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FINAL REPORT

Demonstration of Innovative Community based Water Cycle Management System

Stage 1: Sustainability screening and evaluation

Prepared by

Institute for Sustainable Futures

For

Sydney Water Corporation

UTS
University of Technology, Sydney

Demonstration of Innovative Community Based Water Cycle Management System

Stage 1: Sustainability screening and evaluation

Final Report

For Sydney Water Corporation

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Institute for Sustainable Futures

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EXECUTIVE SUMMARY

This project is the first stage of a *Demonstration of Innovative Decentralised Sewage Treatment Technologies and Management Systems* Project. This first stage looks at both the development and application of a sustainability screening and evaluation tool. The tool is used to recommend a sustainable and appropriate technology option for community based wastewater systems. Its use is trialled in one of the Priority Sewage Program (PSP) areas at Galston High School. This site is considered appropriate for the technology demonstration as the soil horizon at the School is representative of the Hawkesbury-Nepean area (which the PSP area covers). That is, it has a clay layer overlaying a shale cap which overlays sandstone.

Prior to development of the tool, a literature review was undertaken to collate existing research on sustainability criteria and assessment techniques. This review covered literature from international sources, Institute for Sustainable Futures studies and Sydney Water Corporation studies and other Australian studies.

The sustainability screening and evaluation tool was developed to address six key sustainability objectives (3 environmental, 1 technical, 1 social and 1 economic). A star rating system was developed, by which technologies (and technology options) for a specific site could be ranked and compared to determine which was the most sustainable and appropriate for that site. The tool is intended to be compatible with that developed by The Institute for Sustainable Futures and CSIRO in the Sydney Water Corporation Edmondson Park project. The six essential sustainability criteria were embedded in an 8-Step tool. The steps and their application to Galston High School are as follows:

1. ***Define effluent end-use scenarios***. This first step addresses potential outcomes or options for use, reuse or disposal of the treated effluent. End use determines effluent water quality, which impacts on technology and management choices; so nominating a particular end use for a particular site is the first step. Sub-surface irrigation was the desired end use for Galston High School.

2. ***Determine water and nutrient quality requirements for end uses***. For the end uses identified in Step 1, determine the water quality (including nutrient if necessary) requirements in the region.

3. ***Narrow selection of water quality requirements for site***. For the particular end use(s) selected in step 1, determine what the water quality requirements are in the region. For sub-surface irrigation in NSW, this is different to other states in Australia.

4. ***Generate and define process combinations to meet end uses***. This will most likely involve identifying several combinations of technologies which can meet the end-use scenario selected. For Galston High School, current practice and best practice technology options were selected for comparison.

5. ***Check minimum performance standards (PASS/FAIL)***. In this step, compliance performance standards (such as tamper proofing) and any site constraints (such as land space available) are identified and technology combinations are assessed against relevant standards and constraints. Technologies which fail are either modified or discarded from further analysis.

6. ***Check appropriate fit-for-purpose water quality cascade***. This identifies any opportunities for delivering water only to the level required for that end use, that is, ensuring there is a match between quality required and the quality provided. For example, effluent to be reused for irrigation being treated only to the level required to meet health and environmental standards.

7. ***a) Evaluate and rank technology options according to defined sustainability objectives and criteria.*** This step involves evaluating the remaining eligible options against the seven

sustainability criteria (see Appendix A). The sustainability scores for each option are then compared and an optimal option recommended for a particular site.

b) Address management issues. Once a technology option has been decided upon, management issues that will need to be addressed include: risk management, centralised management, enabling awareness and engagement and stakeholder distribution of costs.

8. ***Monitor and evaluate the chosen technology against objectives/criteria.*** This step takes place after the technology option has been recommended and implemented. It will be monitored and evaluated against the same 7 sustainability criteria indicated in Appendix A.

Communication and consultation with stakeholders should ideally be done at intervals throughout the process. Galston High School, was happy for Sydney Water Corporation and the Institute to undertake the seven step process to recommend a technology option without further consultation with the school.

Four technology options were identified and screened using the sustainability and evaluation tool. *Option 1* is intended as a reference case or benchmark because it is incorporates Ecomax. Ecomax (the main component of Option 1) is the only on-site technology with which SWC has direct experience. It is assumed that SWC considers it ‘current best practice’ in the NSW context. Its inclusion in the options analysis allows it to be compared with other technologies commonly considered overseas best practice. *Options 2* and *3* are considered best practice in some parts of the US, Europe and New Zealand. *Option 2* incorporates recirculating sand filters, which are reasonably common in Australia now. *Option 3* uses Orenco technology, already widespread in the US, Europe, and NZ, and claimed to be one of the most reliable and effective on-site technology systems. *Option 4* is intended to be indicative of another common technology category: automated/advanced wastewater treatment systems (AWTS).

The outputs from using the tool at Galston High School recommended that of 4 options screened, technology option 3 was most appropriate for the site. That is, an *Innoflow* interceptor tank followed by the *Advantex* textile filter and UV disinfection.

This project represents a first pass at developing a sustainability screening and evaluation tool to recommend the most sustainable and appropriate technology option for a particular site.

The tool’s flexibility is demonstrated by the breadth of technologies assessed in this first pass, and by the difference in the scores generated both at a technology level and at the option level. The tool’s flexibility and robustness will be further tested through application on other sites, and by its ability to take into account site-specific constraints.

All objective categories in the tool were given equal weight *i.e.* environment, social, technical, and economic categories get the same weighting. A limitation of this is that these important decisions about weighting have been made by the analysts, rather than by a representative group of potential stakeholders. To overcome this limitation the incorporation of participatory decision-making processes to obtain information about community preferences is highly recommended.

The tool recognises the limitation of simply addressing technology scale issues by including the capacity for explicit consideration of a set of management concepts (centralised management, risk management, engagement, and distribution of costs and benefits amongst stakeholders).

The tool has been designed and iteratively reviewed during its first application to meet the objectives outlined above. However, it should be seen as a work in progress. Different kinds of applications, different scenarios, and different users will provide a greater breadth of opportunity for sensitivity analysis, evaluation and modification where necessary.

In addition to involving the community and other stakeholders throughout the decision making process, it is recommended that SWC acknowledge and address where appropriate, that community scale wastewater systems fit within a broader context of sustainable urban water systems, for example by installing water efficient technologies to reduce the volume of wastewater production (in addition to other upstream benefits).

Other specific recommendations include reviewing individual star ratings rather than the overall scores of the options. The former is likely to be more significant and meaningful than the latter. Focusing on ratings for particular criteria enables review and discussion about trade-offs between criteria.

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ABBREVIATIONS

BOD	Biochemical Oxygen Demand
CBA	Cost Benefit Analysis
DET	Department of Education and Training
MCA	Multi Criteria Analysis
PSP	Priority Sewerage Program
SWC	Sydney Water Corporation
TSS	Total Suspended Solids
UV	Ultra Violet
WP21	Water Plan 21
EPA	Environmental Protection Authority
DoH	Department of Health
SS	Suspended Solids
T.Coli	Thermotolerant coliforms

1 INTRODUCTION

Sydney Water Corporation (SWC) recognises that small scale community based or decentralised sewage treatment provision has potentially significant benefits over highly centralised systems in a range of situations. These benefits cover all conceptual areas of sustainability (i.e. ecological, social, economic and technical). Ecological benefits include greater resource use efficiency and closing water cycles locally. Social benefits include better opportunities to engage with the water cycle and accept responsibility for individual decisions, earlier provision of services, and opportunities for local job creation. Financial benefits include easing the move towards service provision as a business model and potentially lower capital costs and operating costs for SWC and therefore the consumer. . Technical benefits include reduced risk potential associated with system failure, and less complex maintenance and refurbishment requirements.

However, SWC has limited experience with such technologies. Therefore the overall aim of the project is a demonstration of assessing, implementing, monitoring and evaluating such technologies in the SWC service area. The demonstration community based system will be installed at Galston in the Hornsby Shire.

1.1 Project Scope and Objectives

This project represents '*Stage 1*' of a longer-term project to implement and monitor a sustainable and appropriate community based sewerage treatment technology at Galston High School. The scope of this first stage is to develop a sustainability screening and evaluation tool for community based sewerage treatment systems; to use this tool to evaluate a range of technology combinations and management processes; and then to recommend an appropriate technology combination for Galston High School.

The objectives of this project are to:

i) develop, use and review a broad set of criteria for both selection and performance evaluation of community based water cycle management options. The criteria should be sufficiently generic to be useful for SWC beyond this project in other Priority Sewerage Program areas of the Hawkesbury—Nepean catchment;

(ii) demonstrate a best practice community based water cycle technology system that meets or exceeds the discharge limits required by DoH, EPA, NP&WS and local councils;

(iii) develop stakeholder confidence in community-based systems to meet financial, environmental, public health and social sustainability outcomes;

(iv) demonstrate that the technology can be effectively operated, maintained, remotely monitored, and managed on a service provision basis;

/(v) demonstrate that the technologies are cost effective options compared with conventional centralised reticulated sewerage treatment;

(vi) demonstrate that the chosen technology is cost effective compared to the existing effluent management arrangements at Galston High School;

(vii) provide an education resource for the public, stakeholders and SWC;

(viii) improve capacity and willingness of SWC, DoH, NP&WS and EPA personnel and the community, to work in partnership, to debate, evaluate and appraise community based options;

(ix) provide long term benefit to the school; and

(x) evaluate the performance of the system in relation to the sustainability criteria and WaterPlan21 (*WP21)* objectives.

Stage 1 relates directly to the first objective listed above, and indirectly to all the other objectives.

2 PROJECT BACKGROUND

Under the Septic✓Safe program, NSW council investigations have found that many on-site treatment systems (10% to 80%) are failing. Faulty design and/or installation, lack of servicing or misuse are just some of the many causes of failure, resulting in contamination of the land, waterways and groundwater with pathogens and nutrients. Solutions to the problem of failing on-site systems can be characterised by the scale of the technology proposed: either connect the community to a large scale centralised reticulated sewage system, or upgrade the technology and management of on-site and community based solutions.

In the past, water service providers have almost always opted for centralised reticulation. There are many reasons for this, but three stand out here. Firstly, it is always easier to continue to implement familiar solutions. Secondly, many 'state of the art' community based sewerage systems in NSW have a high percentage failure rate for technological, political, and social reasons. Thirdly, communities have tended to see anything other than centralised treatment as inadequate. Each of these reasons comes with its own set of complicating factors, but these are beyond the scope of this report.

Centralised reticulated sewerage systems to service the unsewered villages in the Priority Sewerage Program (PSP) are estimated to cost between $26,000 and $70,000 per lot. In contrast, centrally managed advanced community based technologies currently being used in the USA, Canada, Europe and New Zealand have been shown to have much lower capital costs (US EPA, 2000; Innoflow Jamberoo proposal, 2001). Although these technologies are well established elsewhere, they have not yet been installed in Australia. On the basis of international experience, installing these advanced technologies in the Sydney region is estimated to have a capital cost between $5,000 and $20,000 per dwelling—a potentially significant saving which provides sufficient impetus for further investigation of these options.

The majority of homes on the backlog sewerage list are in the Hawkesbury—Nepean catchment (approximately 14,500 lots out of a total of 16,828). Hence, there is a need to establish whether these new advanced community based technologies are suitable to the conditions in the Hawkesbury—Nepean area. The site at Galston High School is representative of the Hawkesbury—Nepean region because, unlike the surrounding areas, the soil horizon within the school grounds consists of clay soils overlaying a shale cap.

This project will provide SWC with first hand technical, financial, social, environmental and management assessments that will contribute to the business decision of whether to install and manage community based sewerage services in the Hawkesbury—Nepean area.

3 METHODOLOGY AND DESIGN

The sustainability screening and evaluation tool was designed with the following guiding principles and objectives in mind:

- The tool is flexible and robust;
- The tool is useful for Sydney Water Corporation beyond the scope of this project. That is, it can be applied to other Priority Sewerage Program areas (or any sites considering community based sewage treatment technologies);
- The tool enables all areas of sustainability to be addressed when screening and evaluating on-site technologies;
- The tool enables the inclusion of issues of management, education and implementation which may be independent of the chosen technology combination;
- The sustainability objectives, criteria, and performance levels are performance-based;
- The level of detail of the tool is appropriate and efficient. It is broad enough to be widely applicable and detailed enough to be measurable and capture all important issues related to sustainable and appropriate technologies;
- The tool can be used to evaluate the technology during operation;

The tool is evaluated against these criteria in Section 10.

The tool was developed from two primary sources:

- an extensive literature review of existing approaches to sustainability criteria and assessment techniques, with a particular focus on water related applications,
- relevant SWC documents and ISF projects completed for SWC.

3.1 Literature Review Outcomes

The literature review was undertaken to understand which sustainability criteria had been identified in similar studies, and the tools used to assess these criteria–sets. The literature was drawn from SWC studies, other Australian studies and some international studies.

Other Australian studies:

- **Diatloff, N. (2001),** ***Draft Sustainability Criteria for Wastewater Management in Low Density Areas and New Developments*****, February 2002, Sydney**. This document includes a list and explanation of sustainability criteria. The criteria are categorised as Economic, Technological, Environmental, Social and Legislative. These categories are very similar to those developed by Balkema (1998) in The Netherlands (see below) with slight modifications for an Australian context.

International studies:

- **Bradley, B., Daigger, G., Rubin, R., and Tchobanoglous (2000),** ***The Sustainable Development Case for On-site Wastewater Treatment, US.*** This study presents a sustainability assessment tool for wastewater treatment using a broad range of criteria (including the three aspects of sustainability: social, environmental and economic). These three aspects were given equal weighting, although the criteria within each category could vary and were case-specific. To demonstrate this sustainability assessment tool and its criteria, a conventional on-site treatment technology (septic system) was compared to a more advanced treatment technology, the textile filter pressure dosed system.

- **Balkema, A. (1998),** ***Sustainability Criteria for the Comparison of Wastewater Treatment Technologies,*** **11th European Junior Scientist Meeting, 12-15th Feb 1998, Wildpark Eekholt.** This paper addresses the focus of much of Annelies Balkema's work on sustainability criteria used for assessing and comparing wastewater treatment systems. The broad set of sustainability criteria was based on definitions of sustainability and appropriate technology. Balkema breaks the criteria in to four categories: economic, environmental, social-cultural and functional.
- **Lundin, M., Molander, G., and Morrison, G. (1997),** ***Indicators for the Development of Sustainable Water and Wastewater Systems,*** **Technical Environmental Planning, Chalmers University of Technology, Goteborg.** This study developed indicators of sustainability in the context of sustainable urban water systems. These were used to discuss and enable comparison of sustainable sanitation systems. The indicators focused on environmental issues and technical efficiency of systems.

Relevant criteria from these international and Australian studies were added to the sustainability criteria developed in this project. The methods of assessment outlined in these studies were also reviewed and incorporated in this project in terms of best approaches (simple yet robust) to weighing criteria and comparing wastewater options.

3.2 Relevant SWC projects

Edmondson Park Project

The Edmondson Park project for SWC was a collaboration between CSIRO Urban Water and ISF. The primary objective of the project was to develop, document, and trial a new process for creating and evaluating options for 'doing things differently' to deliver sustainable urban water services to greenfield sites. Two documents were produced: the *Greenfield Manual—Version 1* (ISF and CSIRO, 2002), which details a process for creating and evaluating sustainable water servicing options, and the *Edmondson Park Feasibility Study* (ISF and CSIRO, 2002), which details the outcomes of applying the Greenfield Manual process to a particular case study.

A major component of the Edmondson Park project was to develop a process to assess the relative contributions to sustainability of vastly different options. This process built on existing SWC documents (*e.g. Towards Sustainability* (SWC, 2001), the *State Owned Corporations Act* 1989 Section 20E, the *Sydney Water Act*) where it made sense to do so and developed new concepts and resources where necessary to create a hierarchy of sustainability objectives, criteria and performance levels. This hierarchy was applied to the options developed in the feasibility report. The hierarchy was extensively reviewed and modified through various meetings and processes with SWC staff. Thus, it made sense to build on the Edmondson Park Greenfield Manual sustainability rating process in the current project.

The sustainability objectives developed in the Edmondson Park study are reproduced below, along with a brief explanation of each. The first three are related to ecosystems, the next three are related to social systems, and the last is related to economic systems.

1. *Minimise resource use*: *e.g.* water, energy, materials, transport.

2. *Minimise waste and by products and maximise resource use efficiency*: *e.g.* wastewater, nutrients, biosolids, construction waste, office waste, operations waste, lifecycle pollutants.
3. *Maintain ecological function*: self explanatory, and ensures ecosystem issues explicitly considered: *e.g.* mimic natural flows, protect, maintain, enhance indigenous ecosystems and habitats.
4. *Foster awareness of and engagement with the water cycle*: this objective focuses on the way that people understand development and their place in it, and on getting the processes right to involve people as water cycle pioneers. The concept here is to make it easy for both the community and SWC staff to 'do the right thing'. Appropriate behaviour, awareness and action are facilitated by for example, managing service provision into the future, ensuring community involvement in decisions relating to water cycle management (but not hands-on management of their own water cycle). 'Civic hydrology' might be thought of as an underpinning principle of this approach. Civic hydrology is the notion that aesthetic form as well as function enables engagement, enjoyment and responsibility.
5. *Contribute to amenity*[1]: this objective focuses on people, and the outcomes for people from the development, and includes such concepts as fostering a vibrant and liveable community; ensuring equity of access to amenity; enhancing and protecting biodiversity; and designing for inherent beauty and aesthetic.
6. *Satisfy utility*: this people-focused objective is concerned with ensuring compliance *e.g.* meeting public health standards and fire protection needs; ensuring accessibility (all people have a 'right' to adequate and safe water cycle and SWC has 'responsibility' to provide same).
7. *Minimise whole of life cost to the community*: an economic objective that ensures internal and external financial, social, and environmental costs and benefits are accounted for and distributed justly.

As noted above, comprehensive criteria and performance levels were developed for each of these objectives in the Edmondson Park project. However, the Greenfield Manual criteria and performance levels were intended for water cycle service provision for a subdivision, and hence had limited relevance for this community based demonstration project.

Our approach was therefore to critically review our Edmondson Park hierarchy in the light of additional information gleaned from the literature review, and with a view to developing a tool to meet the guiding principles and objectives outlined earlier in this section. The tool was continually modified, clarified, and improved as we applied it during this project. Further recommendations for tool development are outlined in Section 10.

The complete sustainability objectives, criteria, and performance rating system for community scale sewage systems are shown in Appendix A. The objectives, along with a brief explanation, are shown below. The key difference between these objectives and those developed for Edmondson Park is in their intent, which relates to the stage of the development or planning process at which they are applied. The Edmondson Park objectives are deliberately aspirational and all-encompassing because they are designed to be applied in the very early planning and design stages. The objectives in this community scale sewerage provision project are to be used to differentiate between technology and management systems, which occurs at a much later stage in the planning and design process, and so need

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[1] The Macquarie Concise Dictionary (2nd Ed) has the following definitions for amenity: 1. agreeable features, circumstances, ways, etc. 2. features, facilities, or services of a house, estate, district, etc, which make for a comfortable and pleasant life.

to be more operationally focused. The assumption is that the objectives developed here are implemented within a framework which is consistent with the broader aspirations described in the Greenfield Manual. That is, that the broader sustainability objectives are still an integral part of the total project.

