development lots sized from 5 to 150 hectares with predicted populations ranging from 1,000 to 25,000.

The projected total population for South Can Tho was calculated to be 278,000 people. This calculation was based on existing development plans about half the development lots, for which the number and type of housing was available. For other lots where development plans were not available, estimates were made based on similar or neighbouring development lots. This projection is significantly higher than the projection of 120,000-150,000 people put forward in the construction master plan for Can Tho City approved by the Prime Minister at Decision 207/2006/QD-TTg dated Sep 07, 2006. In this study the population projection is built up from the actual number of dwellings proposed (55,600 dwelling) and an average occupancy rate of 5 people (based on the end-use study and also see Slingsby and Do Xuan Thuy, 2002). A population projection of 278,000 was therefore used as the basis for detailed modeling. A sensitivity analysis of the costing results was performed to determine whether similar or different results would be obtained for the lower population projection of 150,000 people.

Total wastewater generation

Based on the water end use and population analyses, it was calculated that once the case study area is fully occupied, wastewater

[1] More recently the UAA informed the team that there are now 26 development projects being carried out by 19 investors, of which 23 projects have approved 1/500 drawings and 3 approved concept plans. These include 19 residential areas, 6 resettlement areas and 1 driving school. Currently 12 projects have commenced infrastructure construction (5 mostly and 7 partly completed). The outstanding 14 are in investment preparation procedure.

generated would amount to 58,000m^3/day. Calculations were completed in an Excel model as shown below in Figure 4.

FIGURE 4: EXTRACT FROM WATER AND WASTEWATER BALANCE MODEL

	A	C	D	E	F	G	H	I	J
1	Calculate waterwater and nutrient production per development								
2									
3	Building description	Area (m2)	No. properties	Water demand (m3/day)	Wastewater discharged (m3/day)	Blackwater discharged (m3/day)	Greywater discharged (m3/day)	P produced (kg/day)	N produced (kg/day)
4	Lot	8000							
5	Row-house -Trading and service m	23,871							
6	Villa	20,621							
7	High-end apartment building	39,745		1206	1146	72	1074		
8	Hotel	50,993	5	79	63				
9	Trading center	40,106		334	267				
10	Financial center – Office building	51,563		356	285				
11	Foreign language & Tourist school	9,187	1	82	66				
12	Healthcare facility	4,200	1	189	152				
13	Preschool facility	7,300	1	65	52				
14	Land for transportation and green s	156682							
15	Totals	404,268		2312	2031	72	1074	10	69
16		376,179							
17									
18	Lot	10000							
19	Row house 4 storey	135578	1107	835	793	50	743		
20	Villa	25682	78	59	56	4	52		
21	Semi detached villa		64	48	46	3	43		
22	Public & service facilities	209882		1451	1161				
23	Land for green space	4404							
24	Totals	375546		2392	2055	57	838	12	86
25		617,952							
26									
27	Lot	1200							
28	Section A & B								
29	Row house independent structure	14734	183	138	131	8	123		
30	Row house shared structure 5-9 sto	47791	82	62	59	4	55		
31	Villa	25704		0	0	0	0		
32	Administration buildings	27175		188	150				
33	Public & service facilities	36977		256	204				
34	Land for green space	14467							
35	Totals	166848		643	545	12	178	1	10

Non-res calculation | V, VV, N Balance | Summary - flows | Option Infrastructure | Unit Costs | Option 1 costing | Op1_ass | Option 2 costing | Option 3 costing | Option 3 costing separ

3.4 ANALYSIS OF WASTEWATER QUALITY

In order to design appropriate treatment systems, it was imperative to have local information about wastewater quality that takes into account the pre-treatment of blackwater in household septic tanks. As wastewater treatment is a relatively recent activity in Vietnam, there is little data to draw on. The only local data available was that used to design the KfW treatment plant which concerned combined raw wastewater quality (rather than domestic wastewater alone). No further information was available through CTWSSC or CTU. Analysis of wastewater quality was therefore conducted by the Centre for Natural Resources and Environment Monitoring (CNREM), Can Tho.

CNREM collected and analysed effluent samples of black water (after treatment in a septic system), greywater and combined wastewater from a small set of houses in Can Tho in April 2010. Some results were discarded as outliers, and combined wastewater results were all discarded since interference from stormwater gave confusing results with very high suspended solids and low nutrient concentrations. The average of the remaining samples based on appropriate proportions of blackwater and greywater are shown in Figure 5.

Figure 5: Analysis of raw wastewater in Can Tho compared with other raw wastewater figures from other sources

Parameter	Source			
	CNREM	KfW	Metcalf/Eddy	Henze/Ledin
BOD (mg/L)	190	192	210	250
COD (mg/L)	223	265	625	530
Suspended solids (mg/L)	141	350	210	300
Total N (mg N/L)	33.5	6	35	30
Total P (mg P/L)	3.6	3	7	10
Fat oils and greases (mg/L)	47	-	-	-
Coliform (MPN/100mL)	1.3×10^{6}	2×10^{5}	5×10^{7}	5×10^{10}

Sources: 1- CNREM analyses from samples in Can Tho, based on calculated proportion of black and grey water (with min and max calculated as one standard deviation from the average) 2- Feasibility study, Wastewater System of the Central Area of Can Tho city 3- (Tchobanoglous and Burton, 1991) 4- (Henze and Ledin, 2001), p.60

From the results presented in Figure 5 it is apparent that the combined wastewater analysis previously conducted in Can Tho city in preparation for the KfW plant was for a stream that is likely diluted with stormwater, since there is no separate stormwater system. It is also clear that the presence of septic tanks reduces the suspended solids as compared with raw wastewater quality in textbooks. In addition, it can be seen that the result for coliforms in the CNREM analysis is slightly low as compared with international figures.

3.5 Analysis of nutrient content of wastewater streams

Nitrogen, Phosphorus and Potassium loads associated with wastewater streams in South Can Tho were estimated using assumed N, P and K loads for Vietnam of 3.13, 0.45 and 1.8 kg/p/a respectively (N and P from (Wohlsager et al., 2009) using the formulas of (Jönsson and Vinnerås, 2003); K from (Jönsson and Vinnerås, 2003) based on calculations for China). Results of the end use study were used to estimate the quantity of each wastewater stream including blackwater, urine and brownwater (faeces + flushwater). Loads of N, P and K associated with urine were determined based on the distribution of nutrients between urine and faeces as described by Jönsson and Vinneras (2003) where 88% of N, 67% of P and 73% of K are in urine. Total calculated nutrient loads associated with urine wastewater flows from South Can Tho are shown in Table 3.

Table 3: Calculated nutrient content of urine wastewater flows in South Can Tho

Nitrogen	2.75 kg/p/a
Phosphorus	0.30 kg/p/a
Potassium	1.31 kg/p/a

3.6 Spatial analysis of case study area

Two of the options under consideration included a combination of centralised and decentralised treatment systems. Analysis was therefore required to determine the boundary between areas where wastewater would be treated in the centralised system and those where decentralised treatment would be appropriate. Consultation with CTWSSC and CTU informed the choice of boundary, and spatial analysis using Geographic Information Systems (GIS) was used to finalise the decision.

Parameters included in the analysis were:

- Predicted population density based on calculated population projections (with reference to planned administrative and business districts).
- The staging of developments over time (the year in which each development plot is predicted to be complete as estimated by CTWSSC).
- Pumping distances required for different configurations.
- The availability of green space (important for technologies such as subsurface constructed wetlands).
- The location of major canals suitable for discharge of treated wastewater.
- The location of major roads, to avoid requirement for pipes to be placed under large roads and intersections.

Figure 6 illustrates the anticipated population density for different parts of South Can Tho and Figure 7 shows the anticipated staging of developments over time.