Thus, the first three objectives below, which relate to ecosystems, are the same as the corresponding Edmondson Park objectives, but the criteria developed here are quite specific and focused on the aspects of the objectives that are directly relevant to community scale sewage service provision. The next two are focused on specific operational aspects of community scale sewage as they directly relate to social systems. The fourth objective encompasses technical performance and risk and the fifth includes mechanistic aspects of amenity. The final objective here relates to cost, and is similar in intent to that developed for Edmondson Park.

1. *Minimise resource use*: operations greenhouse gases, embodied energy in key components, and consumables during operation and maintenance.
2. *Minimise waste and by-products*: beneficial reuse and recycling of nutrients and water, minimise waste throughout lifecycle.
3. *Maintain ecological function*: current best practice in species, ecosystem health, and hydrologic regime management.
4. *Satisfy utility and maximise performance efficiency*: short and long-term flexibility and robustness, technology risk assessment, operational interventions.
5. *Contribute to amenity*: odour, noise, and visual obstructions.
6. *Minimise whole of life cost to community*: as for Edmondson Park objective.

Each objective has a set of criteria, and each criterion has a range of performance levels, which are explained with examples (see Appendix A for the complete hierarchy). Performance levels vary between ★, which represents worst conceivable or poor or inadequate performance, and ★★★★★, which represents best conceivable or excellent or highly preferred performance.

The sustainability ranking is the core of the screening and evaluation tool developed for this project. The following section explains how ranking is integrated into the tool.

4 SUSTAINABILITY SCREENING AND EVALUATION TOOL

This section explains the general process for assessing the sustainability of on-site wastewater treatment systems using the tool. Sections 5–10 relate specifically to its application at Galston High School.

The following flow diagram (*Figure 1*) outlines the process for screening and evaluating the sustainability of on-site technologies and ranking them in accordance with the sustainability criteria and appropriateness for a particular site. The remainder of Section 4 explains the rationale behind each of the steps, and shows how the steps should be applied.

The tool evolved over the project period as new ideas or information became apparent. Such evolution is healthy, and should continue as the tool is applied to other contexts. The tool should be seen as a work in progress, rather than the definitive answer.

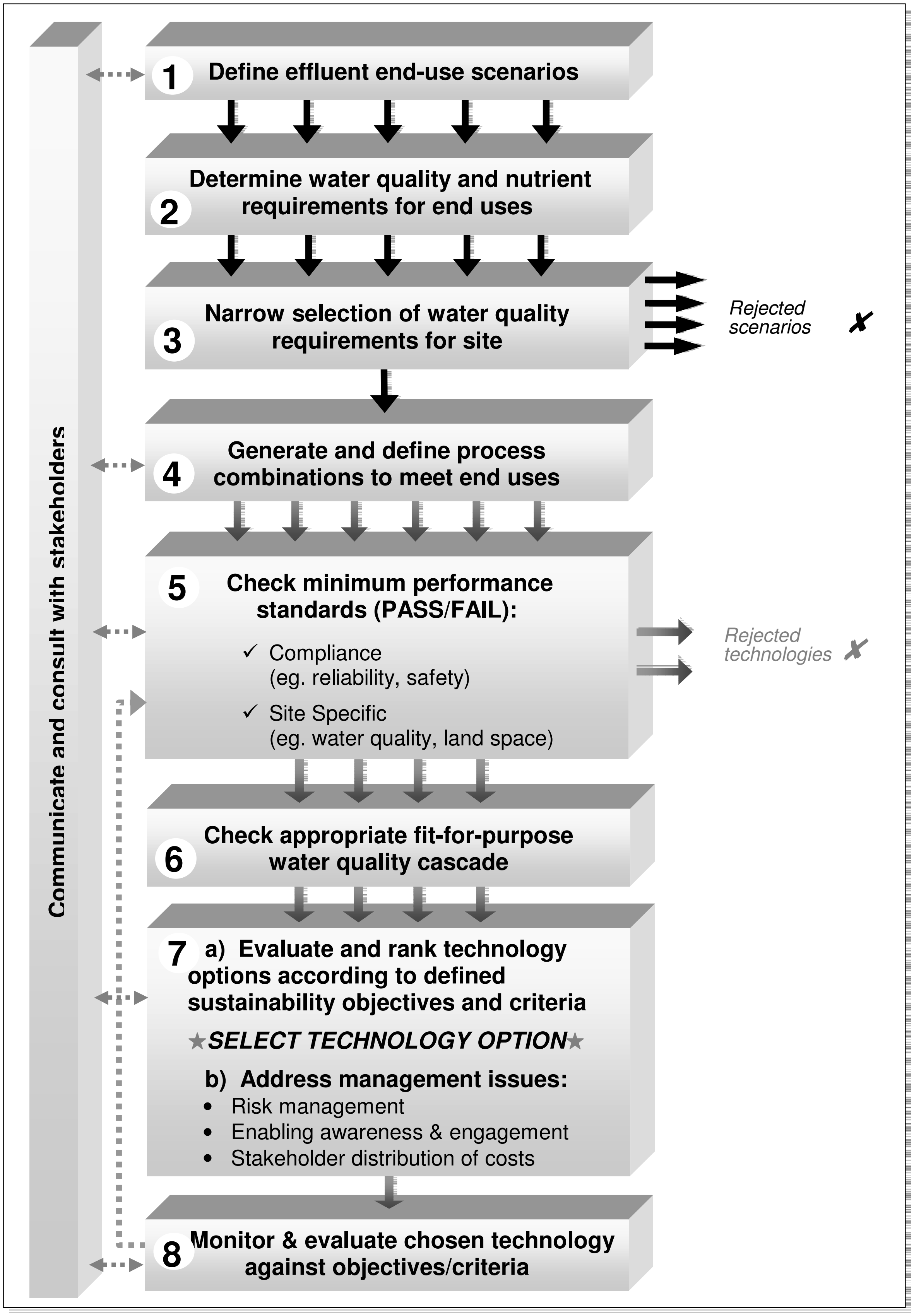

Figure 1: Sustainability screening and evaluation tool.

4.1 STEP 1: *Define effluent end-use scenarios*

Particular end uses have particular water quality requirements. Water quality requirements determine the extent of treatment and therefore the kinds of technologies that need to be considered. So the first step is to define the end-use of the effluent for a specific site.

Potential outcomes or options for use, reuse or disposal of the treated effluent are provided in *Figure 2*. This list is not exhaustive. This will enable some decisions to be made as to what is desired or required for the specific site. There may be a number of viable options for the effluent and it may be necessary to evaluate the on-site systems for each viable effluent outcome scenario.

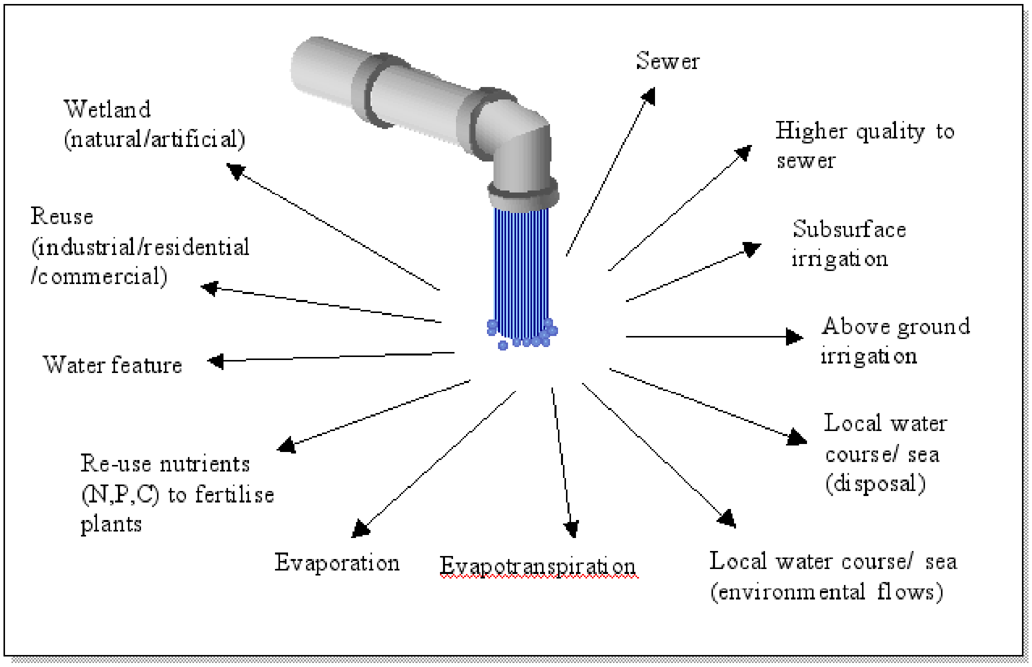

Figure 2: Potential end-use categories for on-site wastewater treatment systems.

4.2 STEP 2: *Defining water quality and nutrient requirements for ①*

Particular end uses have particular water quality requirements. Having defined the end use of interest on a particular site in Step 1, here we identify the water quality required by that end use. It may be the case that several effluent end-use categories require the same water quality treatment, or conversely, that specific end uses within a category require different levels of treatment.

NSW water quality performance standards differ from other states in Australia in that effluent to be applied as sub-surface irrigation must meet the same performance standards as effluent being applied as above ground irrigation (NSW Health Dept, 2001). Therefore, in NSW sub-surface irrigation requires disinfection of effluent prior to land application.

Table 1 outlines the three classes of water quality for various end uses of effluent, as defined by the NSW Health Department. Each class must meet certain performance requirements. Class A includes effluent disposal via trenches, beds, mounds or off-site transfer; Class B includes both sub-surface irrigation and surface and spray irrigation; Class C includes indoor reuse of the effluent for toilet flushing or washing machine use.

Table 1: Effluent treatment standard required for particular land application systems.

Water Quality Class	Category	Sewage/Greywater treatment	Treatment performance requirements
A	**Sub-soil** (>300mm depth) ○ **Trenches** ○ **Beds** ○ **Mounds** ○ **Off-site transfer**	Sewage or Greywater treatment: o Septic tank o Collection well o Greywater tank o CED pre-treatment tank o Biolytic filter o Greywater diversion (no treatment) o Sewage ejection unit (no treatment)	Primary treatment to separate solids from liquids. No performance standard.
B	**Irrigation** ○ **Sub-surface** (300-100mm) ○ **Surface and spray irrigation** (< 100mm to above ground level)	Sewage or greywater treatment o Aerated wastewater treatment system o Domestic greywater treatment system o Textile filter o Aerobic sand filter (which incorporates an active disinfection process)	A secondary treatment disinfected effluent to the following standard is required: o BOD < 20mg/L o SS < 30 mg/L o *T.Coli* < 30 per 100mL
C	**Indoor** ○ **Toilet flushing** ○ **Washing machine**	Greywater treatment only (sewage may be considered in the future) o Domestic greywater treatment system	A secondary treatment disinfected effluent to the following standard is required: o BOD < 20 mg/L o SS < 30 mg/L o *T.Coli* < 10 per 100mL

Source: NSW Department of Health (2001) Advisory Note 4.

The water quality requirements outlined above do not include nutrients. Of course, nutrient concentrations and forms can be important for some end uses, for example, surface or sub-surface irrigation. If applicable for a particular site, relevant nutrient quality requirements will need to be included at this stage of the process.

4.3 STEP 3*: Narrow selection of water quality requirements for site*

In this step, *Table 1* is narrowed down to one Water Quality Class and appropriate nutrient objectives that are viable at the specific site and in keeping with the specific project's objectives. Note that the selected class may contain more than one effluent end-use scenario. It is important to consider at this stage whether the site has any specific water quality requirements. For example, is it adjacent to a nominated wetland?

4.4 STEP 4: *Generate and define process combinations*

In this step a set of decentralised technology options is generated which will meet the water quality classes defined in *Step 3*. Each option may include a combination of technologies or a stand-alone technology.

It is important at this step to ensure that the process combinations decided upon meet public health standards in terms of effluent quality required.

4.5 STEP 5: *Check minimum performance (pass/fail)*

This step involves checking whether the technology options defined in *Step 4* pass minimum performance standards (*i.e.* compliance/satisfy utility and site specific constraints).

If a technology 'fails' on one or more of the minimum performance criteria, then it is either modified appropriately or eliminated from further consideration.

Compliance performance

Minimum performance standards for compliance are outlined in *Table 3*. These were developed with the Galston site in mind, and may need to be reviewed for applicability for other sites.

Table 2: Minimum performance compliance criteria.

Criterion	Minimum performance level
✓ Operation and Maintenance/ Backup service	Ensure backup support is available within an acceptable[2] period of time following system failure
✓ Tamper proofing	YES or NO (*e.g.* locks, fences present, or built in to the design of the technology. The latter is preferred)
✓ Acceptable odour levels	Active odour control measures in place

Potential site constraints

Possible site constraints are listed in *Table 4* and should be checked off prior to continuing the screening process. Again, this is a 'PASS/FAIL' checkpoint where the technology option may be removed from further consideration if it fails one or more of the following site constraints.

Table 3: Potential site constraints on the choice of technology options.

Potential site constraint	Description
✓ Land space	Is there sufficient land space at the site for the technology option?
✓ Water table	Where is the water table at the site? Will this affect the performance of the technology option?

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[2] 'acceptable' needs to be specified for particular sites and particular technologies. For example, if a system operates on a level alarm, and has 24 hours excess storage capacity in failure mode, then a maximum response time of 12 hours might be deemed 'acceptable'

✓ Soil type and depth	What type of soil (soil horizon) is present at the site and what is the depth of soil (*i.e.* to bedrock)? Will the performance of the technology option be compromised substantially by this soil horizon and depth?
✓ Aspect/Slope	Are the technologies and the end uses consistent with the slope and aspect?
✓ Flood potential	Is the site in a flood potential zone? If yes, will this substantially compromise the performance of the technology option?

4.6 STEP 6*: Check appropriate fit-for-purpose water quality cascade*

Different sources of household effluent have different levels of contamination. For example, effuent coming from the toilet is highly contaminated because it contains faeces, which contains pathogens. Effluent coming from used bath water is relatively less contaminated. The relative contamination of typical household effluent source categories are depicted in the water quality cascade concept in *Figure 3*.

Figure 3: Water quality cascade concept.

Application of the water quality cascade concept is an important element of efficient and appropriate system design. That is, deliver water at the quality required for the end use, and design the system's treatment components so that they meet the required level of treatment. It may not be necessary to combine all untreated wastewater streams and consequently treat it to a single water quality class. It may be more efficient to have different wastewater streams of varying quality and treat and reuse them separately. According to the Swedish EPA (1995, cited in Hellstrom *et al.*, 2000), wastewater from toilets is the source of approximately 90% of the nitrogen and 70% of the phosphorus typically found in residential wastewater.

An example of this fit-for-purpose concept is treating the effluent from toilets separately for sub-surface irrigation and separately treating the effluent from the remaining sources (kitchen, laundry, shower) to a level where it can be reused for surface irrigation (see *Figure 4*). This process of source separation is potentially more efficient because less contaminated water requires less resource intensive treatment (Hellstrom *et al.*, 2000). Of course there is a trade-off between this operational resource intensity and the increase in resources and embodied energy invested in duplicated fittings, and the increased complexity of the plumbing.

If opportunities are identified at this point, technology combinations and compliance performance may need to be reviewed *i.e.* it may be necessary to loop back to Step 4 before proceeding.

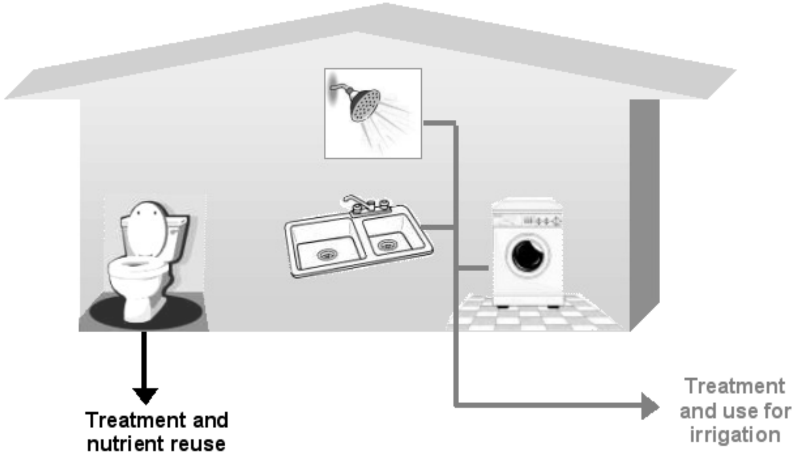

Figure 4: Example of fit-for-purpose water quality cascade for household on-site treatment.

4.7 STEP 7a*: Evaluate and rank options*

This step involves evaluating the remaining eligible options against the sustainability criteria (see *APPENDIX B*) to determine which option is preferable for this specific site. In the past, options were typically compared using cost benefit analysis (CBA). CBA has been used for many years as a means of determining the relative merits of competing options. In this approach, benefits (say in terms of additional water made available through the construction of a new dam) are compared to costs (often the present value of operating and capital costs to the service provider) to produce a benefit-cost ratio (BCR). Ideally, where the benefit/cost is greater than 1, the project would proceed[3]. Such approaches are legitimate, and are commonly used, but there is a risk that only those costs and benefits accruing to the water service provider are included as they tend to be more easily quantified (*e.g.* volumes generated, dollars spent, *etc*). Concepts such as improvement in environmental protection, restoration of an ecosystem, greater amenity and impacts on third parties tend to be ignored.

However, as economic, ecological and social performance are measured in different units, broad benefit/cost analysis has proved difficult in the past. This circumstance is exacerbated by the limitations in our ability to measure performance generally, our focus on a narrow set of economic performance indicators, and the inherent difficulty of assessing social or ecological performance. Nevertheless a range of techniques is now available that has the potential to assess performance of options against a range of criteria that are measured in different units. These techniques allow quantification of tangible and less tangible benefits and dis-benefits, and facilitate their comparison on a common basis. Multi Criteria Analysis (MCA) is one such technique.

The approach taken in this project for evaluating and comparing the on-site wastewater treatment options against the criteria draws on the principles of Multi Criteria Analysis. A

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[3] SWC do undertake many projects with benefit-cost ratio < 1 and instead focus on the project with the highest NPV.

weighted star system has been developed which enables the options to be ranked against criteria and compared. From this, an appropriate technology option can be recommended.

MCA does however have some inherent problems. For example, MCA is heavily dependent on the valuation and allocation of relative weightings of the criteria. It may be reasonable for some of these weightings (or variables) to be allocated by a small group of experts based on available data. However, the assessment of socio-economic and cultural variables is ultimately about the values of people in the community.

For this pilot project, we have taken a simple approach to weighting which is analysed in more detail below. We stress that this is one example where broader social sustainability criteria are important and relevant—allocating weightings to qualitatively different criteria needs to be a participatory process.

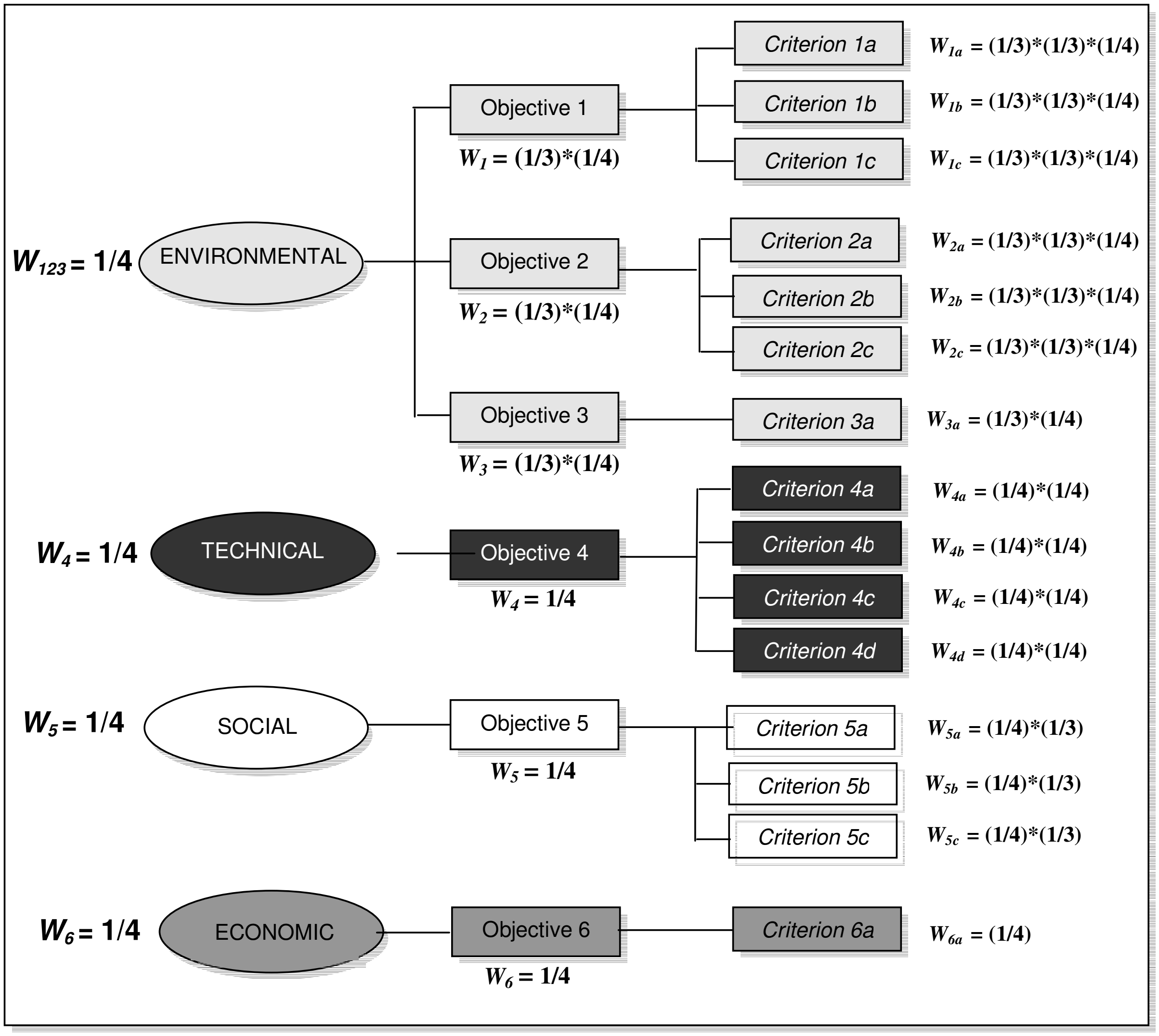

Figure 5: Concept diagram illustrating equal weighting of four areas of sustainability.

The four areas of sustainability identified (environmental, technical, social and economic) are weighted evenly in this first instance. *Figure 5* shows how each objective and criterion is weighted accordingly. This has the effect of giving each aspect of sustainability equal consideration mathematically. On the surface, this might seem to be a reasonable approach. However, the impact is that individual criteria have vastly different weightings and therefore some criteria are inadvertently relegated to very low relative importance. For example, criterion 1a, which relates to minimising greenhouse gas emissions over the lifecycle of the system, has just one-eighth the weight of criterion 6a, which relates to the whole of life community cost. Whether this is considered reasonable or not ought to be the topic of discussion and debate amongst an appropriately representative group. The effect of this anomaly is demonstrated in Sections 9 and 10.

On a site-by-site case, individual criteria may be weighted more heavily, depending on constraints unique to the site and/or project. For example, if the site is in an ecologically sensitive area, such as adjacent to a protected wetland, then the criterion relating to maintaining ecological function may be weighted much higher than other environmental criteria. This variation in weightings can be agreed upon through a stakeholder/community consultation process to determine what is important to each stakeholder group.

Once all technology options have been evaluated and ranked, they can be compared. The technology option (or options) with the highest score is considered more sustainable and appropriate for the specific site. The remaining steps relate to the chosen technology option.

4.7.1 Risk Assessment

Criterion 4.3 (see *Appendix A* for criteria) addresses technology risk assessment. Risk is defined by Standards Australia (AS 4360) as:

> *The chance that something will happen that will impact on objectives. Risk is measured in terms of consequences and likelihood.*

Risk assessment involves identifying risks, then assessing the probability that the risk will occur and the severity of the consequences if it does occur. For community based wastewater treatment systems, risks may include: human exposure to treated (or untreated) wastewater, failure of system, and discharge of unacceptable pollutant levels to surface or sub-surface water body.

The method used in this tool to assess risks associated with the on-site treatment technologies is outlined in *Table 4*. The first step involves identifying risks. The focus of risk identification for this tool is system failure and the key failure modes. Management of these significant risks is dealt with separately in *Step 7b*.

For this process of risk identification, we considered impacts in the three domains of sustainability: environmental, social, and economic. Technical risks were not separately considered since they must be able to be articulated using one or more of the sustainability aspects. If a wastewater treatment system fails, then almost all[4] possible consequences can ultimately be reduced to impacts associated with contaminated water. The impact of the contaminated water is dependent on its destination. We identified three possibilities:

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[4] The intent of this project is to set up a generic process to choose between technologies. A comprehensive risk assessment process is beyond the scope. So, whilst other risks are possible, we assume they are managed through, for example, good occupational health and safety practice.

- contaminated water going to groundwater: in this failure mode the potential socio-economic impact (from, for example, drinking water sourced from groundwater) is likely to be greater than the ecological impact (municipal wastewater from a community based system is likely to have limited deleterious impact on groundwater ecosystems in built up areas);

- contaminated water going to terrestrial surface: here again, the social impact likely outweighs the ecological impact; and

- contaminated water going to surface water: this failure mode has potentially significant ecological and social impacts. Contaminated water can end up in surface water either by surface overflow or by movement through groundwater systems. This failure mode is concerned with the presence of contaminated water in surface water, regardless of the path, since the path is covered in the two failure modes above.

All other risks were deemed less significant, and are excluded from the risk assessment process. Where appropriate, these less significant risks have been included in other sections of the tool *e.g.* risk of odour is deemed to be a nuisance, rather than a threat to health, so it is excluded from the risk assessment process, and included under Objective 5 relating to amenity.

The second step involves assessing the probability or likelihood that the risk will occur. A performance level is assigned (from those performance levels outlined in *Table 5*). The third step involves assigning a level of severity of consequences (from those outlined in *Table 6*). The final step involves using the risk assessment matrix in *Figure 6* with the performance levels from Step 2 and 3 to obtain a star rating (1-5 stars) for the overall level of risk.

Table 4: Simplified risk assessment steps.

	Risk Assessment	
Step		Description/Notes
1	Define and identify environmental, social and economic failure modes	Failure modes for all system components are the same. These modes are: Contaminated water to: a) GROUNDWATER (=social impact); b) SURFACE (= social impact) c) SURFACE WATER (= ecological/social impact)
2	Assess probability of failure mode occurring at the specific site	Assign performance level from *Table 5*.
3	Assess severity of the consequences if each hazard occurred	Assign performance level from *Table 6*.
4	Calculate risk (1-5 star rating) using risk matrix.	Use the 3x3 risk matrix in *Figure 6*.

Table 5 outlines the five levels of probability of a risk occurring. These levels are often used in a qualitative risk assessment (Standards Australia, AS4360).

Table 5: Probability of risk occurring.

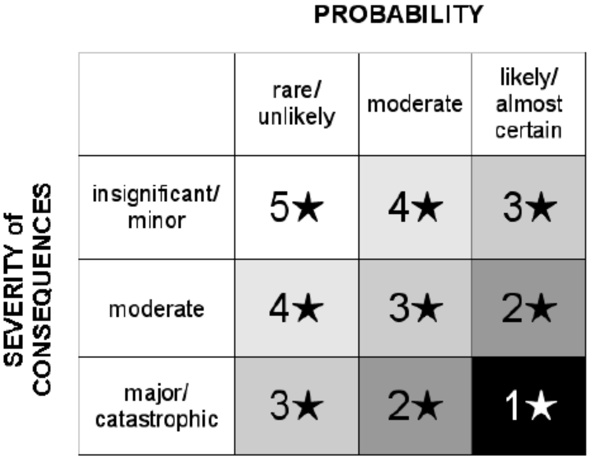
Risk probability level	Description
Rare	not expected to occur but is theoretically possible
Unlikely	possible but very unlikely
Moderate	possible but not probable
Likely	probably occur at some time
almost certain	expected to occur in most circumstances.

Table 6 outlines the five levels of severity of consequences. Again, these levels are commonly used in a qualitative risk assessment.

Table 6: Severity of consequences star ratings.

Risk severity level	Examples
Insignificant	
minor	No lasting detriment to the environment; minor or no impact on community, buildings and legal issues.
moderate	Long-term but reversible detrimental environmental or social impact (such as chronic discharge of pollutants annoying community and/or ecosystem); probable serious breach of regulation; business group reputation is tarnished.
major	Significant extensive and/or irreversible detriment to the environment and/or community; fatal, long-term or irreversible disabling effects on human health; eradication of endangered species; irreversible major breach of regulation, serious litigation.
catastrophic	-

Figure 6 is a risk matrix, which allows the levels of likelihood and severity of a risk occurring to be combined in order to determine an overall level of risk which can be included in the sustainability assessment.



PROBABILITY

SEVERITY of CONSEQUENCES

	rare/ unlikely	moderate	likely/ almost certain
insignificant/ minor	5★	4★	3★
moderate	4★	3★	2★
major/ catastrophic	3★	2★	1★

Figure 6: Risk assessment matrix.

For this purpose, the level of risk is given in terms of a star rating, 1-5, where 5 stars is preferred, in keeping with the sustainability rating system. The lower the level of risk (that is the higher the star rating) the more acceptable is the level of risk. For a risk star rating of 4 or 5, little or nothing may need to be done to manage the risk. If, however, the risk is of a medium (3 star) to high (1 or 2 star) level, then it may be intolerable and will need to be treated or managed. Risk management is outlined in *Step 7b* in *Section 4.8.2*.

4.8 STEP 7b: *Management Process*

The performance of a particular technology or combination of technologies is a function of both the inherent capacity of the technology and the way in which the technology is implemented, *i.e.* the management of the technology, or the way in which people interact with the technology. Because the inherent aspects of the technology are open to less conjecture and therefore are more precise and measurable, they are the focus of the detailed sustainability assessment. However, the actual implementation of the technology (*i.e.* the design, construction, operation and maintenance) can significantly influence a technology's ability to achieve its potential.

In this step then, the focus is on management aspects: the interactions between people and the technologies. This draws out a fundamental principle of sustainability: enabling people to take appropriate responsibility for their decisions and actions. As noted earlier, in section 3, we assume that this tool sits within a broader sustainability framework, and in particular, that socio-economic objectives are strongly articulated at the principles level. The intent here is make an explicit link to that broader framework by identifying opportunities to raise awareness of the importance and breadth of appropriate management strategies to achieve sustainability.

Four good practice management concepts and opportunities have been identified:

- Centralised management;
- Risk management;
- Enabling awareness and engagement; and

- Stakeholder distribution of costs.

The first two relate directly to enabling quantitative performance of the technology, the latter two to qualitative performance. The aim of the following sections is to outline the significance of these concepts to community scale sewage service provision. At this early stage, no guidance is given for judging how well or how poorly the concepts have been incorporated into a particular scenario. That should occur in later stages of the SWC project.

4.8.1 Centralised Management

The NSW Department of Local Government's **Septic✓Safe** program highlighted the local need for improved management of on-site systems. It is often the case that failure of on-site systems is due to inappropriate management of the technology, not the technology itself. Beavers (1999) from the Queensland Department of Primary Industries made the point that the primary reason for the unacceptably high failure rates of on-site systems was a complete lack of management. No one took responsibility for ensuring adequate construction, operation or maintenance, not surprisingly, many systems failed.

The question then is who ought to take responsibility for on-site of community scale sewage treatment systems? For some relatively simple technologies already existing in low-risk areas, it may be appropriate for local governments to assist householders in accepting that responsibility. Thus, one of the outcomes of the **Septic✓Safe** program is a series of educational tools for residents about installation, operation and maintenance of septic tanks (*e.g.* ISF, 2000). However, many systems require more professional maintenance than the householder is willing or able to provide. Otis (1998) notes "*we have not accepted the fact that on-site systems are treatment plants that must be designed and maintained by qualified people*".

The other option is to challenge the nexus between the scale of the sewage treatment technology and the location of responsibility and management. At present, centralised sewage treatment facilities are the responsibility of the appropriate government authority, whether a specific water and sewage authority, or a local government authority. In this context, 'centralised' means any service that extends beyond the landholder's boundary. Systems operating within the boundary of the landholder have traditionally been assumed to be the responsibility of the landholder or resident. In the emerging model of centralised management, the scale and location of the technology are incidental to where responsibility for installation, operation, and maintenance lie. That is, a central authority takes responsibility for supplying sewage services, regardless of whether the treatment device/s are distributed or centralised.

Centralised management of decentralised, small scale or on-site systems is increasingly recognised as fundamental to ensuring effective performance (US EPA, 2000b). Advantages of centralised management system include (Otis, 1998):

- freedom from uncertainty of performance;
- freedom from householder responsibility;
- greater predictability of costs;
- greater control of ensuring environmental protection; and
- greater control over protection of public health.

The US EPA has produced guidelines for management of on-site/decentralised wastewater systems. They are a set of recommended practices needed to raise the level of performance of on-site systems by improving their management (US EPA, 2000c). Five separate model programs have been developed, each of which has the goal of protecting human health and the environment. The five model management programs are:

- system inventory and awareness of maintenance needs;
- management through maintenance contracts;
- management through operating permits;
- utility operation and maintenance; and
- utility ownership and management.

Each model program includes a set of recommended approaches for planning, siting, design, performance, installation, operation, maintenance, and monitoring of wastewater systems.

Centralised management of distributed technologies is a new way of doing business for Sydney Water, and for most water and sewage authorities in Australia. It raises many questions that SWC is working on answering, and has the potential to provide many benefits. Recent work on the SWC Edmondson Park project completed by ISF and CSIRO demonstrated an important finding, which adds weight to the argument to move towards centralised management.

In the Edmondson Park Feasibility Report (ISF and CSIRO, 2002), annualised capital costs were estimated for a set of options ranging from fully centralised at a very large treatment scale (a single plant providing treatment for many hundreds of thousands of equivalent tenements) to complete allotment-scale treatment technology. Traditionally, the boundaries for thinking about cost are determined by our current approach to who is meeting the cost. In contrast, for the Edmondson Park study, all the capital costs were included to supply the service to the house. That is, for centralised sewer, we included the house line, as well as an appropriate proportion of the collection network and sewage treatment plant. For allotment scale, we included a composting toilet, a greywater treatment system, a wetland, and the appropriate plumbing.

Using this system boundary, there was no significant difference amongst the full range of options in terms of annualised capital costs for water, stormwater, and sewer service provision. This finding is significant because we know that distributed technologies hold significant potential benefits in reducing operating, maintenance, and replacement costs, and reducing greenhouse gas emissions, as well as strong potential for job creation and enabling local engagement with the water cycle. If the total capital costs are essentially independent of the scale of the technology, then the cost/benefit ratio for centralised management of distributed technologies further improves.

Centralised management is therefore included in this sustainability ranking process because it needs to be an explicit consideration in enabling distributed, community scale technologies to meet their objectives.

4.8.2 Risk Management

Risk management as defined by Standards Australia (AS 4360:1999 Risk Management) is:

> *an iterative process consisting of well-defined steps, which, taken in sequence, support better decision making by contributing a greater insight into risks and their impacts. The risk management process can be applied to any situation where an undesired or unexpected outcome could be significant or where opportunities are identified. Decision makers need to know about possible outcomes and steps to control their impact.*

Risk management provides a mechanism for dealing with potential risks and the severity of their consequences in a proactive manner. The risk management process is depicted in *Figure 7*. In *Step 7a* (*Objective 4*), the on-site technology risks are assessed in terms of likelihood of occurrence and severity of consequences. *Figure 7* shows that this risk assessment phase is just one component of risk management. Different technologies have different inherent risks. The risk management process allows treatment or management of these potential risks in order to minimise their occurrence and their impact, or to distribute the impacts more evenly across stakeholders.

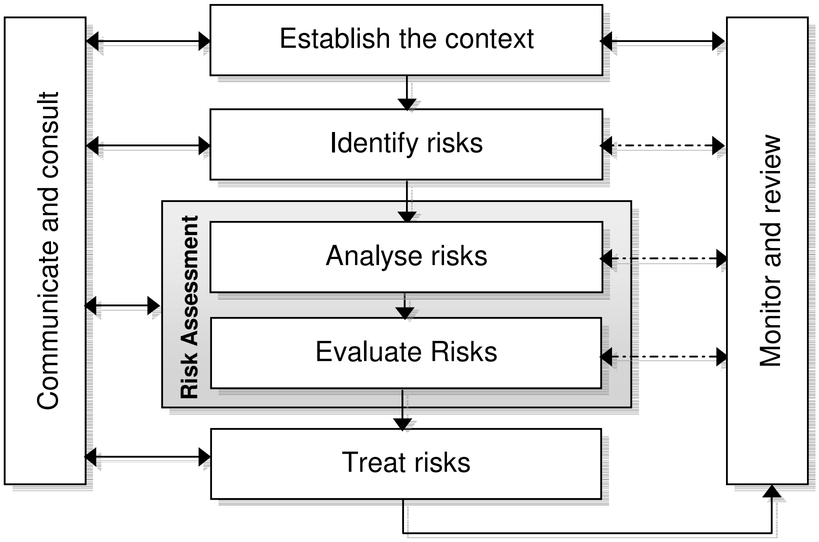


Figure 7: The Risk Management Process in Australia and Europe.