Figure 6: Anticipated population density for development lots in South Can Tho

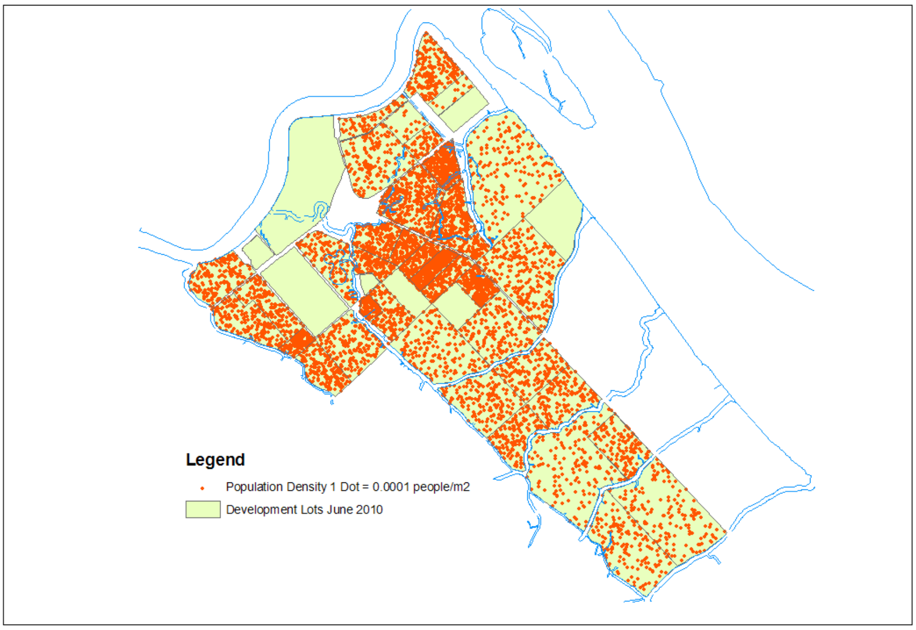


Figure 7: Anticipated staging of developments over time in South Can Tho

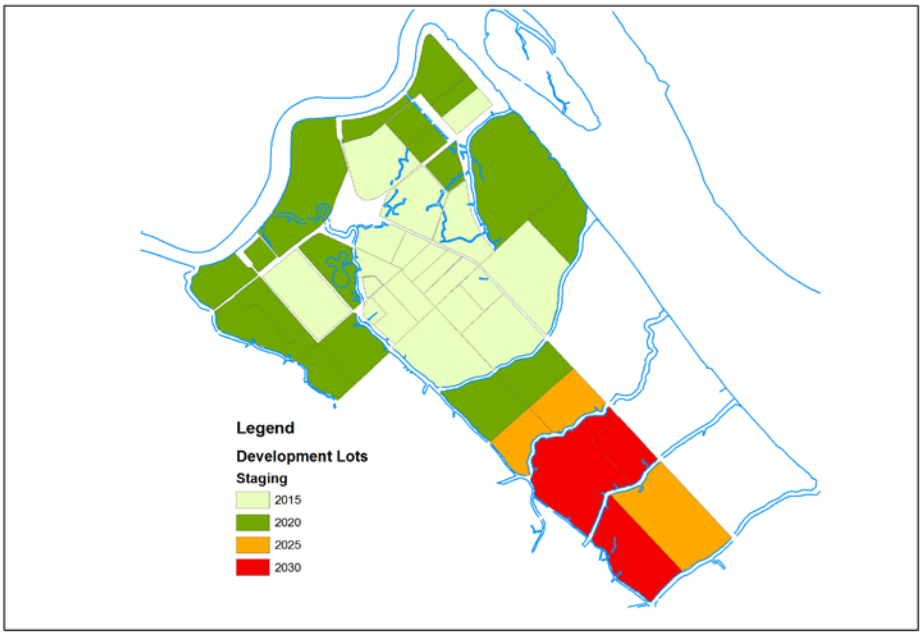
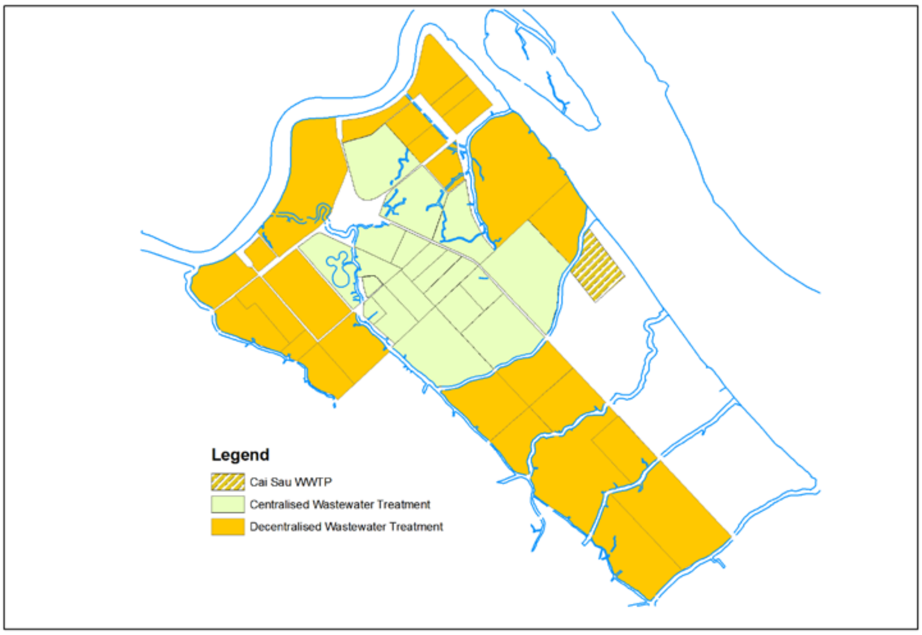


Figure 8 shows the boundary between areas to be treated centrally through an upgrade of Cai Sau WWTP and those where decentralised systems were considered for Options 3 and 4.

Figure 8: Final configuration for division of areas to be serviced by centralised and decentralised wastewater treatment



3.7 Criteria and considerations to inform technology choice

There are a large number of potential technologies which could be employed at the centralised and decentralised scales. For all options a septic tank was included at the household scale and was followed by additional treatment to meet the national standard QCVN 14. For options that included a centralised wastewater treatment component, an upgrade of Cai Sau wastewater treatment plant was envisaged. This treatment plant uses a trickling filter for biological treatment and anaerobic sludge digestion for stabilisation. For the decentralised technology choice, a range of parameters were elicited and considered (Table 9) informing the final decisions made by the research team in collaboration with CTU and CTWSSC and in consultation with DoC and DONRE.

Table 9: Considerations selecting decentralised wastewater technologies for inclusion in the study

Proven	Whether the technology been proven successful at full-scale application (ideally in a tropical developing country)
Land and landscape	Land area requirements Landscape aesthetics Avoids potential breeding of mosquitoes Avoids odour issues
Geography and climate	Ability to cope with high water table Ability to cope with flat topography Ability to cope with high rainfall peaks Resilient to the impacts of climate change
Energy	Low energy requirements to mitigate climate change impacts Ability to cope with intermittent electricity
Skills required	Operation/Maintenance requirements (skills and frequency) Monitoring requirements (skills and frequency)
Regulations	Meets appropriate effluent quality (QCVN 14) Preference for locally available materials and technologies (Decision 1930)
Function	Available to treat wastewater at appropriate scale (volume for predicted population) for South Can Tho developments and density Reliability – ability to cope with variability in influent flow/quality

The final decision was to include anaerobic systems (baffled reactor followed by anaerobic filter) with a planted horizontal gravel filter and disinfection step for decentralised systems in options 2 and 3. This system performed well against almost all of the above criteria and considerations and could be designed and constructed locally unlike many decentralised package systems which would need to be acquired from foreign companies. For greywater and brownwater (faeces + flush water), a recirculating sand filter was selected, again as a robust technology that could be designed and constructed locally. A further option using an innovative decentralised environmental technology that includes macro-organisms and micro-organisms was initially included and later discarded due to lack of availability of local cost information.