Source: Standards Australia AS 4360:1999.

Since risk is unavoidable, that is, there is always some degree of risk, the goal of risk management is acceptably low risk, rather than the unattainable notion of zero risk. Here, acceptably low risk can be interpreted as 4-5 star performance (see *Figure 6*). For example, we have defined risks with rare probability and moderate consequences as 4 star, and thus acceptable. Risks which must be managed are those with scores of 1-3 stars. There are three kinds of risks which must be managed: those perceived as likely to occur; those with major or catastrophic consequences; and those perceived as moderately likely with moderate consequences.

Examples of treatment or management of risks are provided in *Table 9*. Since risks are assessed in terms of probability and severity, risk management is focused on either reducing the probability (*i.e.* mitigation or prevention) or a process for minimising the severity of consequences if the hazard does occur.

Table 7: Examples of ways to manage/treat risks related to on-site systems.

Risk	Treatment/management examples	
	Reduce probability (*i.e.* prevent)	**Minimise severity** (*i.e.* reduce impact)
Exposure to treated/untreated wastewater	Adequately cover infiltration area, *e.g.* by good practice construction Ensure technology option meets all relevant codes/standards[5] Ensure adequate signage and education opportunities	Ensure effluent is treated to bathing water quality
System failure	Monitor remotely Maximise capacity to deal with shock loads (hydraulic, toxic, biological) Minimise hydraulic shock loads to system through water efficient technologies and practices Maximise physical robustness	Raise alarm quickly and appropriately Ensure speedy effective response *e.g.* through guaranteed available, appropriate, local, technical support (skills and parts)
High maintenance requirements	Minimise complexity of technology	Distribute costs of maintenance more evenly across stakeholders [6] Ensure maintenance responsibility is with service provider rather than user (*i.e.* minimise owner intervention).
Unacceptable noise levels	No action possible	Encase technology part creating noise in sound-proof casing
Safety risks	Minimise occupational health and safety issues	

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[5] This may include SWC building work practice requirements; Council requirements; site requirements.

[6] This is to ensure high costs are not unfairly burdened on one stakeholder group. For example, under SWC's priority sewage program, costs for high priority areas will be recovered from the entire customer base.

According to West (2001), examples of key elements of an efficient and reliable on-site system include:

Reducing probability of risk:

- watertight septic tank;
- on-going education of householders, regulators, real estate agents and other stakeholders;
- professional training for community based service people;
- watertight small diameter PVC or PET pipes with heat welded joints; and
- remote monitoring.

Minimising severity of risk:

- septic tank effluent filter;
- correctly designed and constructed infiltration trenches; and
- interactive databases;

Significantly and appropriately, these risk management strategies cover both technology and management aspects of design, installation, operation and maintenance.

4.8.3 Enabling awareness and engagement

This component of sustainable management discusses maximising the sustainability of the on-site treatment system through fostering awareness, engagement and understanding of the water and wastewater cycles by users and other stakeholders.

The principles and strategies for social awareness and engagement listed below are adapted from the ISF/CSIRO Edmondson Park project. These are consistent with and extend Sydney Water Corporation's community consultation and education approaches. Although these principles and strategies are an important part of developing a sustainable on-site wastewater management system, a detailed strategy for their inclusion in this project is beyond the scope of this stage. Here again we assume that this process is taking place within a broader sustainability framework, and that these principles will be addressed in subsequent stages of the project.

There should be an aim to achieve a level of understanding of wastewater services provided to the resident community such that householders take responsible action and there is a sense of pride in 'pioneering' a more sustainable approach. Indicators or elements of such a management system might include:

- Systems are established to support community participation and involvement in, input to and deliberation on the management of wastewater services at the site;
- Resident's report that they feel involved in the process of managing the water systems provided to them, in managing their impacts on the aquatic environment and in recommending improvement that could be incorporated in future stages of the development;

- Level of awareness is determined through qualitative and quantitative analysis at regular intervals (say every 2 years);
- Monitoring and reporting is carried out to provide regular feedback to customers on performance of the wastewater system serving the site;
- All purchasers receive effective educational material providing accessible and comprehensive information about their wastewater system. This indicator to apply to original and subsequent purchasers;
- Community determines in-stream water quality standards (as per the 'Healthy Rivers' process;
- No system failures attributable to irresponsible action by householders; and
- awareness and training of owners and users (this may be any of: SWC staff, local government, contractor, owner).

A successful and sustainable management system also involves maximising social wellbeing and personal exchange. Such a system might have the following characteristics:

- Social interaction network between community members is frequent and complex;
- 'market research' in existing comparable sites is used to determine how the users/ residents think the systems could be improved;
- No odours or unsightly visual obstructions;
- Number of people able to inadvertently experience aesthetic and/or green lines of sight is maximised;
- Number of people aware of local heritage sites and their significance to different community constituents is maximised;
- Local heritage sites are celebrated and respectfully incorporated into public spaces;
- Aesthetic experience is maximised;
- Civic focus is maximised;
- Personal wellbeing is maximised;
- Personal safety is maximised;
- Equity of access to aesthetic experiences is ensured; and
- Protection of heritage sites is ensured.

4.8.4 Stakeholder distribution of costs and responsibilities

This concept relates to the management and distribution of costs and responsibilities to the stakeholders. Whilst *Objective 6* of the Sustainability Criteria is to "*Minimise whole of life cost to the community*" of the on-site system, the individual costs incurred by each stakeholder need to be managed to ensure that they are equitable. The preliminary capital cost outcomes from the Edmondson Park project, discussed in the introduction to Section 4.8, further demonstrate the opportunity and need to think carefully about the basis for allocating costs to stakeholders. That is, whilst the total cost of one system may be lower than another, different apportioning of the individual costs borne by different stakeholders may not reflect that decrease. For example, under current cost allocation processes, the cost to the resident of an on-site system may be much more than a standard sewer house line connected to a centralised sewerage network, at the same time reducing the cost to the water utility. It may therefore be necessary to redistribute costs such that the water utility contributes differently to the total system cost.

Stakeholders who may need to be included in the cost analysis are:

- users/landowners/residents;
- Sydney Water Corporation staff;
- Local government staff;
- NSW government agencies, including:
    - NSW Health
    - Environment Protection Authority
    - PlanningNSW
    - Department of Land and Water Conservation
    - Department of Local Government; and
- decentralised sewage treatment industry representatives (including academics, consultants, engineers, designers, manufacturers, installers, repair and maintenance providers).

4.9 STEP 8*: Monitor & evaluate chosen technology against sustainability objectives and criteria*

The sustainability criteria have been designed as both a screening and evaluation tool. It is envisaged that after the chosen technology option has been installed and monitored over an appropriate period, its performance should be evaluated against a similar set of criteria. So, this step will involve monitoring the chosen technology combination once it has been implemented and evaluating it against the sustainability objectives and criteria in *Steps 6* and *7*. This is essentially part of the ongoing management process.

In addition to the minimum compliance criteria listed in *Table 5*, the criteria listed in *Table 8* should also be incorporated in the evaluation process. Reliability and safety are obviously significant criteria, and were excluded from *Table 5* only because of the difficulty of obtaining verifiable information on these criteria at this early stage.

Table 8: Additional criteria for evaluation purposes.

Criterion	Minimum performance level
✓ Reliability	To be determined separately
✓ Safety	To be determined separately

4.10 Summary of Screening and Evaluation Tool

The previous sections explained the concepts behind the development and application of the screening and evaluation tool for on-site technologies. The core of the process is a set of sustainability objectives, criteria, and performance levels, developed through integrating appropriate aspects of the outcomes of the Greenfield Manual and Edmondson Park project (ISF and CSIRO, 2002) with an extensive national and international literature review. These criteria were then embedded in a logical sequence of steps aimed at posing key questions for designers of community based sewage treatment systems.

In Sections 5–9, the tool is applied to the pilot project, Galston High School. In Section 10, the results of this application are interpreted, and in Section 11, the tool is reviewed and critiqued.

5 SITE CHARACTERISTICS

Galston High School in Galston, NSW, is being used to trial both the implementation of a sustainable on-site wastewater treatment system and the screening and evaluation tool developed in this project. Sections 5–10 show the outcomes of the application of the screening and evaluation tool to this site.

Galston High School is an agricultural school. There are currently 970 students and staff. The effluent volume produced per year is thought to be 3.3 ML. The site available at Galston High School for the treatment system is adjacent to the main school building, near the current pump-out tank. The potential area for reuse (sub-surface irrigation) includes the area adjacent to treatment plant on small agricultural grounds, gardens, two football fields behind main school building and two large sporting fields across the road. According to a recent preliminary site analysis (SWC 2002), the total estimated area of Galston High school is 9.6 hectares and Galston Park (across the road from the High School) is 8.6 hectares. Both sites contain a mixture of buildings, open space and extensive natural bushland (SWC, 2002).

The following table (*Table 9*) provides more detailed site characteristics.

Table 9: End-use and site characteristics for Galston High School.

Parameter	Data	Notes/Comments
Land space available: **a) For treatment technologies**	-	It is envisaged that there is sufficient space adjacent to the existing septic tanks to install the treatment system.
b) For irrigation	7.094 ha	This figure does not include gardens and landscaped areas which are also potential locations for sub-surface irrigation.
Soil type	Heavy clay	-
Soil depth	1-2m	-
Slope	-	Over-all land is essentially flat (i.e. on top of a sandstone plateau)
Flood potential	-	Very low; site is on the ridgeline, therefore there is no risk of flood water inundation for extended periods.
Geology	-	heavy clay overlays shale which overlays sandstone
Vegetation	-	sporting fields covered by grass and surrounded by native forests, pasture, vegetable gardens, arable area (crop production and grazing), some fruit growing and school gardens/landscaped areas.
Aquatic environment	-	no open water streams or water bodies in the vicinity only a 'dry' drainage ditch through the school agricultural area

Source: Sydney Water Corporation, 2002.

The draft land capability report (SWC, 2002) provides a preliminary assessment of the site and its potential for effluent reuse. Whilst it concludes that the application of recycled water to the Galston study site appears to be technically feasible, it identifies several major limitations. These are:

- the shallow, acidic and moderate to low fertile soil types;
- the potential for imported fill materials to have been used in playing field construction;
- large buffer zones may be required for low quality effluent, preventing irrigation in certain areas of the study site, particularly near buildings, native vegetation, steep slopes, ephemeral waterways and site boundaries;
- the variable school semester program and school laboratory wastes may vary effluent quality and quantity accordingly; and
- assessment of the potential health risks related to the current land-use are dependent on recycled water treatment quality and application method.

6 WATER QUALITY REQUIREMENTS

For Galston High School the effluent end use is to be sub-surface irrigation. The most significant advantage of sub-surface irrigation with treated effluent relative to conventional irrigation practices is the direct application of water and nutrients to the root zone, enabling efficient and effective uptake. Sub-surface systems are also much less prone to tampering. Acron Noble list some other advantages (2000):

- Potable water conservation;
- Reduced risk of airborne transportation bacteria;
- No evaporation or run off;
- No overspray on pathways or common areas; and
- No splash damage or water marks on fences/walls etc.

The primary disadvantages of sub-surface irrigation are the difficulty associated with detecting problems, and the necessity to dig the system up if repair becomes necessary. An aesthetic disadvantage relates to potential 'streaking', where grass directly above the irrigation tubes is lusher than that between tubes.

Opting for sub-surface irrigation means the technology options selected for screening must provide adequate effluent quality for this end use. Unlike most other health departments in Australia, the NSW Health Department requires that effluent to be reused for sub-surface irrigation be treated to the same water quality class as above ground irrigation (NSW Health Dept, 2001). The key point is that disinfection is currently necessary for sub-surface irrigation in NSW

At this site, it is not feasible to separate the effluent stream into water quality classes and treat the streams separately. That is, there is a single defined influent stream which must be treated. This is in part because extensive plumbing already exists at the site and it does not make sense to retrofit this infrastructure. So, there is no real opportunity to apply the fitness-for-purpose concept.

Two anomalies have been identified for the effluent stream at Galston High School:

- School influent characteristics might be expected to have higher concentrations of organics and suspended solids than municipal wastewater because toilets represent the major school end uses. However, information provided by the Department of Education and Training indicates school influent is typically low in suspended solids presumably because of water inefficient habits of school children;
- Pump out records indicate large effluent volumes when there are no occupants. This suggests either inaccuracies in volume records or extensive infiltration which would increase the volume and decrease effluent strength. The source of such infiltration is not obvious, since local groundwater tables are unlikely to intersect with the collection system within the school.

Both of these anomalies should be clarified at the design stage. Preliminary analysis currently underway is the first step in this process.

7 WATER BALANCE

The capacity of the community-based system must be designed to meet the need of the school, both in terms of wastewater treatment and irrigation demand. Whilst a more detailed water balance needs to be undertaken at a later stage of the overall demonstration project, this section discusses available data and preliminary analysis of a water balance at the site. According to the recent draft land capability report (SWC, 2002), "the climate of the Galston area appears to provide favourable conditions for a reuse scheme. Recycled water application can be used as a resource to compensate for the apparent moisture deficit."

The following *Table 10* summarises available relevant data for Galston High School. The data are derived from a range of sources, including the draft land capability report, meter readings and fax memos.

Table 10: Data available for Galston High School used to determine the required capacity of on-site system.

Parameter	Data	Units	Notes/Source
Number of students	900	Students	Source: fax memo. Noel Jackson (General Assistant Galston High) to Rob Blackall 5/2/02
Number of staff	70	Staff	As above
Days used per year	210	days/yr	Assumption based on average school timetables
Daily water consumption: *Peak quarter*	39.4	KL/d	This data is based on quarterly meter readings for Galston High School over the period 6/5/97 – 17/5/02. Peak consumption was generated by divided peak quarter usage by number of days in that quarter. Similarly for minimum quarter.
Minimum quarter	8.1	KL/d	
Annual water consumption	4.8	ML/a	Average based on meter reading data for the period 1/11/00 – 31/10/01.
Pump out volume (sullage removal)	3.3	ML/a	Sullage removal 1/12/00 – 30/11/01; Source: fax memo. Noel Jackson (General Assistant Galston High) to Rob Blackall 5/2/02
Rainfall: *Annual median*	1000.9	mm/a	Median annual rainfall in the Galston area; Source: Martens (1998 and 2002) cited in SWC (2002)
Wettest quarter	Jan-Mar	-	These are based on averages, source: SWC (2002)
Driest quarter	July-Sept	-	
Evaporation: *highest*	Oct-Mar	-	These are based on averages; source: SWC (2002)
lowest	June-July	-	
Moisture 'deficit'	330	mm/a	On an annual basis, evaporation exceeds rainfall by this amount; There is a small moisture 'surplus' in June, and substantial moisture 'deficit' during Nov-Dec. source: Martens (1998 and 2002) cited in SWC (2002)

A simple calculation shows (3.3Ml/yr)*(yr/210d)*(10^6L/ML)*(1/1000p) = 16L/c/d. According to Crites and Tchobanoglous (1998), typical wastewater flow rate for a school is 41.25L/c/d. Whilst some of this discrepancy could be attributed to large differences in toilet flush volumes between the USA and Galston, this lower than expected daily wastewater volume for Galston further clouds the anomalies identified in the previous section. Wastewater is produced at the school at times when it is essentially unoccupied, and yet the total volume suggests a low average water use, which goes against the idea that infiltration could be contributing to the wastewater flow. A more detailed water balance is necessary to produce reliable figures for design.

A preliminary water balance can be undertaken to estimate the required flow rate and application rate for the grounds to be irrigated. Two methods are reported here. Firstly, using a rough rule of thumb (Ormiston, 2001) of 5mm/d as an application rate for subsurface irrigation, one would require an area of 1800m^2 for reuse. This area would be readily available in existing school gardens with easy access to the likely location of the sewage treatment facility.

The second method uses the Netafim online calculator to estimate the area required for irrigation. The input assumptions are provided in *Table 11* and the outputs in *Table 12*. See *Appendix C* for more detail.

Table 11: Input assumptions (estimates only) to determine flow rate and application rate of effluent irrigation using Netafim technology.

Input parameter	Data	Units	Notes/Comments
Land area to be irrigated	3000	m^2	This area could represent a 10m strip along two sides of the existing football field. Much more land is available.
Ground cover	Shrubs or Turf in clay soil	-	A more detailed analysis including soil horizon may reveal sand soils at the depth the dripperline is to be installed. The analysis presented here is therefore conservative.
Row spacing between techline	0.51	metres	This was an average estimate. For clay, Netafim recommend spacing of 18 – 24 inches.

Source: SWC (2002); Netafim Calculator (http://www.netafim-usa-landscape.com/Landscape/calc/).

Table 12: Output data (estimates only) of design specifications for Netafim sub-surface drip irrigation.

Output parameter	Data	Units	Notes/Comments
Total Techline length required	5 884	metres	Techline is Netafim's trademark irrigation distribution material
Dripper spacing	0.46	metres	This is the length between drippers on the Techline
Number of drippers required	12 871		Drippers are the point sources of effluent irrigation along the techline
Dripper flow rate	1.5	L/hr	This is the constant flow rate for each dripper
Flow rate over total area	324	L/min	This is the flow rate over the total defined area.
Application rate	6.1	mm/hr	This is the total flow rate expressed as a hydrologic loading rate

Source: Netafim Calculator (http://www.netafim-usa-landscape.com/Landscape/calc/).

Based on the input assumptions in *Table 11*, the online Netafim calculator estimates that for an area of 3000m^2, representing clay soil with either shrubs, groundcover, or turf, a daily application period of 1 hour would distribute 6mm, which is equivalent to about 19 kL. The total annual flow estimate at the school of 3.3ML is equivalent to 9 kL/d, based on 365 days per year, or 16kL/d, based on the number of days the school is in use (*i.e.* 210 days per year).

Leaving aside the issue of wet weather storage at this early stage of the analysis, it would seem that there is no limitation from land required for irrigation.

However, these figures are only intended to be indicative and a thorough water balance will need to be undertaken. Daily time steps with local rainfall data should be used to size wet weather storages. In addition, to accurately design the sub-surface irrigation scheme, the design parameters outlined in *Table 13* may need to be determined. These are outside the scope of this stage of the project.

Table 13: Design parameters for effluent irrigation systems

	Parameter	Unit
Effluent	Design flow, average annual	kl/d
	Design peak flow	kl/d
Irrigation area	-	ha
Buffer zone allowance	area	ha
	width	m
Land for storage	-	ha
Water balance	Design total annual precipitation	mm/y
	Design total annual runoff	mm/y
	Design evapotranspiration	mm/y
	Design percolation rate	mm/y
Organic loading rate (as BOD_5)	-	kg/ha/d
Other constituent loading rates	-	kg/ha/d
Effluent quality	Total dissolved solids (TDS)	mg/l
	Electrical conductivity	ps/cm
	Sodium absorption ratio	(mmol/l)D2
	Ca, Mg, K & Boron	mg/l
	BOD_5	mg/l
	TOC	mg/l
	COD	mg/l
	Suspended solids	mg/l
	Grease	mg/l
	Metals and pesticides	mg/l
	Nitrogen (total)	mg/l
	Phosphorus (total)	mg/l
	pH	mg/l
Application rates	Length of operating season	wk/yr

	Application period	hrs
	Average weekly rate	mm/wk
	Maximum weekly rate	mm/wk
Storage capacity		m^3

Source: Acron Noble (200), *Acron Noble Case Study – Beechmont State School – Treated Effluent Re-Use Project*, Acron Noble Decentralised Waste Water Treatment Systems.

8 ALTERNATIVE COMMUNITY BASED SEWAGE TREATMENT TECHNOLOGIES

This chapter defines and summarises the chosen technology options to be screened against the sustainability criteria. The broad range of technologies considered is shown in *Appendix C*. Options for assessment were assembled from that range. The four options listed in *Table 5* are intended to be indicative, rather than exhaustive. They represent categories of technologies and enable comparison between technologies considered to be best practice in NZ and USA and technologies already common in NSW.

Option 1 is intended as a reference case or benchmark because it incorporates Ecomax. Ecomax (the main component of Option 1) is the only on-site technology with which SWC has direct experience. We assume that SWC considers it 'current best practice' in the NSW context. Its inclusion in the options analysis allows it to be compared with other technologies commonly considered overseas 'best practice'. *Options 2* and *3* are considered 'best practice' in some parts of the US, Europe and New Zealand. *Option 2* incorporates recirculating sand filters, which are reasonably common in Australia now. *Option 3* uses Orenco technology already widespread in the US, Europe and NZ, and claimed to be one of the most reliable and effective on-site technology systems. *Option 4* is intended to be indicative of another common technology category: automated/advanced wastewater treatment systems (AWTS).

Information on the range of technologies outlined in *Appendix B* was obtained from a number of sources:

- performance evaluations undertaken on either trials or existing uses of the technologies;
- fact sheets from government bodies such as US EPA;
- notes (and literature) derived from Sarah West's study tour of community based wastewater treatment systems in US, Europe and NZ;
- existing notes, literature and knowledge at The Institute for Sustainable Futures; and,
- product information from the technology manufacturers.

Table 14: On-site wastewater treatment options for Galston High School.

Option	Technology process
1	Existing technology septic tank ➔ *ECOMAX*
2	Existing technology septic tank (with filter) ➔ recirculating sand filter (*Garden Master*) ➔ UV disinfection
3	*INNOFLOW* interceptor tank (with filter) ➔ *ADVANTEX* textile filter ➔ UV disinfection
4	*ACRON NOBLE AWTS* ➔ *UV disinfection.*

In some scenarios, small diameter watertight pipes can be used to connect various treatment technology components. The advantages and issues of using such pipes are discussed briefly in *Box 1*.

Box 1: Small diameter watertight pipes

Small diameter pipes can only be used where the effluent quality is relatively good in terms of suspended solids (SS), otherwise clogging of pipes can occur. Low SS in the effluent exiting the septic tank can be achieved by using a good quality filter. Such filters can prevent 50–90% of solids from leaving the septic tank.

Small diameter watertight pipes are generally used in conjunction with pumping. The use of small diameter watertight pipes has many advantages over conventional pipes, which are larger and generally not watertight. SWC usually designs conventional systems for up to six times the baseflow, largely because they are not watertight.

Some advantages of small diameter watertight pipes include:

- Reduced flow due to no illegal connections or wet weather infiltration;
- Reduced pipe diameter due to reduced flow;
- Reduced trenching;
- Reduced system cost due to reduced pipe size, flow and trenching;
- Increased flexibility to detour round obstacles such as trees or Aboriginal sacred sites;

Plastic pipe is commonly used because it is more economical in small sizes and is resistant to corrosion (US EPA 2000a).

8.1 Option 1: Septic Tank and Ecomax

This first option involves existing technologies in use in Australia for which SWC has independently analysed performance data. As such, it represents the current benchmark. *Option 1* can be compared to innovative new technologies in Europe, US and NZ which have not yet been trialled in Australia. *Option 1* does not meet the water quality class required for sub-surface irrigation in NSW, which requires active disinfection. *Ecomax* technology does not include sub-surface irrigation, thus, does not require disinfection.

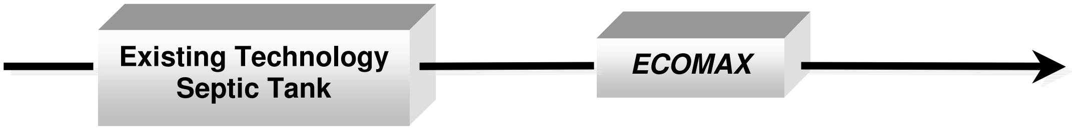


Figure 8: Concept diagram of the technologies in *Option 1*.

8.1.1 Septic tank (existing technology)

A septic tank is a traditional on-site wastewater treatment technology, which consists of a holding tank that also acts as primary treatment device (US EPA, 2000b). The septic tank is often the first treatment unit in a series of treatment technologies. The main aim of the septic tank is to:

- collect and store the wastewater;
- segregate settleable (sludge) and floatable (scum) solids;
- allow accumulation;
- digest organic matter; and
- discharge treated effluent (Bounds, 1997).

In general, a longer flow path in a septic tank means greater settling of solids. The use of a filter will also minimise the amount of suspended solids leaving the tank. There are many variations of septic tanks being developed which aim to improve the performance efficiency in wastewater treatment. However, for the purpose of this option, which is to provide a reference case scenario, a standard septic tank technology will be assumed.

Figure 9 illustrates a typical septic tank cross section.

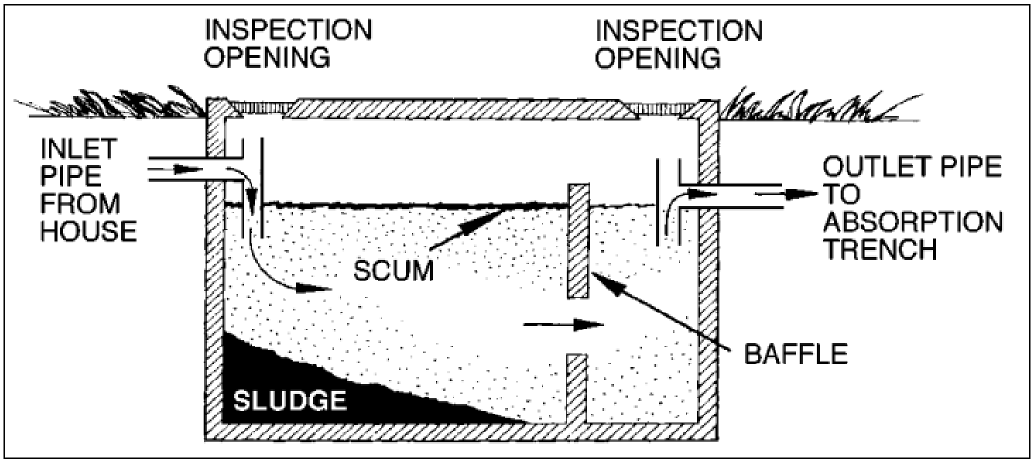


Figure 9: Cross section of a typical septic tank.

Source: Institute for Sustainable Futures (2000), *On-site System Training Course: septic tank and absorption trench systems*, prepared for Mulwaree Shire Council by ISF, Sydney.

8.1.2 Ecomax

Ecomax is a passive wastewater treatment and dispersal technology. Ecomax influent must be pre-treated. Ecomax and includes the following components (Ecomax, *www.ecomax.com.au*):

- Two Ecomax cells;
- Active ingredient—an industrial by-product which has a strong Phosphorus adsorption capacity (usually high in iron and aluminium sesquioxides);
- Top soil (acting as a substrate for grass); and
- Grass cover.

A typical system has two Ecomax cells which are used in rotation. The cells are comprised of:

- A leach drain (or tunnel) for storage and leaching;
- Underlying impervious membrane; and
- Amended soil treatment medium.

The system operates by effluent flowing under gravity from the septic tank to the storage leach drain in an Ecomax cell. The effluent then disperses radially through the amended soil away from the leach drain. Some effluent is lost by evapotranspiration and/or effluent escaping over the perimeter bund.

Figure 10 illustrates the cross section (front view) of an Ecomax. In this diagram, the ground level is shown as flat, however in some instances, the topsoil and vegetation is more mounded.

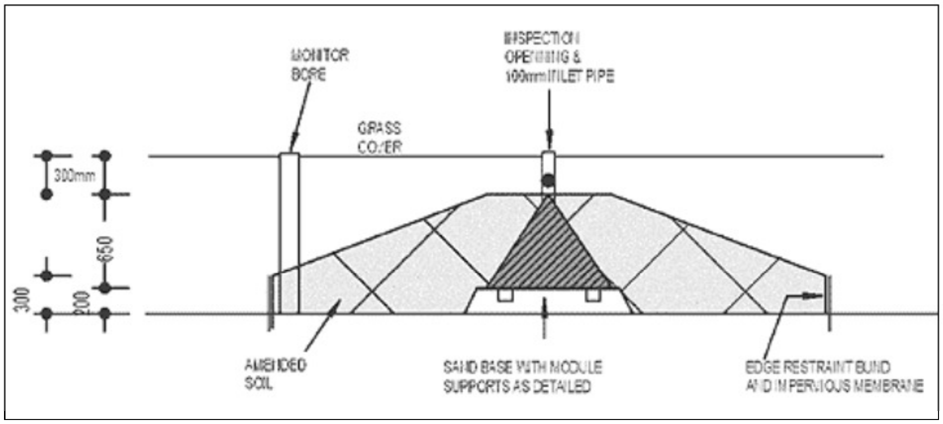


Figure 10: Schematic of below ground installation option of Ecomax.

Source: Ecomax (*homepage*), [*Online*], available: http://www.ecomax.com.au/plan1.html

Ecomax claims to have the following features (Ecomax, *www.ecomax.com.au*):

- Complete effluent distribution control;
- Highly effective fines filtration;
- Phosphorus adsorption;
- Nitrogen nitrification/denitrification;
- Organic oxidisation and reduction;
- Hydraulic retention control;
- Coliform reduction during retention;
- PH adjustment;
- Water and nitrogen uptake by transpiration;
- Water uptake by evaporation;
- Water dispersal by absorption;
- Significant reduction of micro-organisms through microfauna predation;

- Heavy metals reduction; and
- Passive technology—no moving parts or electricity required.

8.2 Option 2: Septic tank (with filter), recirculating sand filter, UV disinfection

This option utilises the sand filter preceded by a septic tank with filter.

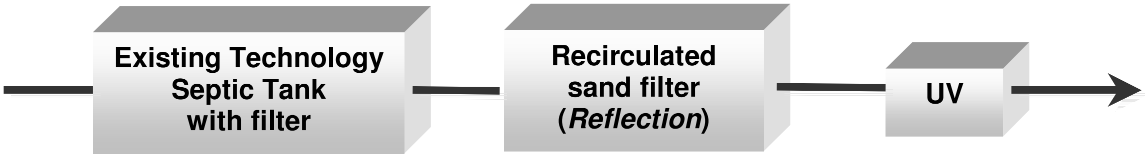


Figure 11: Concept diagram of the technologies in *Option 2*.

8.2.1 Septic tank (existing technology) with filter

This is the same as the septic tank described in *Section 8.1.1* but with the addition of a filter. The filter retains some of the suspended solids in the septic tank, rather than allowing them to flow into the next treatment technology (the reticulated sand filter in this case).

8.2.2 *Reflection* recirculating sand filter

In the US and Northern Europe, both sand filters and textile filters are considered top of the range for household or cluster on-site systems (West, 2002).

The *Reflection* recirculating sand filter is aerobic, and does not need to be back-flushed. It recirculates the effluent 5 times, in the same way that the effluent is recirculated in the Advantex system.

Figure 12 illustrates the *Reflection* Recirculating Sand Filter. The system operates with an automatic siphon dosing system. This enables the effluent from the interceptor tank (1) to be stored in a tank (2) until a high water line is reached, at which point the siphon begins operating and rapidly drains the tank to the lower water line, forcing the effluent into the sand filter (3). The effluent reaching the bottom of the sand filter is drained into the recirculating storage tank (4), which is also operated by an automatic siphon. The treated effluent is then dosed to sub-surface irrigation (5) (Reflection, *homepage*).

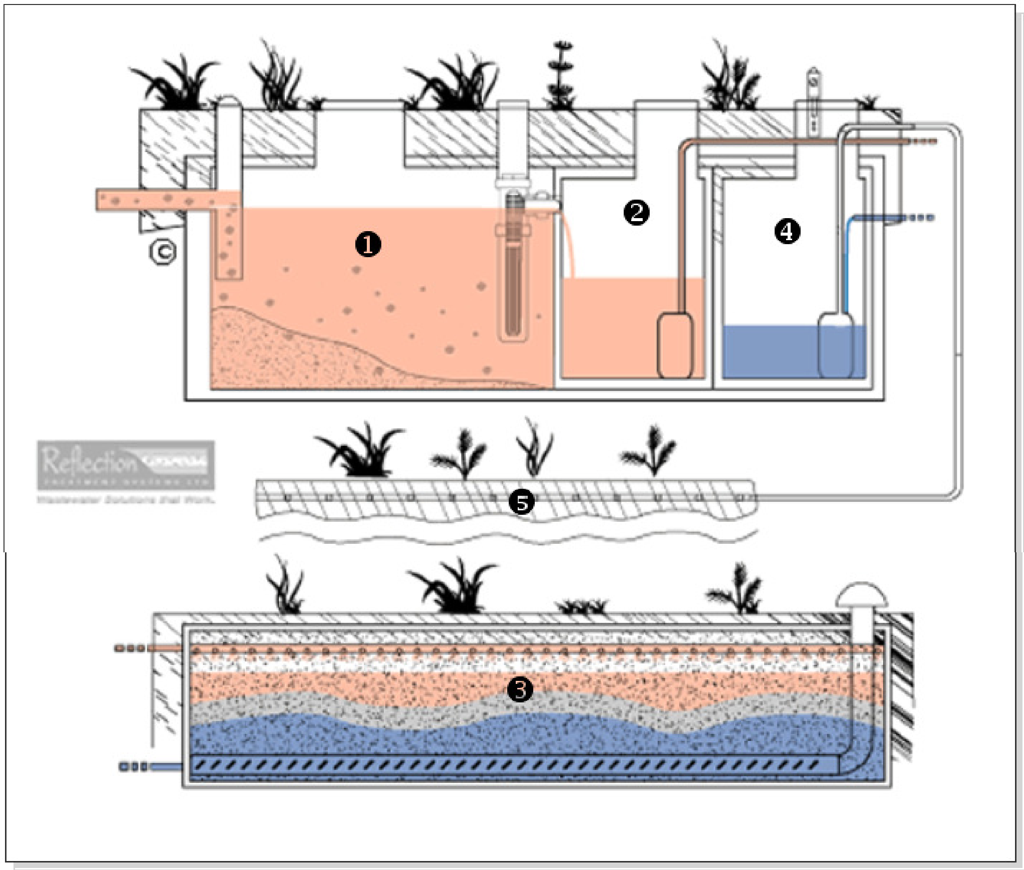


Figure 12: schematic of the *Reflections* Recirculating Sand Filter (RSF).

Source: Reflections (homepage), Reflection Treatment Systems [*Online*], available: http://www.septic.co.nz

Other features of the Sand Filter include (US EPA, 1999):

- Handles significant fluctuations in influent volume and strength;
- Can be used on sites with shallow soil cover, high groundwater, or inadequate permeability;
- Cost effective;
- Flush-to-ground;
- Simple maintenance;
- No odour, no noise; and
- BOD & TSS levels below 10 mg/L and total nitrogen reductions of 40-50%.

8.3 Option 3: Innoflow septic tank, Advantex textile filter and UV disinfection

This option presents best practice technologies as trialled and used in the US and New Zealand.

Figure 13: Concept diagram of the technologies in *Option 3.*

8.3.1 Innoflow inceptor tank

According to Ball & Bounds (1998), the septic tank effluent pump (STEP) system differs from conventional septic tank systems as specially designed pumps convey the effluent under pressure through small diameter watertight pipes (see *Box 1*). As discussed in *Box 1*, the use of small diameter flexible and watertight piping means installation costs and disruption to obstructions are minimised and inflow and infiltration are avoided.

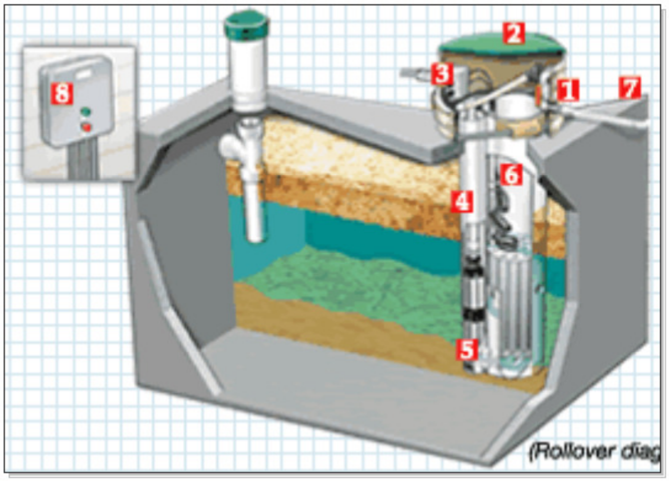


Figure 14: Schematic of the ProSTEP™ Effluent Pumping System (interceptor tank).

Source: Orenco Systems (homepage), [*Online*] available: http://www.orenco.com/ [27/6/02]

8.3.2 AdvanTex textile filter

As mentioned in *Section 6.2.2*, sand filters and textile filters are considered top of the range for household or cluster on-site systems (West, 2002). The Advantex textile filter was designed by Orenco in the US and although in use in NZ, Canada and Europe, has not yet been installed in Australia. The system is a recirculating packed bed filter that uses a highly absorbent engineered textile for the treatment media. The system operates by pulse dosing the effluent from a septic tank onto vertically layered textile sheets. During the 15-second hydraulic loading, the filtered septic effluent is trickled evenly across the top of the textile media. It is during the 6–8 minute pause when the microbes in and on the textile media break down the organic matter in the effluent. The effluent is recirculated 5 times to achieve a very high effluent quality.

Figure 15: An installed AdvanTex system in New Zealand.

Source: West, S. (2001)

Other features of the AdvanTex system are that (Orenco, www.orenco.com):

- de-nitrification occurs via a collection well in the base of the unit;
- they are extremely compact;
- they are completely watertight, thus flooding and wet weather infiltration are not an issue; and
- effluent quality of 3–7 mg/L BOD and TSS is commonly achieved, with 40 to 70% total nitrogen removal;
- treatment is consistent even during peak flows;
- there is no generation of activated sludge;
- it has low energy consumption;
- it is robust and tamper proof;
- it is installed flush-to-ground;
- it is cost effective;
- there are no odours, no noise; and

- it has a remote monitoring system.

8.3.3 UV disinfection

Ultraviolet disinfection operates by UV radiation damaging the DNA molecules in bacteria, viruses and other micro-organisms. UV disinfection lamps require electricity to transfer electromagnetic energy from mercury arc lamps to an organism's genetic material (US EPA (1999).