4 Wastewater Treatment Options

The options considered are described in detail below, including common features, the different spatial configuration, treatment trains and unit costs of various components that were used as inputs to the cost-effectiveness analysis which is described later in Section 5.

4.1 Common features for all options

All four options have a number of features in common. The chosen technologies for all options are all designed to meet QCVN 14 effluent standard Class A, for disposal into waterways which may be used as a drinking water source.

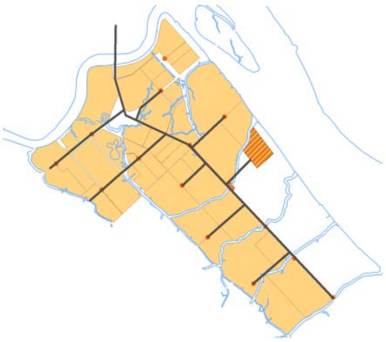
In all options, the local pipe network (within areas of 400-500 houses) included is a pressurised pipe network. This type of network was chosen to avoid construction challenges associated with the extremely flat terrain, which would require pipes to be set at depths beneath the high water table (at 1m) to allow for gravity flow. It is recognised that this solution is more expensive and has higher energy consumption than a gravity system. For the basis of comparison this approach was kept consistent between the different options, since the main purpose of this study is to compare the four options. During implementation of the final chosen option it will be important to study the feasibility and benefits and concerns of each possibility, and take into account any existing infrastructure already constructed by developers.

All options use the same disinfection technology: ultra-violet treatment in order to meet the effluent standard. This method of treatment was chosen due to concerns about environmental harm associated with chlorinated compounds if chlorine were to be used, and the prohibitive cost of technologies such as ozone and micro-filtration. Ultra-violet disinfection requires a filtration pre-treatment step to reduce turbidity for which a sand-filter or disc filter may be used.

The cost for electricity used in calculations for all options was 1,020VND/kWh in 2011 and assumed to rise at a rate of 2%. Cost of labour was taken as 105,000VND/person day in 2011 based on analysis by CTWSSC for labour costs associated with Cai Sau WWTP and assumed to rise at a rate of 5% each year.

For all options a discount rate of 8% was used in the analysis as this rate is indicative of a government funded project in Vietnam. Analysis used a 30 year timeframe to account for operation and maintenance as well as asset replacement costs.

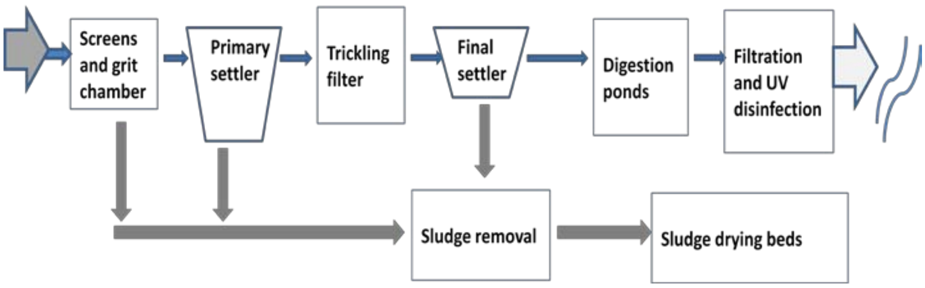
4.2 Details of treatment options



Option 1 – Fully centralised treatment

This option involves upgrading of the 30,000m^3/day Cai Sau treatment plant by an additional 66,940 m^3/day (for maximum population of 278,000) using trickling filter technology (as employed in the Cai Sau treatment plant currently being built) followed by additional ultra-violet disinfection (Figure 10).[2] A backbone sewer pipeline would be installed along the spine road in parallel to the KfW pipeline.[3]

Figure 10: Treatment train for Option 1



In the present value calculation (presented in Section 5), the following unit costs were used. Capital costs included the pipe network (with costs for pipes and digging trenches sourced from various suppliers) and 138,000 million VND for the backbone system based on estimates prepared by CTWSSC with additional pumps between development plots and the backbone.

Costs for the upgrade of the Cai Sau treatment plant were based on scaling up the costing figures for the KfW project on the basis of the flow required, totalling 231,000 million VND for the plant (excluding tendering, consultancy, project management and physical contingency costs). The costs of disinfection were 18,000 million VND based on international prices since this equipment would be imported. Operation and maintenance costs included those for

[2] Cai Sau WWTP was designed at a time when the relevant Vietnamese standard for the effluent was TCVN 5945-1995 in Category B which did not have any requirement on the level of coliforms, hence the need for an additional disinfection step to the process in the context of this study.

[3] The pipeline for Cai Sau WWTP is already at capacity based on wastewater collected from Ninh Kieu, the urban area to the north of South Can Tho and hence an addition pipeline is required.

energy, labour and an annualised equipment replacement cost for the network, pipes and the treatment plant during the 30 year analysis time-frame. The land available at the Cai Sau site is 25 hectares which would likely be sufficient to house the proposed upgrade.

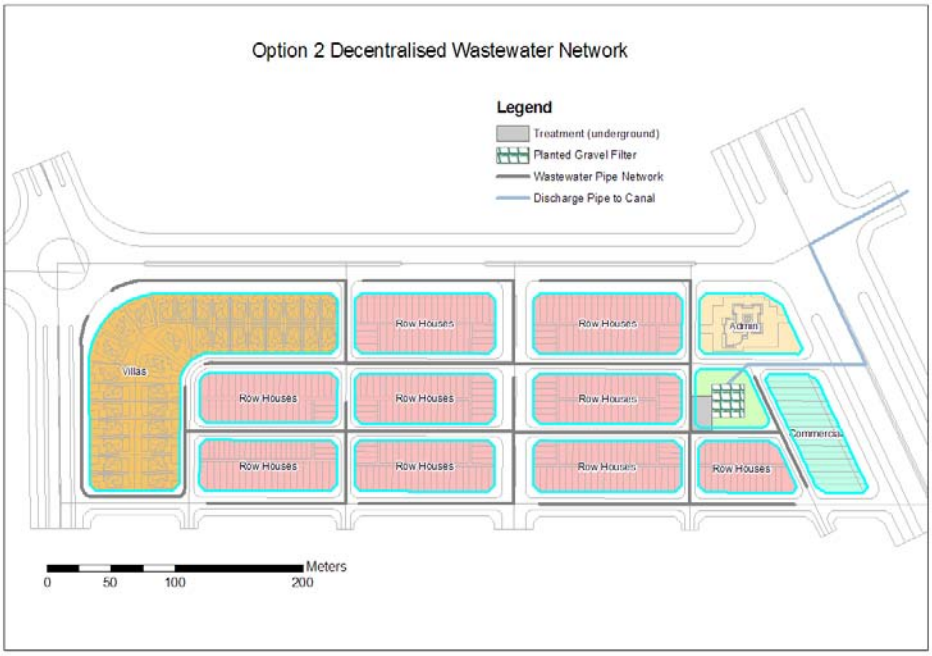
Option 2 – Fully decentralised treatment

Installation of local treatment plants for every 400-500 houses, each treating 500m^3/day using a technology suited to residential areas. For the whole study area, this results in a total of 115 local treatment plants. Whilst this size of treatment plant was used in this study, it is also possible to use the same technology at a larger scale for 1,000 or 1,500 houses by implementing a modular design.

The technology is an anaerobic baffled reactor, anaerobic filter and horizontal planted gravel/small stone filter followed by ultra-violet disinfection. This treatment technology (without the disinfection component) has been successfully employed widely in South East Asia by BORDA and other agencies (for example see Nguyen et al., 2010).