The effectiveness of UV disinfection is highly sensitive to concentration of colloidal and particulate matter in wastewater.

UV tubes can vary in lifespan from 6 months to several years. They are costly, but broadly effective.

8.4 Option 4: ACRON NOBLE, UV disinfection

This option was selected to represent a best practice Aerated Wastewater Treatment System (AWTS). *Acron Noble* AWTS's are widely used in Eastern Australia with successful performance results.

8.4.1 ACRON NOBLE

The *Acron Noble* aerobic wastewater treatment system (AWTS) treats household wastewater through an intense aeration and disinfection process. It incorporates an advanced biological nitrogen removal technology. The system can be extended to include options as tertiary treatment and advanced monitoring (Acron Noble, 2001).

Features of the *Acron Noble* AWTS include (Acron Noble, 2001):

- a single plant has a relatively small footprint;
- no odour if operated correctly;
- the option of a control system (including real-time, online remote monitoring) on the plant can reduce risk of contamination of the environment; and
- the option of tertiary polishing plants, UV disinfection, flow meters, Multi Media Filters, auto chemical dosing to increase effluent quality for irrigation, toilet flushing reuse or disposal.

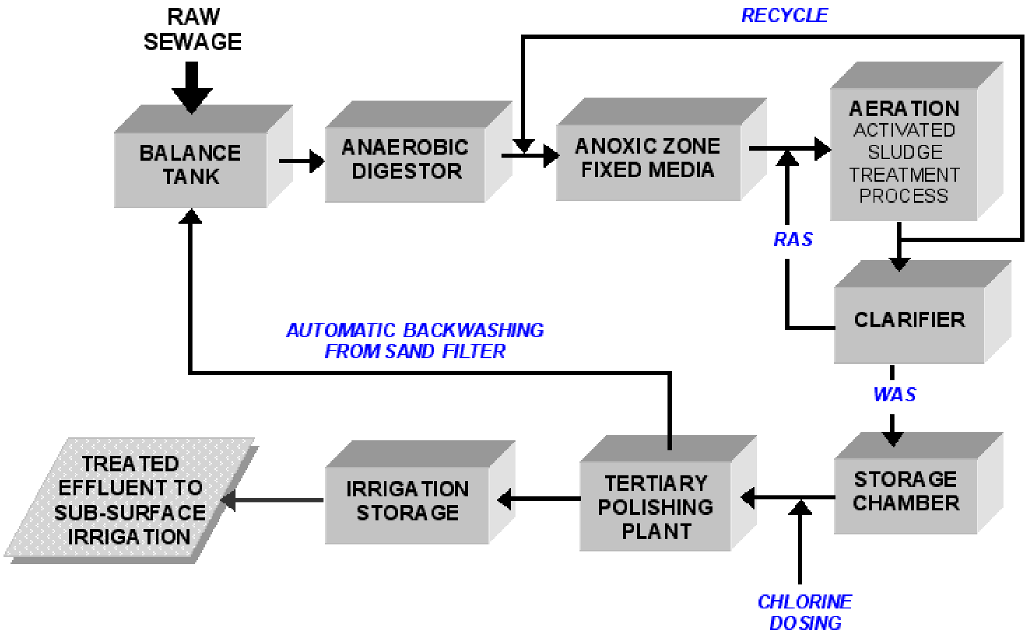
Some disadvantages include: it demands relatively constant operation to sustain the biological media, high energy use, high maintenance costs and the AWTS is very sensitive to shock loads and irregular use (Colac Otway Shire, 2002).

8.4.2 UV disinfection

The UV disinfection unit used in the *Acron Noble* system is from medium or low pressure mercury lamps which are designed for the specific application. The UV disinfection unit is installed after a multi media filter which ensures that extremely clear water is delivered to the UV system, thus maximising the performance efficiency of the UV disinfection (in terms of maximum kill rate and sterilisation) and reducing the risk of failure (Acron Noble, 2001).

See *section 8.3.3* for more information on UV disinfection.

Figure 15 illustrates a schematic of the *Acron Noble* AWTS which includes tertiary polishing (filtration and disinfection).



RAS = Return Activated Sludge; WAS = Waste Activated Sludge

Figure 16: Process schematic diagram of the Acron Noble AWTS.

Source: Acron Noble Pty Ltd DWG NO AN1018-06 25/06/01

8.5 *Effluent reuse: NETAFIM*

Once the effluent has been treated via one of the options described above, it will be reused for sub-surface irrigation at or in the vicinity of Galston High School. The technology for effluent reuse will be *NETAFIM* land treatment systems because it is used by Orenco. NETAFIM is a sub-surface drip irrigation system for land treatment. This system carries out organic and nitrogen removal in addition to reducing fecal coliforms.

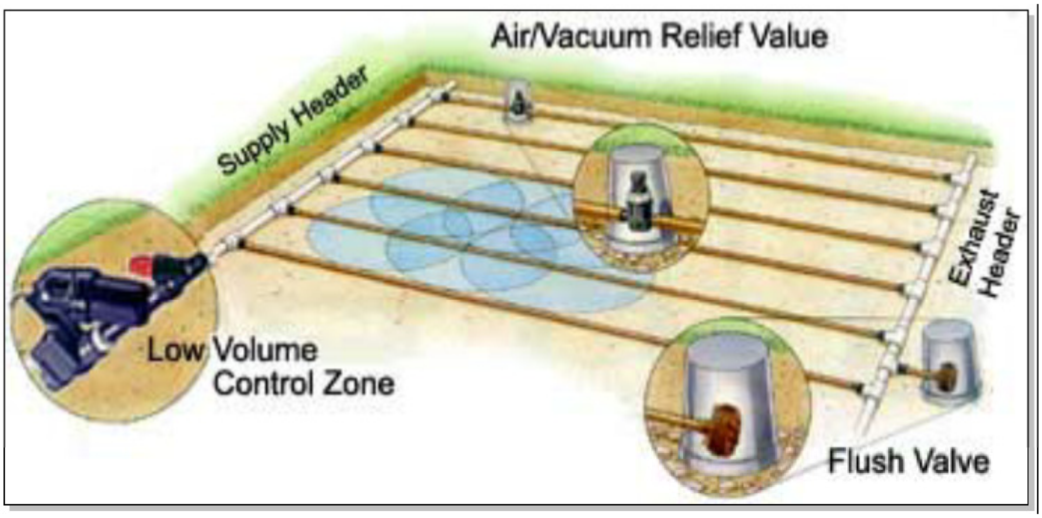


Figure 17: NETAFIM dripline irrigation system.

Source: Netafim, ttp://www.4dripirrigation.com/Landscape/typical.htm]

Some of the advantages of *NETAFIM* include (*NETAFIM*, http://www.netafim.com):

- High survivability rates and easier plant maintenance in any landscape situation and all weather conditions;
- Efficient use of water;
- No odour or aerosol drift;
- Allows the reuse of treated wastewater in an environmentally friendly way; and
- Relatively simple installation and minimal maintenance requirements.

Figure 18: Bioline pressure compensating dripperline for effluent.

Source: [http://www.netafim-usa-landscape.com/ Landscape/techline.htm]

9 OPTIONS ANALYSIS

9.1 Minimum Performance Standards

Table 15 screens the technology options for compliance minimum performance standards. Those which receive one or more cross (✘) have failed at least one minimum performance standard and are thus not eligible to considered as a potential option.

Table 15: Results of screening options against minimum compliance performance standards.

COMPLIANCE Performance Standards	Option			
	1	2	3	4
Operation and Maintenance/ Backup service	✔	✔	✔	✔
Tamper proof	✔	✔	✔	✔
Acceptable odour levels	✔	✔	✔	✔
PASS/FAIL:	PASS	PASS	PASS	PASS

The following *Table 16* screens the technology options for site-specific requirements. Those which receive one or more cross (✘) have failed at least one minimum performance standard and are thus not eligible to considered as a potential option.

Table 16: Results of screening options against minimum site-specific performance standards.

SITE-SPECIFIC Performance Standards	Option			
	1	2	3	4
Land space	✔	✔	✔	✔
Water quality class	✘	✔	✔	✔
Water table	✔	✔	✔	✔
Soil type and depth	✔	✔	✔	✔
Aspect	✔	✔	✔	✔
Flood potential	✔	✔	✔	✔
PASS/FAIL:	FAIL	PASS	PASS	PASS

From the results in *Tables 15* and *16*, the following options 'Passed' and therefore will be considered in the next step of the Sustainability Screening and Evaluation Tool:

- *Option 2;*
- *Option 3;* and
- *Option 4.*

Although Option 1 failed on water quality class, it is considered in the sustainability and evaluation tool because, as discussed in 8.1, it represents a benchmark.

For clarity, Option 1 failed on water quality class because there is no disinfection in this option. However, Ecomax does not require disinfection, because it is a passive disposal technique, rather than an active reuse.

9.2 Check appropriate fit-for-purpose water quality cascade

For the purpose of this site, Galston High School, it is not feasible to separate the effluent stream into water quality classes and treat the streams separately. That is, there is a single defined influent stream. SWC have proposed that for this demonstration site, treated effluent will be reused for sub-surface irrigation. So there are no further options to implement a water quality cascade.

9.3 Screening against Sustainability Criteria

Each option was screened against each sustainability criterion and given a star rating of 1 to 5 stars, 5 being optimal (see *Appendices C* to *F* for ratings given to each criterion for each option). Because each option comprised two or more technologies with quite different system potentials, it was necessary to rate each technology individually where possible, then average the ratings of individual technologies in an option to give the overall rank for that option. For example, *Option 3* comprises three technologies: Innoflow interceptor tank, Advantex textile filter, and UV disinfection. For the criterion *4.1 Maximise short-term flexibility (ability to handle load fluctuations)* Innoflow was given 5 stars, Advantex 4 stars, UV disinfection 1 star and Netafim 4 stars. Hence an average of 3.5 stars was given to this *Option 3*. This also provided a transparent screening process. The results of both the technology screening and options screening is provided in *Appendix C*. The rationale behind each rating is provided in the box adjacent to the score.

Once each option was given a rank for each criterion, weighted average scores were determined using the weightings outlined in *Figure 5*.

The following *Table 17* summarises the star ratings given to of each option. Each rating was then multiplied by the appropriate weighting given to that criterion (see *Figure 5*).

Table 17: Star ratings of Options 1-4.

Objective	Criteria	OPTION			
		1	2	3	4
1. Minimise resource use	1.1 Minimise greenhouse gases during operation	4.00	2.90	3.13	2.00
	1.2 Minimise embodied energy in key components	2.50	2.25	1.75	1.30
	1.3 Minimise consumables during operation and maintenance	5.00	3.83	3.63	3.17
2. Minimise waste and by products	2.1 Maximise beneficial reuse and recycling of nutrients (N, P, K, C)	2.00	4.00	4.00	4.00
	2.2 Maximise beneficial reuse and recycling of water	2.00	4.25	4.25	4.25
	2.3 Minimise waste (solid, liquid or gaseous) throughout lifecycle	3.00	3.50	3.75	3.30
3. Maintain ecological function	3.1 Nominated indigenous terrestrial and aquatic ecosystems to be protected such that they continue to operate, or are enabled to operate, in perpetuity	5.00	5.00	5.00	5.00
4. Satisfy utility and maximise performance efficiency	4.1 Maximise short-term flexibility (ability to handle load fluctuations)	2.50	2.75	3.50	2.67
	4.2 Maximise long-term flexibility (ease of modifying capacity, i.e. relative disruption required)	1.50	3.25	3.75	3.30
	4.3 Technology risk assessment	3.00	3.00	5.00	4.00
	4.4 Minimise user intervention	4.50	3.25	3.63	3.17
5. Contribute to amenity	5.1 Odour	4.00	4.50	5.00	4.33
	5.2 Noise	5.00	4.38	4.50	3.33
	5.3 Unsightly visual obstructions	4.50	4.13	4.50	3.50
6. Minimise whole of life cost to the community	6.1 This cost is the sum of capital, operating and maintenance, decommission and asset renewal of infrastructure and management programs for wastewater treatment and reuse and/or disposal.	4.50	3.50	3.75	3.50

10 RESULTS AND INTERPRETATION

10.1 Summary of Sustainability Rating Assessment

Table 18 summarises the results from the outputs of the tool. See *Appendix C* for all intermediate results, outputs and justifications for ratings. These results have been summarised from Output 2 (see *Table C-2* in *Appendix C*). Output 1 (also in *Appendix C*) shows the vast differential in relative criteria weightings. We responded to this in Output 2 by reducing the weighting of the cost criterion to be consistent with that of next highest weighted criteria. This issue is discussed in more depth in the next section.

Table 18: Summary of overall score (out of 5) for each option.

	OPTION			
	1	2	3	4
TOTAL (/5)	**3.1**	**3.1**	**3.4**	**2.9**
TOTAL (%)	75%	75%	83%	70%

Option 1: Existing technology septic tank >> ECOMAX
Option 2: Existing technology septic tank (w filter) >> recirculated sand filter >> UV disinfection >> NETAFIM
Option 3: INNOFLOW interceptor tank (w filter) >> ADVANTEX textile filter>> UV disinfection >> NETAFIM
Option 4: ACRON NOBLE AWTS >> UV disinfection >> NETAFIM

As *Table 18* indicates, *Option 3* scored the highest result of 3.4 (or 83%), equal second were Option 1 and Option 2 with a score of 3.1 (or 75%), with *Option 4* scoring last at 2.9 (or 70%).

In Criterion *1.1 Minimise operations greenhouse gases*, Option 1 scored the highest relative to the others predominantly because Ecomax is a passive technology which requires little or no operation and maintenance, and no energy input. This was similarly the case in *1.3 Minimise consumables during operation and maintenance*. In both *2.1 Maximise beneficial reuse and recycling of nutrients* and *2.3 Maximise beneficial reuse and recycling of water* Options 2, 3, and 4 received an identical and relatively high score compared to Option 1. This difference is because Options 2, 3, and 4 utilise Netafim technology which allows reuse of effluent and nutrients for irrigation as desired, where as Option 1 uses Ecomax technology which 'disposes' of the effluent in very specific mounds. Option 3 scored highest in *4.1 Maximise short-term flexibility* because the filter on the interceptor tank enables this Option to handle fluctuations in effluent water quality while the storage tanks allow for load fluctuations. Option 4 also excelled in *4.2 Maximise long-term flexibility* because the pod design of the Advantex cells is easily reconfigured to modify the capacity of the system. In contrast, the Ecomax (in Option 1) cannot be easily modified to increase its capacity as the Ecomax cells are large, buried and not precast.

Option 3 excelled mainly because of its short-term and long-term flexibility and reliability, and its relatively low risk. *Option 3* was initially included in the screening process as it is considered one of several best practice options in some parts of US, Europe and New Zealand. Prior to development and use of the sustainability and evaluation tool, some of the SWC project team had thought *Option 3* might be the most appropriate for the site. However it was not anticipated that *Option 1*, Ecomax, would rank close behind *Option 3*. This relatively high ranking of *Option 1* occurred mainly because it is a passive technology with relatively low cost over the anticipated lifetime of the option.

10.2 Critique of the Sustainability Assessment Tool

As discussed in Section 3, the sustainability assessment tool was developed by reviewing and adapting the Greenfield Manual process developed in the Edmondson Park project, and integrating that with a substantial literature review on sustainability indicators for wastewater systems. In this section, we reflect on the process of developing and using the tool, pointing out difficulties and remaining questions, and make suggestions about future use of the tool and potential modifications.

The aim was to develop a tool that balanced the competing tensions outlined below:

- sufficiently transparent to be understood by a wide audience;
- sufficiently specific to be able to distinguish between technologies and sets of technologies;
- sufficiently broad to cover all three aspects of sustainability;
- sufficiently complex to be meaningful; and
- sufficiently practical, generic, and simple to be useful.

As noted in Section 3, the sustainability screening and evaluation tool was designed with the following guiding principles and objectives in mind:

- The tool is flexible and robust;
- The tool is useful for Sydney Water Corporation beyond the scope of this project. That is, it can be applied to other Priority Sewerage Program areas (or any sites considering community based sewage treatment technologies);
- The sustainability objectives, criteria, and performance levels are performance-based;
- The tool enables all areas of sustainability to be addressed when screening and evaluating on-site technologies;
- The tool enables the inclusion of issues of management, education and implementation which can be relevant independent of the chosen technology combination;
- The level of detail of the tool is appropriate and efficient. It is broad enough to be widely applicable and detailed enough to be measurable and capture all important issues related to sustainable and appropriate technologies; and
- The tool can be used to evaluate the technology during operation.

The criteria and the performance levels articulated for different objectives are the practical part of the screening and evaluation tool. Discussions amongst ISF staff and with SWC staff throughout the project have been focused on articulating these in a way that enables the objectives to be achieved. Because the tool has only been applied to one scenario, our opportunity to evaluate it is limited. Nonetheless, in the next few paragraphs, we discuss the strengths and weaknesses noted to date.

The tool's flexibility is demonstrated by the breadth of technologies assessed in this first pass, and by the difference in the scores generated both at a technology level and at the option level. Its robustness is demonstrated in the discussions at project meetings concerning the allocation of particular scores. Although some of these discussions were quite lengthy, they generally ended up with suggestions for clarification in the wording of the criteria and performance levels, rather than changes in the allocation of scores. This suggests that at least within the breadth of views represented in the project, the tool should generate reasonably similar results, regardless of the perspective of the user. This robustness is in keeping with trying to focus the tool on the more measurable aspects of sustainability.

The tool's flexibility and robustness will be tested through application on other sites, and by its ability to take into account site-specific constraints.

The tool does cover all aspects of sustainability: there are three environmental objectives described by seven criteria, two socio-technical objectives (one social and one technical), and one economic objective described by a single criterion. Of course, the untested aspect is the weighting process used to combine the scores allocated to each criterion.

In relation to *Step 7a* of the tool (i.e. ranking the options against the sustainability criteria), the outcome of the options analysis is dependent not only on criteria and performance levels (star ratings) chosen, but also the process and the assumptions by which those performance levels are aggregated. We started out with an obvious first pass assumption which weights all objective categories equally *i.e.* environment, social, technical, and economic categories get the same weighting. Within each objective, each criterion receives an equal weighting.

There are two problems with this approach. Firstly, the impact on the relativity of criteria weightings. Secondly, these important decisions about weighting have been made by the analysts, rather than by a representative group of potential stakeholders. Dealing with these in turn, the impact of these two assumptions is about one order of magnitude difference in criteria weightings (*e.g.* the sole economic/financial criterion has the same weight as the sum of all seven environmental criteria). Our response was to reduce the weighting of the economic criterion to a level comparable to other criteria. Many other responses are possible, and we reiterate that there needs to be broader discussion about how the scores are brought together. This would best be done as part of the ongoing participatory processes associated with this project.

The most successful multi-criteria analysis processes are those which incorporate participatory decision-making processes to obtain information about community preferences (O'Connor, 2000). Participatory processes could include, for example, citizen's juries, in-depth interviews or detailed surveys. There is significant potential for SWC to be involved in developing an innovative approach that combines sustainability criteria selection, systems analysis, and deliberative decision-making in innovative ways.