This decentralised wastewater technology is suitable for residential areas as it requires a relatively small land area (1,000m^2 to treat 65,000m^2 of residential and non-residential buildings), tanks are underground and the planted gravel filter has the appearance of a garden area. The tanks take up an area of 432m^2 which could be used for pavement or parking (whilst still ensuring tanks are accessible), and the planted filter takes up an area of 651m^2. The layout of infrastructure for a development plot is shown to scale in Figure 11. Each decentralised system would be built at the time it is required, which provides flexibility to adapt to the actual rate of urbanisation.

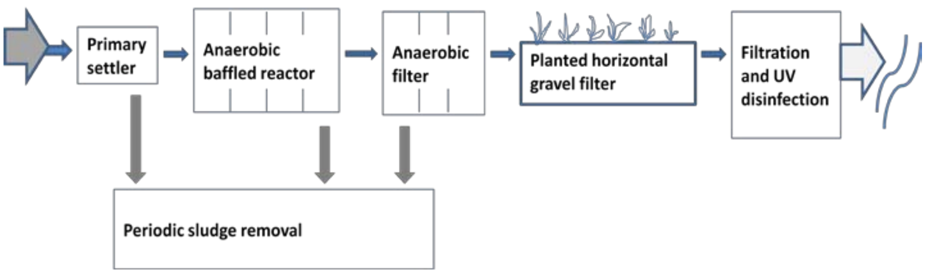
FIGURE 11: LAYOUT OF OPTION 2 AT DEVELOPMENT SCALE



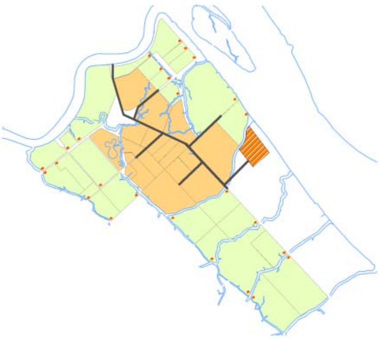
Institutional arrangements would need to be negotiated, in terms of who would outlay the capital cost, whether the developer or CTWSSC would own the asset in the long-term, and who would be responsible for tariff collection and operation and maintenance. In other locations such as the US and Australia, it has been demonstrated that centralised management of such wastewater systems is critical for good long-term operation of this kind of infrastructure.

The treatment train is shown in Figure 12. The settler, the anaerobic baffled reactor (of 3 compartments) and the anaerobic filter are designed for a 12 hour retention time and have capacities of $156m^3$, $54m^3$ and $64m^3$ respectively. The horizontal gravel filter has a length of 30m and width of 20m and is shallow, at 50cm deep. It is planted with *Phragmites ssp.* to enable some uptake of nitrogen and phosphorus from the wastewater and harvesting of the plants.

FIGURE 12: TREATMENT TRAIN FOR DECENTRALISED SYSTEMS IN OPTION 2 AND 3



The unit cost of a treatment system of 500m^3/day capacity in Vietnam is 5,000 million VND (excluding disinfection) and the additional cost of the disinfection step is 300 million VND. The wastewater flows by gravity through the system and hence the only energy requirement for the plant is an effluent discharge pump to convey the final effluent to the nearest canal. Operation and maintenance requires a small amount of regular oversight (two visits per week of 2 hours) and replacement of the horizontal gravel filter and plants every 10 years. Desludging is included in the operation cost and would be undertaken by removal in trucks every 3 to 4 weeks to a sludge disposal area beyond the city limits.

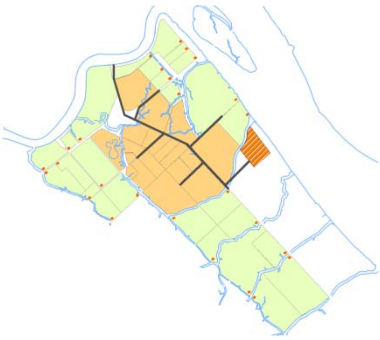


Option 3 – Combination of centralised and decentralised treatment

This option is a mixture of centralised and decentralised wastewater treatment. Centralised treatment is employed for the area closest to the treatment site and the backbone sewer, which is also the area likely to be developed the earliest and with the highest population density (total future population of 105,000 people based on lot scale development plans). This requires upgrading the Cai Sau treatment plant to an additional capacity of 23,000 m^3/day using the same trickling filter technology, and construction of a backbone pipe through the centre of the centralised area parallel to the KfW pipe.

Decentralised plants would be built in areas that are likely to be developed later, less dense and more distant from Cai Sau WWTP. These local treatment plants would follow the same design as in Option 2 of 500m^3/day systems treating water from 400-500 houses for a total future population of 173,000 people. In total, this requires 78 smaller decentralised treatment plants which could be constructed as required based on the actual rate of urbanisation.

The present value costs for this option include a smaller backbone pipe and network and a 23,000m^3 upgrade of Cai Sau WWTP at a cost of 79,000 million VND (based on KfW costs). Decentralised treatment system costs are the same for Option 2.



Option 4 – Combination of centralised and decentralised treatment with resource recovery

Option 4 includes a combination of centralised and decentralised treatment facilities, based on the same areas as identified in Option 3.

As with Option 3, a 23,000m^3/day upgrade of Cai Sau WWTP would be required along with an additional backbone sewer.

For decentralised areas, the urine is separate from the remaining wastewater stream and is taken through a series of steps shown in Figure 13. Urine is separated using urine-separating flush toilets in homes. The urine is collected in underground tanks (one tank for every 40-50 households). Every 3 days, trucks come to pump out the urine and transport it to rural areas. Here it would be stored in large 700m^3 capacity storage units for 6 months to ensure sterilisation then sold as fertiliser. Receptor and storage tanks are displayed to scale in Figure 14. To ensure a high safety margin and enable use of urine on all crops, 6 months is the storage time recommended by the World Health Organisation (2006).

Figure 13: Urine diversion, collection, transport and re-use

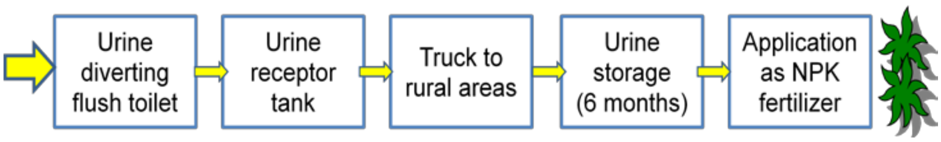
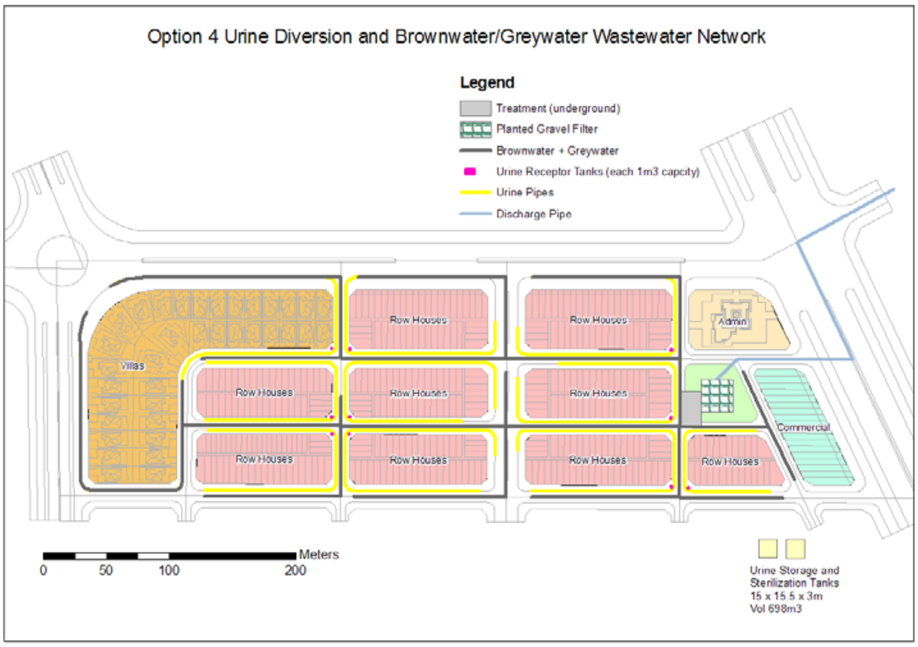
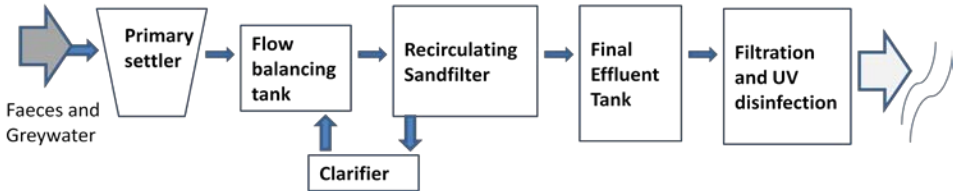


Figure 14: Layout of Option 4 at development scale



The remaining wastewater is treated at a decentralised scale of 400-500 households (500m^3/day) using a recirculating sand-filter and ultraviolet disinfection (see Figure 15). Removal of urine removes the majority of nitrogen and phosphorus in the domestic wastewater and hence the effluent of the recirculating sand filter is expected to be of high quality and very low nutrient levels which is environmentally beneficial. It would also be possible to design and use the treatment technology specified in Option 2 in place of the recirculating sand-filter. The sand-filter would be configured as 4 sand-filters in parallel, each with 370m^3 capacity. A flow-balancing tank of 24h storage is included to avoid flooding the filter and to allow for pulse-dosing.

FIGURE 15: TREATMENT TRAIN FOR DECENTRALISED TREATMENT OF GREYWATER AND FAECES FROM TOILET



The unit costs for urine diversion are 4.3 million VND per household. This total accounts for the additional cost of a urine diverting toilet, the collection tank at the scale of 40-50 households and storage costs in a rural area. The trucking cost to rural areas is an additional 146.4 million VND/year.

The benefit from sales of fertiliser was calculated from the equivalent value of the nitrogen and potassium in a typical chemical fertiliser NPK 20-0-10 Buffalo Head (Dau Trau Brand). The price of fertiliser per metric tonne in 2010 with 5% VAT was 6,972,000 VND. The value of the fertiliser is therefore 476,000 VND/yr for each household from which urine is collected.

The cost of each decentralised treatment plant of 500m^3/day for the remaining greywater and faeces by recirculating sand-filter is 4,344 million VND. This treatment plant has an energy use of 60,000 kWh/yr which is required for re-circulation pumping. The required land area is 1,950m^2, of which 600m^3 is concrete tanks that can mostly be stored underground and 1,350m^2 for the sand-filter which can be covered in grass and used as parkland.

5 Comparison of Costs of Different Options

An economic analysis of the costs of four options was conducted based on a rigorous methodology developed by ISF in the Australian context (Mitchell et al., 2008) and adapted to the project context (Willetts et al., 2010). All capital and operation and maintenance costs were included (including energy, labour and equipment/asset replacement) over a 30 year period of analysis. To determine the present value a discount rate of 8% was applied, based on CTU estimates of the discount rates conventionally applied to a government-funded project in Vietnam. The analysis presented is based on a 'whole of society cost', which includes the costs of government (likely to bear capital costs), CTWSSC (likely to bear operation and maintenance costs) and householders (though some householder costs that are consistent across the four options were not included). It is possible that developers would be implicated in the options including decentralised components however detailed consideration of developer's costs was outside the scope of analysis.

Sources of costs included relevant national norms for prices of standard materials (such as sewer pipes etc.), the KfW design documentation of Cai Sau treatment plant, costs of decentralised systems built by BORDA in Vietnam and estimates for disinfection and some other components from Vietnamese and international companies. The major costing assumptions have already been described in the above sections detailing each option.

5.1 Results of detailed cost assessment

The economic analysis provided clear results, as detailed in Table 4 and the Figures below. Figure 16 illustrates the calculated net present value of each option. Figure 17 and Figure 18 indicate the relative capital and operation/maintenance costs of options. Figure 19 shows the present value of revenue associated with sale of fertiliser in Option 4.

TABLE 4: RESULTS OF DETAILED COST ASSESSMENT

Cost of option in present value million VND (2010)	Option 1 Fully centralised	Option 2 Fully decentralised	Option 3 Centralised /decentralised	Option 4 Centralised /decentralised with resource recovery in decentralised areas
Present Value Capital Cost	517,000 (27m USD)	276,000 (14m USD)	256,000 (13m USD)	330,000 (17m USD)
Present Value Operation and Maintenance Cost	4,000	1,900	2,200	2,300
Present Value Revenue from Fertiliser Sales	-	-	-	11,800
Net Present Value	-521,000 (-27m USD)	-278,000 (-14m USD)	-258,000 (-13m USD)	-321,000 (-18m USD)
Levelised cost per household	20 (1,000 USD)	11 (600 USD)	10 (500 USD)	13 (700 USD)
Levelised cost per m^3 water consumed	0.064 (3.4 USD)	0.030 (1.6 USD)	0.029 (1.6 USD)	0.036 (1.9 USD)

*All calculations based on a population projection of 278,000. Costs for a population of 150,000 shown below in sensitivity analysis