Although not explicitly used in this application, the tool acknowledges the limits of a technology focused assessment process, and includes the capacity for explicit consideration of a set of management concepts (centralised management, risk management, engagement, and distribution of costs and benefits amongst stakeholders). These are intended to provide guidance for later stages of this pilot project, and should be evaluated at that time.

The appropriateness and efficiency of the tool has not yet been truly tested because the people who developed the tool are the same people who have used it in this first application. Assigning performance levels to the range of objectives and criteria set out in the tool requires broader and deeper information than existing SWC tools. At first sight, one could see that requirement as a decrease in efficiency. However, sustainability is a broader decision-making framework than those currently in use, so some increase in information and interpretation is perhaps unavoidable. What remains to be seen is how others will interact with the tool, and whether the criteria and performance levels are sufficiently clear to provide adequate direction for information searching and interpretation.

Various steps have been taken in the development of the tool to manage the level of detail required. For example, *Criteria 1.2*, *minimise embodied energy in key components*, is explicitly worded to focus users on major components only, and to avoid being sidetracked into fine detail. Again, the effectiveness or otherwise of these steps will only be evident with more use of the tool.

To summarise, the tool has been designed and iteratively reviewed during its first application to meet the objectives outlined above. Nonetheless, it should be seen as a work in progress. Different kinds of applications, different scenarios, and different users will provide a greater breadth of opportunity for sensitivity analysis, evaluation and modification where necessary.

11 MONITORING & EVALUATION

The sustainability criterion is designed such that it can be used as an evaluation tool in addition to screening technology options. As noted earlier, it is envisaged that after the chosen technology option has been installed and monitored by SWC over an appropriate period, it will be evaluated. In addition to the criterion listed in *Table A* (see *Appendix A*), the following criteria should also be evaluated.

- Reliability
- Safety

These criteria were not included in *Table A* to screen the various technology options as it is difficult to identify sufficient verifiable information prior to installation of the technology.

12 CONCLUSIONS

This project endeavoured to develop and trial a sustainability screening and evaluation tool for community-based wastewater systems. The initial focus was the development of sustainability criteria and their application in screening and comparing different technologies. Through the course of the project it became apparent that whilst the application of the sustainability criteria is an important stage, it is only one step in a process that needs to be undertaken. The 2–step tool initially conceived of developed over the project timeline into an 8–step tool. The ability of the project team (SWC and ISF) to adapt to new or revised knowledge was advantageous and enabled commitment to the original project objectives to be upheld whilst maintaining flexibility and rigour. The 8–step tool developed in this project is a first attempt at articulating this process. It should continue to be developed through a reflective process of application, adaptation, and trials elsewhere and be modified as appropriate.

Sustainable community-based wastewater systems are embedded in a broader context of sustainable urban water systems. These systems will interact with other constructed and natural systems in the urban region and beyond, such as the local ecological environment, the local social and cultural environment, and institutional and economic frameworks and structures (Fane, 2002). Sustainable urban water systems include the whole physical urban water cycle including water, wastewater and stormwater. They also include technical, organisational and community aspects of these natural and constructed systems. What constitutes a sustainable urban water system will vary based on time and place. So too will the subset of sustainable community based wastewater systems. This time and site-specific aspect of sustainable systems does not exclude the development of sustainability assessment tools towards the goal of sustainability. Rather, it means that this development process will be ongoing.

The 8–step process developed here reflects the case study at Galston High School.

The output of the tool indicated that *Option 3*, including the Innoflow interceptor tank, Advantex textile filter and UV disinfection, was the most sustainable and appropriate option for community-based wastewater treatment at Galston High School. This option was initially included in the screening process as it is considered one of several best practice options in some parts of US, Europe and New Zealand. *Option 3* excelled mainly because of its short-term and long-term flexibility and reliability, and its relatively low risk. *Option 1*, Ecomax, and *Option 2*, septic tank and sandfilter, ranked equal second. *Option 1* scored well because it is a passive technology with relatively low cost over its lifetime. *Option 2* had similar scores to *Option 3*, but performed relatively poorly on risk and flexibility grounds.

13 RECOMMENDATIONS

This section discusses recommended actions in relation to both the development and use of the sustainability screening and evaluation tool and its specific application at Galston High School.

13.1 Sustainability Screening and Evaluation Tool

The following recommendations relate to the generic sustainability screening and evaluation tool developed in this project.

- As discussed in Section 12, sustainable community based wastewater systems lie within a broader context of sustainable urban water systems. Addressing this inextricable link means taking a more integrated holistic approach. One example of this would be to ensure all water-using appliances and fixtures (which relate to the volume of wastewater generated) are water efficient. For existing facilities, this can be done by retrofitting the significant water-using appliances and fixtures with efficient technologies. For new developments this means ensuring all new water-using technologies fitted are water efficient. According to Carew et al (1999) both the likelihood and severity of consequences of failure of on-site systems are reduced by minimising the volume of wastewater entering the on-site treatment system;
- One of the most important components of the tool developed in this project may be the weightings applied to the sustainability criteria. The weightings have a significant influence on the tool outputs. This means the process by which the weightings are decided should be an appropriate, inclusive and rigorous process. In this particular project, no stakeholder consultation was undertaken as the recipient of the technology (Galston High School) was happy to bypass consultation at this stage and allow SWC and ISF staff to use their professional judgements. However, in general it is recommended that some form of consultative process be used to include relevant stakeholders and the community. Weightings can often be highly subjective and thus it is important to have input from all those who will be impacted by the tool outputs. Participatory processes can include a variety of methods, such as citizen’s juries, focus groups and feedback panels.
- A further recommendation is to continue to build on the sustainability criteria and star rating process to improve its transparency and precision as part of a screening and evaluation tool. The language used and assignment of ratings may continue to be contested. The tool will improve with use, and acceptance will likely improve as the usefulness of the tool grows.
- In relation to the assignment of weightings, rather than working backwards using the conceptual assumption that environmental = social = economic = technical importance, another approach might be to write all criteria on separate pieces of paper (regardless of what ‘objective’ category they fall under) on the table and work with client and other stakeholders to position the criteria in a way which shows which are of equal importance, which are more or less than others. From this, relative weightings can then be assigned. This process may be iterative.
- A final recommendation is to continue to investigate and trial participatory multi-criteria approaches to develop a ranking process for choosing between options based on sustainability criteria, systems analysis and deliberative decision making processes.

13.2 Galston High School

The following recommendations relate specifically to the planning and implementation of a sustainable on-site wastewater option at Galston High School.

- The output from the tool indicates that the most sustainable and appropriate community based system for Galston High School is *Option 3* (Orenco Interceptor tank, Advantex textile filter, UV disinfection and Netafim drip irrigation system). We recommend that SWC review the tool results table (Table 15) to review the star ratings given to each option for each criteria. Reviewing individual star ratings is likely to be more significant and meaningful than focusing the overall result for each option. The weighting approach adopted here deals with trade-offs between criteria in a particular way. Focusing on ratings for particular criteria enables review and discussion about these trade-offs. Table 15 shows the star ratings for each criteria. For example, While Option 3 ranked the highest overall, it scored relatively lower than Option 1 (septic tank and Ecomax) on several criteria, including *minimise operations greenhouse gases*, *minimise consumables during operation and maintenance*, *minimise user intervention* and *minimise whole of life cost to the community*. If it becomes apparent to SWC that some of these criteria are perhaps more significant that previously thought then the current weightings may need to be altered to reflect this.
- The identification of the barriers and constraints most likely to impinge on the options should be more fully investigated.
- Initiate participatory processes with key internal and external stakeholders to alleviate the barriers and constraints where appropriate, for example, in relation to the current NSW Health's requirement for disinfection of effluent sub-surface irrigation.
- Where barriers and constraints exist, it is recommended SWC identify the opportunities and incentives most likely to support the resolution of the pertinent barriers and constraints, and devise processes to take advantage of the opportunities and incentives.
- Once a preferred option has been selected, it is recommended that a more detailed water balance analysis be undertaken, through continuous short time step (in the order of daily or less) model simulation over an extended time period, using a tool such as UVQ (Mitchell et al, 2000) or Aquacycle (Mitchell, 2000). This modelling should include consideration of the current and future characteristics of Galston High School, such as student numbers, after hours school activities which involve water use and garden/field watering patterns. It will allow the sizing of the recommended option.
- The development of this sustainability tool was the first stage of a longer term project. It is recommended that SWC ensure a sufficient level of community participation in the decision-making process of the next phases.

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APPENDIX A: SUSTAINABILITY OBJECTIVES, CRITERIA AND PERFORMANCE RATINGS

Objective	Criteria	Potential performance levels	Notes
1. Minimise resource use[7]	1.1 Minimise operations greenhouse gases *(kWhr/p/d)*	★★★★★ = no external energy requirements ★★★ = low energy requirements ★★ = medium energy requirements ★ = relatively high energy requirements	This criteria considers only energy required and not the source of that energy. The later is considered independent of technology type and is thus addressed in Step 7b.
	1.2 Minimise embodied energy in key components *(kg/p/d)*	★★★★★ = Low energy ★★★ = Medium energy ★ = High energy	Material ratings: <u>Low</u> = plants, gravel/sand; <u>Medium</u> = glass, concrete, fabrics, activated carbon; <u>High</u> = plastics, metals, zeolite.
	1.3 Minimise consumables during operation and maintenance *(kg/p/d)*	★★★★★ = No consumables required ★ = Many consumables required (eg. all those listed)	Consumables include chemicals, filter cartridges, UV tubes, water for backwashing, etc.
2. Minimise waste and by products	2.1 Maximise beneficial reuse and recycling of nutrients (N, P, C)	★★★★★ = high level of reuse ★★★ = moderate level of reuse	This is only concerned with the extent of reuse rather than the location of reuse (eg on-site or at a distance).

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[7] This objective should be measured over an appropriate life cycle. Need to capture different longevity of different technology options. eg. measure Life cycle greenhouse gases annualised over a period of say 20 years.

Objective	Criteria	Potential performance levels	Notes
	(kg/p/d)	★ = no reuse	
	2.2 Maximise beneficial reuse and recycling of water *(kL/p/d)*	★★★★★ = high level of reuse ★★★ = moderate level of reuse ★ = no reuse	This is only concerned with the extent of reuse rather than the location of reuse (eg on-site or at a distance).
	2.3 Minimise waste (solid, liquid or gaseous) throughout lifecycle *(kg/p/d)*	★★★★★ = no waste ★★★ = ★ = no effort to minimise construction or operation waste	'*no waste*' can mean either complete beneficial reuse of all material leaving the system, or no waste created
3. Maintain ecological function	3.1 Nominated indigenous terrestrial and aquatic ecosystems to be protected such that they continue to operate, or are enabled to operate, in perpetuity	★★★★★ = a + b + c + d + e (enhanced) ★ = a + b + e (maintained)	a) Rare and endangered species on-site are managed appropriately b) No water borne transmission of exotic species into nominated areas or to creeks/trunk stormwater system outside nominated areas c) Hydrologic regime managed within limits tolerated by indigenous ecosystems d) Instream ecosystem health to meet identified community standards e) Quality of all water sources and sinks

Objective	Criteria	Potential performance levels	Notes
			maintained or enhanced such that at least historic quality is achieved.
4. Satisfy utility and maximise performance efficiency	4.1 Maximise short-term flexibility (ability to handle load fluctuations)	★★★★★ = robust ★ = sensitive	This includes hydraulic, biological and toxin loads.
	4.2 Maximise long-term flexibility (ease of modifying capacity)	★★★★★ = modular design in appropriately sized units ★ = fixed capacity	
	4.3 Technology risk assessment: a) Probability of risk occurring	★★★★★ = rare ★★★★ = unlikely ★★★ = moderate ★★ = likely ★ = almost certain	Risks may include: human exposure to treated (or untreated) wastewater; failure of system; discharge of unacceptable pollutant levels to surface or sub-surface water body. ★★★★★ = not expected to occur but is theoretically possible ★★★★ = possible but very unlikely ★★★ = possible but not probable ★★ = probably occur at some time ★ = expected to occur in most circumstances.
	b) Severity of consequences	★★★★★ = insignificant	Examples:

Objective	Criteria	Potential performance levels	Notes
		★★★★ = minor ★★★ = moderate ★★ = major ★ = catastrophic	★★★★★ = No lasting detriment to the environment; minor or no impact on community, buildings and legal issues. ★★★ = Long-term but reversible detrimental environmental or social impact (such as chronic discharge of pollutants annoying community and/or ecosystem); probable serious breach of regulation; business group reputation is tarnished; ★ = Significant extensive and/or irreversible detriment to the environment and/or community; fatal, long-term or irreversible disabling effects on human health; eradication of endangered species; irreversible major breach of regulation, serious litigation.
	4.4 Minimise operation intervention	★★★★★ = no operation intervention required ★★★ = some operation intervention required	This relates to minimum operational requirements regardless of who is responsible for operation.

Objective	Criteria	Potential performance levels	Notes
		★ = frequent operation intervention required	
5. Contribute to amenity[8]	5.1 Maximise amenity: a) Odour	★★★★★ = negligible ★★★ = evident but tolerable ★ = intolerable	
	b) Noise	★★★★★ = negligible ★★★ = evident but tolerable ★ = intolerable	
	c) Unsightly visual obstructions	★★★★★ = negligible ★★★ = evident but tolerable ★ = intolerable	
6. Minimise whole of life cost to the community	6.1 This cost is the sum of capital, operating, and maintenance, decommission and asset renewal of infrastructure and management	★★★★★ = high cost ★★★ = medium cost	Decision making based on least cost life cycle costing from total resource/whole of society perspective, considering externalities and using alternative financial mechanisms.

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[8] The level of amenity experienced with the decentralised system will at least maintain and facilitate that which is experienced on comparable sites with centralised systems. This objective cannot be met by Sydney Water Corporation alone, but it is particularly important for SWC to provide wastewater-related services in ways which actively contribute to facilitating this objective. The targets have been written with this in mind, and attempt to focus on the wastewater-related aspects of amenity

Objective	Criteria	Potential performance levels	Notes
	infrastructure and management programs[9] for wastewater treatment and reuse and/or disposal	★ = low cost	Both internal and external economic, social, and environmental costs that will be borne by the water authority, developer, purchaser, council, and occupant should be included.

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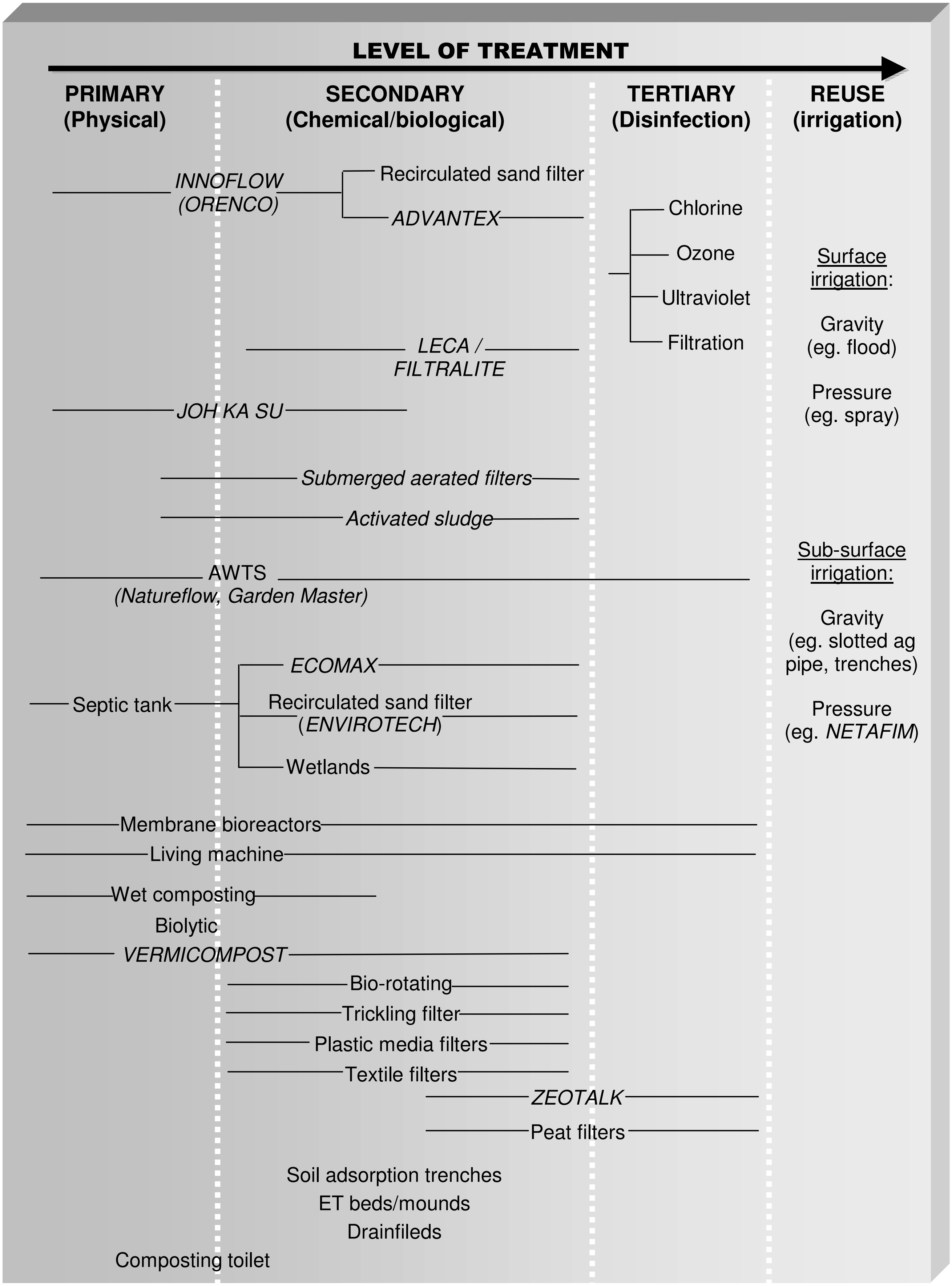
[9] Here, management programs refers to all costs associated with activities which are not directly tangible eg demand management programs, educational programs, etc

APPENDIX B: ON-SITE TREATMENT SYSTEMS


LEVEL OF TREATMENT
PRIMARY (Physical)
SECONDARY (Chemical/biological)
TERTIARY (Disinfection)
REUSE (irrigation)
INNOFLOW (ORENCO)
Recirculated sand filter
ADVANTEX
Chlorine
Ozone
Ultraviolet
Filtration
Surface irrigation:
Gravity (eg. flood)
Pressure (eg. spray)
LECA / FILTRALITE
JOH KA SU
Submerged aerated filters
Activated sludge
Sub-surface irrigation:
Gravity (eg. slotted ag pipe, trenches)
Pressure (eg. NETAFIM)
AWTS (Natureflow, Garden Master)
Septic tank
ECOMAX
Recirculated sand filter (ENVIROTECH)
Wetlands
Membrane bioreactors
Living machine
Wet composting
Biolytic
VERMICOMPOST
Bio-rotating
Trickling filter
Plastic media filters
Textile filters
ZEOTALK
Peat filters
Soil adsorption trenches
ET beds/mounds
Drainfileds
Composting toilet

APPENDIX C: WATER BALANCE CALCULATIONS

The data in *Table C* was derived using the Netafim online calculator at: (http://www.netafim-usa-landscape.com/Landscape/calc/. The input data required for Netafim to calculate the output was:

- Vegetation type (eg. Turf);
- Soil type (eg. Clay);
- Total irrigated area; and
- Row spacing (between 18-22 inches).