FIGURE 16: NET PRESENT VALUE OF ALL OPTIONS

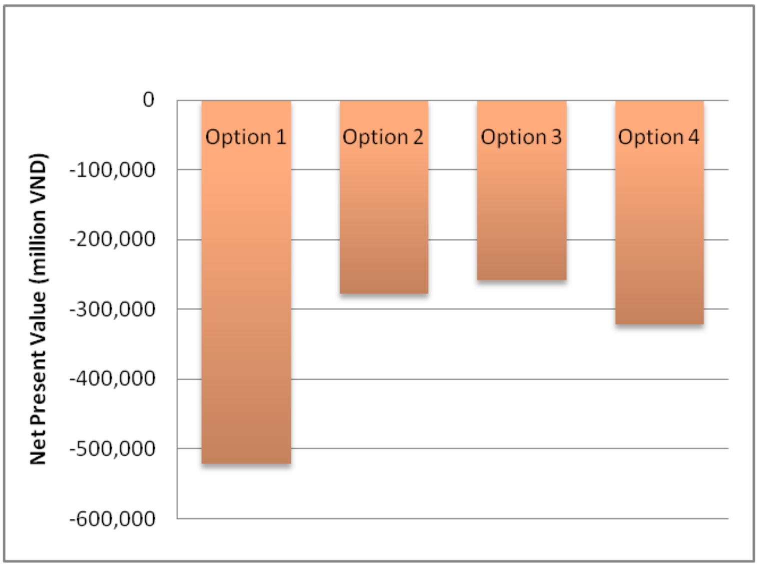


FIGURE 17: CAPITAL COSTS

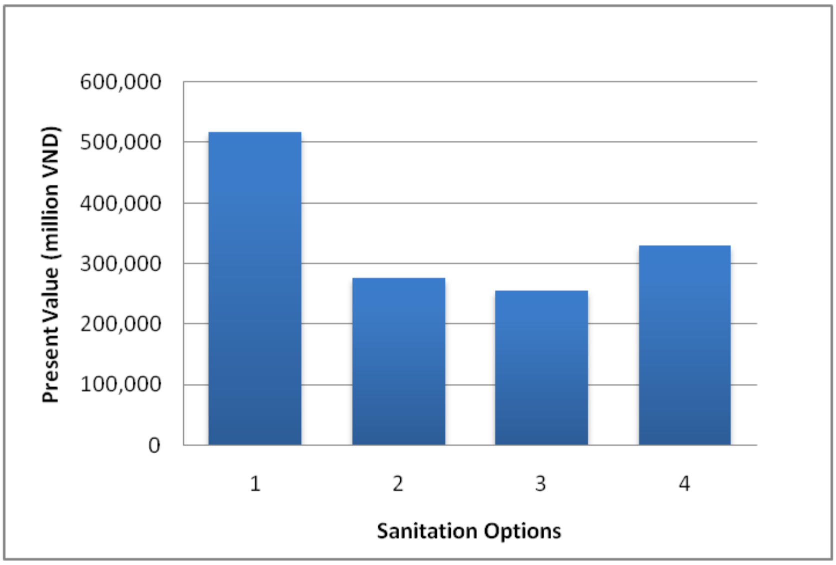


FIGURE 18: OPERATION AND MAINTENANCE COSTS

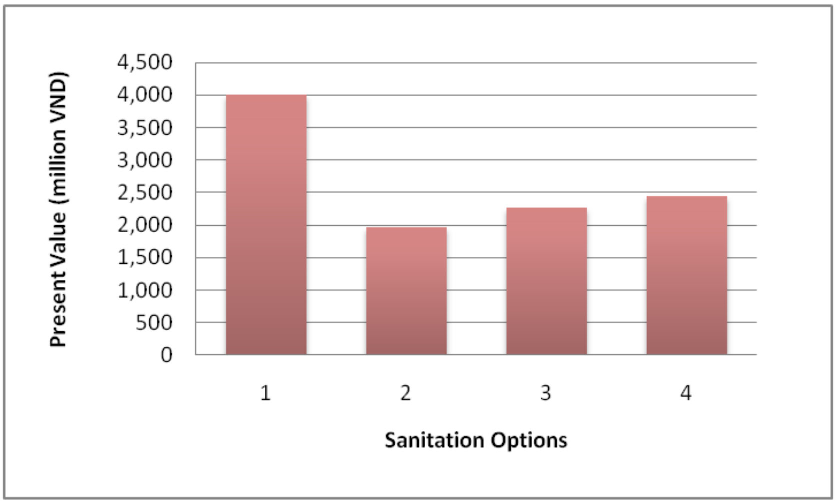
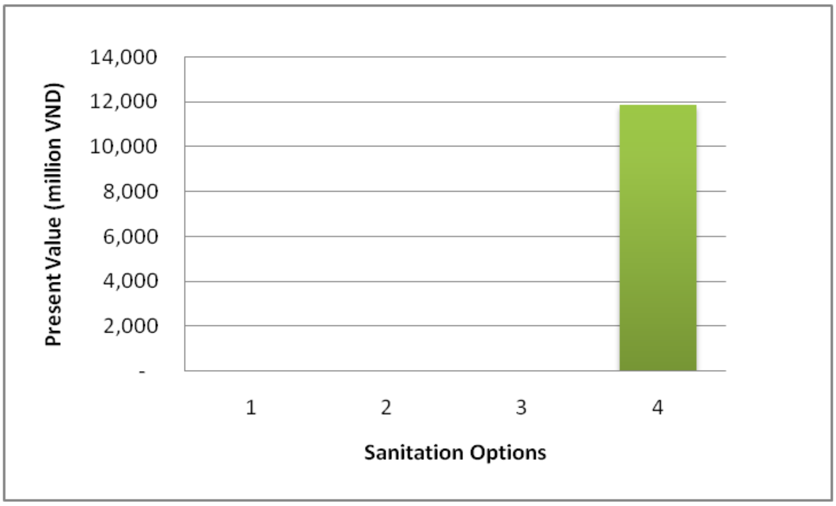


FIGURE 19: REVENUE FROM SALE OF FERTILISER

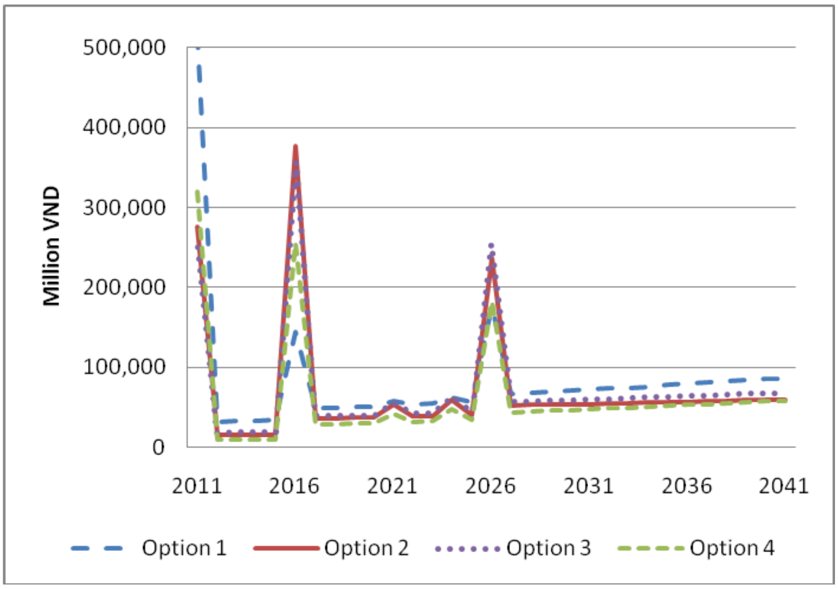


Options 2 (fully decentralised) and 3 (combination of centralised and decentralised) were the least cost solutions (Figure 16). They were found to have the lowest present value capital costs (Figure 16) and also had the lowest present value operation and maintenance costs (Figure 17). This means that they would be the cheapest options both from the financial perspective of the government (currently responsible for capital costs) and CTWSSC (responsible for operation and maintenance costs). Given the potential for inaccuracies in the component costs that make up these calculated costs, there is little significant difference between Options 2 and 3.

Option 4 is slightly more expensive than Options 2 and 3, however has a significant advantage, particularly from the perspective of CTWSSC who would likely look after operational expenses (Figure 18) and revenue. The results indicate that the present value of revenue from sales of fertiliser is five times greater than the present value of its operation and maintenance costs (Figure 19).

Option 1, the centralised solution, was roughly two times as expensive as Options 2 and 3 in terms of both capital and operation and maintenance costs (see Figure 16, Figure 18 and Figure 19). This is in part due to the timing of investments. For Option 1, the upgrade to the centralised treatment plant would need to be undertaken in the short-term, given that development is already occurring in South Can Tho. For Option 2, the investments are staggered over time (Figure 20). For Option 3, the low present value cost is due to the fact that the upgrade of the treatment plant is smaller than in Option 1 (and is capacity that is needed immediately) and the fact that areas that are developed further into the future are serviced by decentralised options which can be built as needed.

FIGURE 20 COST OF ALL OPTIONS OVER TIME



5.2 SENSITIVITY ANALYSIS

Sensitivity analysis was conducted for a range of parameters:

Population projection: The current revised spatial master-plan for South Can Tho anticipates a future population of 150,000 people. This projection is much lower than the figure of 278,000 people resulting from analysis of investor's development plans. The inputs to the model for different development plot areas were changed to reflect a lower population. For a population of 150,000, the present value for each option is shown in Table 5. Operation costs are approximately half those for the larger population and the net present value of fertiliser sales in Option 4 is 6,400 million VND. On these lower population projections, Option 1 is still the most costly, followed by Option 4 (before the inclusion of potential revenue from sale of fertiliser). Option 2 has the lowest net present value (as opposed to Option 3 under the higher population scenario) however the differences between Option 2 and 3 are not significant.

TABLE 5: SENSITIVITY ANALYSIS FOR PROJECTED POPULATION OF 150,000 PEOPLE

	Present value cost of option assuming projected population of 278,000 (million VND)	Present value cost of option assuming projected population of 150,000 (million VND)
Option 1	521,000	363,000
Option 2	278,000	164,000
Option 3	258,000	181,000
Option 4	339,000	231,000

Discount rate: A discount rate of 8% was used as indicative of a government funded project in Vietnam. Increasing the discount rate to 10% (closer to that appropriate for private investment) did not significantly change the results or the relativities between options.

Period of analysis: Reducing the period of analysis to 20 years did not produce any significant change in the results or the relativities between options. This is not surprising since in a present value calculation, it is the costs in the early years which most affect the result.

Timing of development: The rate of urbanisation for South Can Tho is uncertain. Analysis of the results with a slower rate of urbanisation produced slightly different results in that Option 2 and 3 were even more preferable as compared with Option 1. This demonstrated the value in adopting decentralised systems for areas where the timing of development is unclear.

6 Sustainability Assessment Consultation

6.1 Sustainability assessment

In July 2010 the project partners CTWSSC and CTU and key city stakeholders worked through an assessment of the options using the criteria described below in a one-day workshop. The 28 participants included representation from Department of Planning and Investment, Department of Construction, Department of Natural Resources and Environment, Can Tho Centre for Natural Resource and Environment Monitoring, South Can Tho Urban Administrative Authority, Department of Health, Department of Foreign Affairs and the Can Tho Institute for Rural and Urban Architecture and Planning.

In order to apply a broad ranging assessment of the sustainability of each option, ISF prepared a sustainability framework based on criteria under five broad areas of concern. The five broad areas of concern were: (i) technical and risk (ii) social and health (iii) environment (iv) economic and financial (v) contribution to the city's future.

Detailed criteria were developed for each of these areas as shown in Table 6. The criteria reflect relevant national legal requirements (for example requirements for Strategic Environmental Assessment in Vietnam), local issues that had been raised in the development of the project and the planned development orientations for the city. In addition, the criteria were informed by international frameworks for sustainability, particularly for urban water systems (for example Lennartsson et al., 2009 ; Lundie et al., 2005 ; Sahely et al., 2005). CTU partners were consulted on the development of the criteria and the relevant city level stakeholders were given the opportunity to comment on and contribute to criteria proposed for their areas of jurisdiction prior to the workshop.

TABLE 6: DETAILED SUSTAINABILITY ASSESSMENT CRITERIA UNDER THE FIVE AREAS OF CONCERN

Technical & Risk (TR)	Social and Health (SH)	Environmental (Env)	Economic (Eco)	City Future (CF)
System robustness: The ability of the chosen technologies to work well within the Can Tho context, which may include variations in influent quality, high ground water table, rainfall events, potential for intermittent electricity	**Public acceptability**: The public acceptability may be influenced by people's responses about visual amenity, potential for odour, familiarity, landscape, cultural identity etc.	**Impacts on water quality**: Impacts may be on surface water quality, river water quality or ground water quality	**Net present value**: Cost-effectiveness based on life cycle costs (including capital, operation, maintenance and replacement costs) and taking into account timing of costs over a 30 year period of analysis	**Positioning the city as innovative**: Contribution to making the city a regional and national centre for developing and applying new approaches and ideas, in keeping with the overall development objective for the city to make it a centre for innovation for the future
System complexity: Complexity in construction, in operation and maintenance, in management requirements and in institutional arrangements	**Equity between socio-economic groups**: Is there equity in how different socio-economic groups may be impacted? For instance, how will this option influence the price	**Energy use and greenhouse gas emissions**	**Operation and maintenance costs:** Energy, labour and equipment replacement costs	**Contribution to socio-economic development of the city**: strength of contribution to current development priorities
Proven technology at full-scale: There exists successful full-scale application of this technology in other places	**Contribution to public health**: Ability to ensure no human exposure to wastewater (which would result in risk of infection)	**Nutrients re-use potential**: Possibility for nutrients present in the wastewater to be re-used in agriculture	**Cost sharing:** How easy will it be to work out who pays for what?	**Contribution to capacity building**: Contribution to building a strong skill-base in wastewater management and leading approaches in this area
Risk of the plan not being completed: Is the planned system realistic and feasible in terms of the availability of resources and capacity to make it happen	**Employment generation**: Quantity and type of employment opportunity likely to be generated	**Ability to cope with climate change impacts**: Such impacts include dealing with uncertainty, and impacts such as flooding, salinity intrusion and increases in temperature	**Cost recovery potential**: Ability of the operator of the wastewater system to fully recover their costs through user fees	**Resilience and adaptability to uncertainty**: Given that many factors in the future are uncertain, ability to respond to and accommodate changes, for example changes in energy costs, fertiliser costs, land costs, urbanisation rate
			Land-use investment: Amount and type of land required for wastewater treatment	

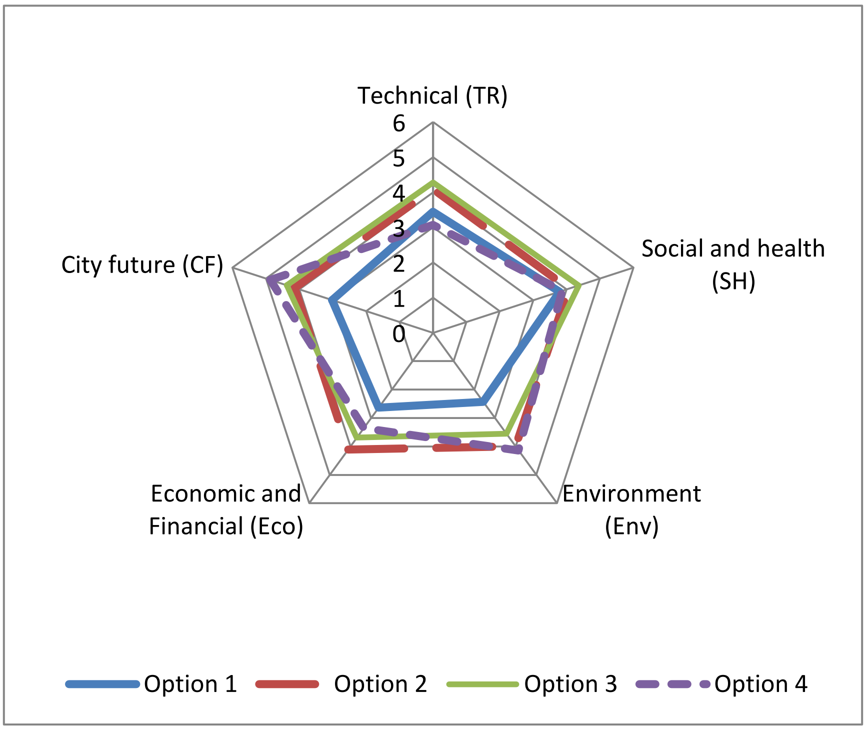
Each participant was provided a fact sheet about each option covering background information against the five areas of concern to assist them in their judgments. Small group discussions were held to identify and clarify any questions and to ensure that there was a common understanding of the criteria and options. Following this, each individual made an assessment of each option against each sustainability criterion. Average scores were then calculated for each area of concern with an equal weighting given to each criterion.

6.2 Outcomes of the sustainability assessment process

The conclusion from the sustainability assessment was that the most beneficial option would be a **combination of centralised and decentralised** treatment for different areas (Option 3). The centralised treatment would service the area closest to currently planned sanitation infrastructure, with the densest concentration of population and likely to be inhabited soonest. The decentralised systems would service other areas, providing flexibility to adapt to the actual pace of development and urbanisation.

The overall results are shown below in Figure 21. Participants ranked each option against each criterion and the average of all participant scores was calculated. A higher score indicates better performance against criteria in that area of concern.

Figure 21: Results of sustainability assessment process



The spider diagram results did not provide conclusive evidence for a clear choice of preferred option, since Options 2 (decentralised) and 3 (combined centralised and decentralised) performed similarly. Small groups therefore took into consideration which areas of concern they wished to give priority and ranked the four options from 1 to 4 based on their priority concerns. This led to a clear preference by all four small groups for Option 3. Option 4 (resource recovery option) was given second preference, followed by Option 2 (fully decentralised) and finally Option 1 (fully centralised) was ranked last and least preferable.

The following description provides explanation for why Option 3 was selected by all groups. **Technically**, the chosen option services the densely populated area closest to existing infrastructure with a capacity upgrade to the centralised treatment plant and supports use of a decentralised technology which is simple in construction and maintenance requirements for less dense areas likely to be developed further into the future. **Socially**, the affordability of this option is ensured through the relatively low cost of this option. **Environmentally**, the energy requirement (and hence greenhouse gas emissions) for pumping is significantly less for Option 3 than for a fully centralised system (though not as low as the fully decentralised Option 2), and the proposed treatment processes would contribute to improved surface and groundwater quality. **Financially**, this option had the lowest net present value. However cost sharing arrangements would need to be put into place for decentralised systems, which would include consideration of whether developers might become responsible for the capital cost of a decentralised system for a given development. This cost is likely to be fairly small within the overall level of investment made by a developer. Finally, in terms of **Can Tho's future**, this option was considered to contribute to innovation and demonstration of a new, tailored approach to wastewater planning that provides flexibility and adaptability to uncertainties such as the rate of urbanisation and potential climate change impacts.

The second preference was for Option 4 (urine diversion and use as fertiliser), with strong interest in this option for future wastewater planning. Option 1 (fully centralised) was the least favoured option as it had the highest overall cost and lowest performance against environmental criteria.

This kind of broad assessment process is most meaningful if there is substantial information made available for each of the proposed criteria to allow an informed judgement to be made. Such information may not be easily at hand unless specifically researched. In this case, significant research effort was invested in analysing the technical, cost and some environmental factors. Ideally, further research and analysis could have informed the social criteria, particularly public acceptability, public health implications and equity across different socio-economic groups.

7 Implications of the Findings

This study provides research findings which have local implications in Can Tho, as well as wider implications for planning urban and peri-urban wastewater infrastructure in rapidly urbanising cities.

7.1 Implementation of the selected option in Can Tho

In Can Tho, Dr Tran Tuan Anh, Vice Chairman of the Can Tho Peoples' Committee, has instructed all the relevant City departments to review the conclusions of this research project and to report back how its conclusions can be taken into account.

Implementation of the selected option (Option 3) would differ significantly from current draft construction plans for South Can Tho. One draft plan makes provision for two large-scale centralised treatment plants (upgrade of Cai Sau to 115,000m^3/day and an additional plant of 20,000m^3/day at the southern extremity of the case study area). Another envisages five semi-centralised treatment plants (between 6,500m^3/day and 105,000m^3/day). Neither of these plans would provide the cost and sustainability benefits made evident through this study associated with the inclusion of more local-scale decentralised wastewater treatment technologies (in the order of magnitude of 500m^3/day). The significant cost savings achieved by reducing energy for pumping and pipe network infrastructure are only accrued in smaller-scale configurations for areas with uncertain rates of urbanisation and further from any existing centralised infrastructure.

A number of specific issues need to be addressed in the short term if the preferred option is to be made feasible. Option 3 utilises a centralised solution for the central, dense area that is likely to be inhabited soonest, hence the following two actions are of immediate concern:

Secure investment for an upgrade to Cai Sau. The planned centralised treatment plant at Cai Sau is not yet completed. If this treatment plant is to be significantly upgraded to provide the additional capacity to treat wastewater from the central area of South Can Tho then investment to fund the increase in capacity must be secured.

Coordinate development with wastewater infrastructure. Development of plots in South Can Tho is already well underway. The implementation of Option 3 needs to be integrated with actual development, and needs to take account of infrastructure already constructed and investments already made within development plots. If investment for an upgrade to Cai Sau WWTP is not secured in the short-term, there is a significant risk that residential development will occur prior to the wastewater infrastructure being in place.

If there is difficulty in securing the required significant investment for Cai Sau, **then this would necessitate reviewing the feasibility of moving to Option 2**, in which all developments include a decentralised treatment plant. In this case land would need to be allocated within development plots to accommodate local treatment systems, and any pipe infrastructure already completed within actual development plots would need to be directed to a local treatment plant instead of a common sewer (as is currently planned).

There are two further important areas for consideration in implementing the preferred option:

Clarify responsibilities for and funding of infrastructure. For the centralised and decentralised components of the wastewater system, clarification and agreement will be needed on who will carry the costs of which parts of the system: the householder, developers or CTWSSC. However, this issue is not specific to the preferred option and negotiation about responsibilities, payments and tariffs is needed for any form of wastewater infrastructure in South Can Tho.

Roll-out the decentralised components of the system. While this study has identified decentralised wastewater treatment technologies that are feasible, cost-effective and sustainable, there is as yet no experience in Can Tho of building or working with the proposed technology. A first step in implementing the option and decentralised systems more widely would be to develop a demonstration of the decentralised system for one development area or for another facility in South Can Tho (such as a hospital). This would enable CTWSSC and other stakeholders to test the technologies locally and gather performance data (including actual costs and performance against the treatment standard QCVN 14), to develop expertise and would provide a model which could then be replicated in other areas.

Finally, given the strong interest in the resource recovery option (Option 4) in which the revenue from fertiliser sales outweighs the operation and maintenance costs of wastewater treatment, it would be beneficial to develop a small-scale pilot project to trial the technology in Can Tho to assess the actual processes involved in terms of the institutional arrangements and also to examine the social acceptability. This would be a useful investment in considering how this approach and these technologies would be feasible in the medium term.

7.2 Wider policy implications

Often the technological solution for wastewater in urban areas in developing countries is assumed to be large-scale systems. The findings of this research project challenge this premise. The research shows decentralised systems to be a valuable component in developing cost-effective, sustainable wastewater solutions, particularly in the face of uncertain rates of urbanisation and in response to climate change mitigation and adaptation concerns. As such, there are a number of policy implications and lessons arising from this study for those engaged in planning wastewater infrastructure.

First and foremost is the need to promote explicit consideration of both decentralised and centralised systems (and combinations thereof) in wastewater infrastructure planning. Policy makers should promote cost analysis of different wastewater options prior to conducting feasibility studies of particular options. In this research study a highly detailed cost-effectiveness analysis for a 30 year period was conducted. In other situations a broad-brush analysis may be sufficient to indicate the least cost solutions and configurations. However both capital and operation and maintenance costs must be considered and included. Proper cost analysis is critical in order to avoid investment in systems that create an on-going operation and maintenance cost burden into the future that cannot be recovered through tariffs. In particular, it is critical that wastewater infrastructure developed for the poor is not beyond their capacity to pay.

Second, the use of GIS to facilitate good spatial analysis of wastewater requirements and overlay physical and socio-economic factors including poverty to inform potential spatial configurations is highly recommended.

Third, this project demonstrated that strict regulations can potentially impede progress in areas such as wastewater treatment, which in Vietnam is a newly growing sector. The effluent quality requirements in Vietnam result in a requirement for disinfection of treated wastewater due to the low level of coliforms permitted. Disinfection adds a significant technical challenge and cost to the treatment process and raises a question about whether treatment to this level of water quality is justified and appropriate in a nation where there is currently almost no secondary domestic wastewater treatment (only septic tanks).

Finally, there is a strong need for demonstration of novel decentralised technologies to assist city stakeholders to gain confidence and experience in decentralised wastewater technologies and provide opportunity for institutional roles and responsibilities to be debated and negotiated. In particular, the significant potential for nutrient re-use through recovery of nitrogen and phosphorus in urine represents a crucial area for further effort and application.

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