Table C: Outputs from Netafim Online Calculator:

Output parameter	Data	Units	Notes/Comments
Total Techline length required	5 884	metres	Techline is the irrigation distribution material
Dripper spacing	18	inches	This is the length between drippers on the techline
	0.46	metres	
Number of drippers required	12 871		Drippers are the point sources of effluent irrigation along the techline
Dripper flow rate	1.5	L/hr	This is the constant flow rate for each dripper
Flow rate (over total area)	324	L/min	This is the flow rate over the total defined area.
Application rate	6.1	mm/hr	

Source: (http://www.netafim-usa-landscape.com/Landscape/calc/

The following figure depicts the dripper spacing and row spacing for Netafim drip irrigation technology.

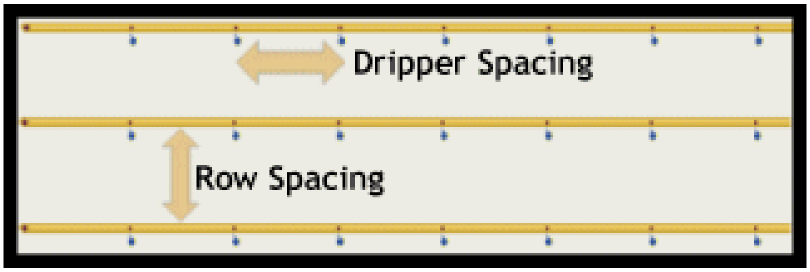


Figure C: Dripper spacing and row spacing for Netafim Techline.

Source: http://www.netafim-usa-landscape.com/Landscape/calc/calcmain.php

APPENDIX D: RESULTS

The following outputs represent the WEIGHTED star ratings for each option against each criteria. The weightings were derived from the concept of giving environmental, social, economic and technical objectives equal value. (See *Figure 5*).The total score at the end of each column is the overall score for the technology option out of 5.

Table D-1: WEIGHTED RESULTS – Output 1.

Objective	Criteria	*Weight*	Weighted ratings for OPTION			
			1	2	3	4
1. Minimise resource use	1.1 Minimise operations greenhouse gases	*0.03*	0.11	0.08	0.09	0.06
	1.2 Minimise embodied energy in key components	*0.03*	0.07	0.06	0.05	0.04
	1.3 Minimise consumables during operation and maintenance	*0.03*	0.14	0.11	0.10	0.09
2. Minimise waste and by products	2.1 Maximise beneficial reuse and recycling of nutrients (N, P, K, C)	*0.03*	0.06	0.11	0.11	0.11
	2.2 Maximise beneficial reuse and recycling of water	*0.03*	0.06	0.12	0.12	0.12
	2.3 Minimise waste (solid, liquid or gaseous) throughout lifecycle	*0.03*	0.08	0.10	0.10	0.09
3. Maintain ecological function	3.1 Nominated indigenous terrestrial and aquatic ecosystems to be protected such that they continue to operate, or are enabled to operate, in perpetuity	*0.08*	0.42	0.42	0.42	0.42
4. Satisfy utility and maximise performance efficiency	4.1 Maximise short-term flexibility (ability to handle load fluctuations)	*0.06*	0.16	0.17	0.22	0.17
	4.2 Maximise long-term flexibility (ease of modifying capacity, ie relative disruption required)	*0.06*	0.09	0.20	0.23	0.21
	4.3 Technology risk assessment	*0.06*	0.19	0.19	0.31	0.25
	4.4 Minimise user intervention	*0.06*	0.28	0.20	0.23	0.20
5. Contribute to amenity	a) Odour	*0.08*	0.33	0.38	0.42	0.36
	b) Noise	*0.08*	0.42	0.36	0.38	0.28
	c) unsightly visual obstructions	*0.08*	0.38	0.34	0.38	0.29
6. Minimise whole of life cost to the community	6.1 This cost is the sum of capital, operating, and maintenance, decommission and asset renewal of infrastructure and management programs for wastewater treatment and reuse and/or disposal.	*0.25*	1.13	0.88	0.94	0.88
	TOTAL		**3.9**	**3.7**	**4.1**	**3.5**
	% TOTAL:		78%	74%	82%	71%

The following output is identical to OUTPUT 1 in *Table C-1* except for the refinement of the weighting of the economic criterion (ie. Criterion 6.1). The rationale for refining this weight is that the economic criterion would otherwise have a weighting 3 to 8 times that of any other criterion (ie it had a weighting of 0.25 compared to other weightings ranging from 0.03 to 0.08). the economic criteria was thus reduced to 0.08.

Table D-2: WEIGHTED RESULTS – Output 2 (reduced COST weighting).

Objective	Criteria	Weight	Weighted ratings for OPTION			
			1	2	3	4
1. Minimise resource use	1.1 Minimise operations greenhouse gases	*0.03*	0.11	0.08	0.09	0.06
	1.2 Minimise embodied energy in key components	*0.03*	0.07	0.06	0.05	0.04
	1.3 Minimise consumables during operation and maintenance	*0.03*	0.14	0.11	0.10	0.09
2. Minimise waste and by products	2.1 Maximise beneficial reuse and recycling of nutrients (N, P, K, C)	*0.03*	0.06	0.11	0.11	0.11
	2.2 Maximise beneficial reuse and recycling of water	*0.03*	0.06	0.12	0.12	0.12
	2.3 Minimise waste (solid, liquid or gaseous) throughout lifecycle	*0.03*	0.08	0.10	0.10	0.09
3. Maintain ecological function	3.1 Nominated indigenous terrestrial and aquatic ecosystems to be protected such that they continue to operate, or are enabled to operate, in perpetuity	*0.08*	0.42	0.42	0.42	0.42
4. Satisfy utility and maximise performance efficiency	4.1 Maximise short-term flexibility (ability to handle load fluctuations)	*0.06*	0.16	0.17	0.22	0.17
	4.2 Maximise long-term flexibility (ease of modifying capacity, ie relative disruption required)	*0.06*	0.09	0.20	0.23	0.21
	4.3 Technology risk assessment	*0.06*	0.19	0.19	0.31	0.25
	4.4 Minimise user intervention	*0.06*	0.28	0.20	0.23	0.20
5. Contribute to amenity	a) Odour	*0.08*	0.33	0.38	0.42	0.36
	b) Noise	*0.08*	0.42	0.36	0.38	0.28
	c) unsightly visual obstructions	*0.08*	0.38	0.34	0.38	0.29
6. Minimise whole of life cost to the community	6.1 This cost is the sum of capital, operating, and maintenance, decommission and asset renewal of infrastructure and management programs for wastewater treatment and reuse and/or disposal.	*0.08*	0.36	0.28	0.30	0.28
	TOTAL		**3.1**	**3.1**	**3.4**	**2.9**
	% TOTAL:		76%	75%	83%	71%

Table D-3: Option 1 ratings (Septic Tank – existing technology; ECOMAX).

Objective	Criteria	/5	Septic Tank (existing technology)	/5	ECOMAX
1. Minimise resource use[10]	1.1 Minimise operations greenhouse gases *(kWhr/p/d)*	4	No energy requirements for operation. However maintenance requires pump outs which involve energy. The later would use small amounts of non-renewable energy sources. Methane is lost to the atmosphere, this increased the amount of greenhouse gases released due to this technology; Also may require pump if gravity flow not feasible	4	Minimal external energy requirements, however small amount of pumping will be required at the site as it is relatively flat.
	1.2 Minimise embodied energy in key components *(kg/p/d)*	3	Primary material is reinforced concrete, secondary materials may include plastics (probably polyethylene)	2	materials include soil, grass, industrial by-product high in iron, impervious membrane (polythene), plumbing (probably plastics)
	1.3 Minimise consumables during operation and maintenance *(kg/p/d)*	5	No additives required.	5	No consumable required.

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[10] This objective should be measured over an appropriate life cycle. Need to capture different longevity of different technology options. eg. measure Life cycle greenhouse gases annualised over a period of say 20 years.

Objective	Criteria	/5	Septic Tank (existing technology)	/5	ECOMAX
2. Minimise waste and by products	2.1 Maximise beneficial reuse and recycling of nutrients (N, P, C) *(kg/p/d)*	-	Potential, however independent of septic tank technology. Septic tank sludge pumpout separate from effluent	2	Potential once off at end of life: adsorbed phosphorus taken offsite; Concentrated source of P; N, C lost to ground, groundwater (need more info on bioavailable Heavy metal extraction);
	2.2 Maximise beneficial reuse and recycling of water *(kL/p/d)*	-	Potential, however independent of septic tank technology. Further treatment likely necessary	2	Water is evapotranspired through grass, however use of grassed area is restricted by contouring.
	2.3 Minimise waste (solid, liquid or gaseous) throughout lifecycle *(kg/p/d)*	3	Pumpouts required to remove sludge approx every 5 yrs; Anaerobic digestion gases released to atmosphere, medium volume of construction waste (soil displaced).	3	No waste, however phosphorus taken away very infrequently (ie approx every 30yrs, which is negligible on a per day rate); high volume of soil displaced in construction; gases?
3. Maintain ecological function	3.1 Nominated indigenous terrestrial and aquatic ecosystems to be protected such that they continue to operate, or are enabled to operate, in perpetuity	-	-	-	-
4. Satisfy utility and maximise performance efficiency	4.1 Maximise short-term flexibility (ability to handle load fluctuations)	3	Relatively insensitive to load fluctuations - hydraulic, biological and toxin, due to large volume, high residence time, diverse microbial ecology. However emergency storage is not guaranteed, so washout can occur.	3	Relatively insensitive to hydraulic and other load fluctuations; however no emergency storage; doesn’t necessarily include 'pre-filter', so could fail if pretreatment inadequate or unable to handle shock loads.
	4.2 Maximise long-term flexibility (ease of modifying	1	fixed capacity, medium size, in-ground (ie burial required),	2	relatively large area, buried, not 'pre-cast'

Objective	Criteria	/5	Septic Tank (existing technology)	/5	ECOMAX
	capacity)		relatively simple to plumb.		
	4.3 Technology risk assessment: a) Probability of risk occurring	2	probably occur at some time (related to management practices). The possibility is more dependent on how the system is managed rather than environmental circumstances.	3	possible but not probable that contamination of groundwater/surface water/surface will occur. The possibility is more dependent on how the system is managed rather than environmental circumstances.
	b) Severity of consequences	-	Partially treated effluent contaminating ground/surface water and rising to the surface can have significant consequences.	3-4	contamination of groundwater/surface water/surface can occur.
	4.4 Minimise operation intervention	4	Depends on management and design, at least annual inspection.	5	very passive system
5. Contribute to amenity[11]	5.1 Maximise amenity: a) Odour	3	On average, just evident but tolerable (assuming reasonable management)	5	designed to be negligible
	b) Noise	5	Negligible. Except during maintenance pumpout.	5	No noise
	c) Unsightly visual obstructions	5	Should be buried, so negligible.	4	negligible, but changed contours
6. Minimise whole of life cost to the	6.1 This cost is the sum of capital, operating, and	4	Relatively low cost. Construction costs: Installation of tank;	5	low cost when annualised over 20 years, however higher capital cost, low to

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[11] The level of amenity experienced with the decentralised system will at least maintain and facilitate that which is experienced on comparable sites with centralised systems. This objective cannot be met by Sydney Water Corporation alone, but it is particularly important for SWC to provide wastewater-related services in ways which actively contribute to facilitating this objective. The targets have been written with this in mind, and attempt to focus on the wastewater-related aspects of amenity

Objective	Criteria	/5	Septic Tank (existing technology)	/5	ECOMAX
community	maintenance, decommission and asset renewal of infrastructure and management programs for wastewater treatment and reuse and/or disposal		Operation costs: negligible; Maintenance costs: pumpout costs, inspection.		negligible operating costs.

Table D-4: Option 2 ratings (Septic Tank – existing technology with filter, Reflections recirculating sand filter; UV disinfection).

Objective	Criteria	/5	Septic Tank (existing technology, with filter)	/5	REFLECTIONS recirculating sand filter	/5	UV disinfection
1. Minimise resource use	1.1 Minimise operations greenhouse gases *(kWhr/p/d)*	4	No energy requirements for operation. However maintenance requires pump outs which involve energy. The later would use small amounts of non-renewable energy sources. Methane is lost to the atmosphere, this increased the amount of greenhouse gases released due to this technology; Also may require pump if gravity flow not feasible	3-4		1	Requires significant amount of energy to transfer electromagnetic energy from mercury arc lamp to an organism's genetic material. It is assumed the energy supplied will be from non-renewable sources.
	1.2 Minimise embodied energy in key components *(kg/p/d)*	3	Primary material is reinforced concrete, secondary materials may include plastics (probably polyethylene)	3	Concrete blocks for housing; plastic pipes/distributors/collectors, sand, pump.	1	mercury arc lamps; reactor; ballasts.
	1.3 Minimise consumables during operation and maintenance *(kg/p/d)*	5	No additives required.		Replace sand every XX years	2	replacement of UV tubes at least each year.
2. Minimise waste and by products	2.1 Maximise beneficial reuse and recycling of nutrients (N, P, C)	-	Potential, however independent of septic tank technology. Septic tank	-	Nitrification/denitrification. ie some N is lost to atmosphere; P potentially	-	

Objective	Criteria	/5	Septic Tank (existing technology, with filter)	/5	REFLECTIONS recirculating sand filter	/5	UV disinfection
products	nutrients (N, P, C) *(kg/p/d)*		sludge pumpout separate from effluent		available. High quality effluent facilitates reuse.		
	2.2 Maximise beneficial reuse and recycling of water *(kL/p/d)*	-	Potential, however independent of septic tank technology. Further treatment likely necessary	-	High quality effluent facilitates broad range of reuse.	-	
	2.3 Minimise waste (solid, liquid or gaseous) throughout lifecycle *(kg/p/d)*	3	Pumpouts required to remove sludge approx every 5 yrs; Anaerobic digestion gases released to atmosphere, medium volume of construction waste (soil displaced).	4	above ground/below ground	2	Used UV tubes.
3. Maintain ecological function	3.1 Nominated indigenous terrestrial and aquatic ecosystems to be protected such that they continue to operate, or are enabled to operate, in perpetuity	-	-			-	-

Objective	Criteria	/5	Septic Tank (existing technology, with filter)	/5	REFLECTIONS recirculating sand filter	/5	UV disinfection
4. Satisfy utility and maximise performance efficiency	4.1 Maximise short-term flexibility (ability to handle load fluctuations)	3	Relatively insensitive to load fluctuations - hydraulic, biological and toxin, due to large volume, high residence time, diverse microbial ecology. However emergency storage is not guaranteed, so washout can occur.	3	This system differs to ADVANTEX as it relies on syphon dosing system rather than time/pulse dosed. So sensitive to hydraulic load. Increased biological load could cause blockage and/or may not be treated adequately.	1	highly sensitive to concentration of colloidal and particulate matter in wastewater.
	4.2 Maximise long-term flexibility (ease of modifying capacity)	1	fixed capacity, medium size, in-ground (ie burial required), relatively simple to plumb.	2	med/large scale; on-site construction required (ie no pre-casts)	5	

Objective	Criteria	/5	Septic Tank (existing technology, with filter)	/5	REFLECTIONS recirculating sand filter	/5	UV disinfection
	4.3 Technology risk assessment: a) Probability of risk occurring	2	probably occur at some time (related to management practices). The possibility is more dependent on how the system is managed rather than environmental circumstances.	3	failure can occur by blockage in piping or in filter bed.	2-4	(note: UV tubes can vary in lifespan from 6 months to several years).
						2	Failure can occur by: a. fouling of UV tubes
						2-3	b. increased concentration of colloidal/particulate matter (TSS) can render UV disinfection ineffective
						4	Exposure to UV radiation in low-pressure and high-intensity lamps (unlikely to occur under normal operating conditions

Objective	Criteria	/5	Septic Tank (existing technology, with filter)	/5	REFLECTIONS recirculating sand filter	/5	UV disinfection
	b) Severity of consequences	-	Partially treated effluent contaminating ground/surface water and rising to the surface can have significant consequences.	3	Would only be picked up through regular effluent checks, so could be long term. However short term malfunctions also possible.	3 4 3 4	Not as significant at this stage of treatment (ie effluent quality is higher than at 'primary/secondary' treatment phase. However, If UV is ineffective, systems potentially allows viruses, spores and cysts to be transmitted to receiving land and/or water body; a. should be picked up through regular maintenance. b. requires effluent quality checks, likely to be sporadic c.
	4.4 Minimise operation intervention	4	Depends on management and design, at least annual inspection.	3		1-3	frequent bulb changes and cleaning required.
5. Contribute to amenity	5.1 Maximise amenity: a) Odour	3	On average, just evident but tolerable (assuming reasonable management)	5	should be aerobic	5	negligible
	b) Noise	5	Negligible. Except during maintenance pumpout.	3-4	recirculating pump	5	Negligible

Objective	Criteria	/5	Septic Tank (existing technology, with filter)	/5	REFLECTIONS recirculating sand filter	/5	UV disinfection
			maintenance pumpout.				
	c) Unsightly visual obstructions	5	Should be buried, so negligible.	3-5	depending on extent of recess into local ground level.	3	small individual units, therefore evident but tolerable
6. Minimise whole of life cost to the community	6.1 This cost is the sum of capital, operating, and maintenance, decommission and asset renewal of infrastructure and management programs for wastewater treatment and reuse and/or disposal	4	Relatively low cost. Construction costs: Installation of tank; Operation costs: negligible; Maintenance costs: pumpout costs, inspection.	3	moderate capital costs, moderate operating and maintenance costs.	1	Relatively high; Capital costs: equipment, structural modifications, electrical, miscellaneous; Operating costs include: power consumption, cleaning chemicals, time and supplies, miscellaneous equipment repairs, replacement of lamps/ballasts/sleeves, staffing requirements.

Table D-5: Option 3 ratings (INNOFLOW interceptor tank with filter; ADVANTEX textile filter; UV disinfection).

Objective	Criteria	/5	INNOFLOW interceptor tank with filter	/5	ADVANTEX textile filter	/5	UV disinfection
1. Minimise resource use	1.1 Minimise operations greenhouse gases *(kWhr/p/d)*	4-5	Requires energy for pump if the utilization of gravity flow is not feasible; Assume submersible pump and filter are included.	4	Minimal energy required to pump effluent	1	Requires significant amount of energy to transfer electromagnetic energy from mercury arc lamp to an organism's genetic material. It is assumed the energy supplied will be from non-renewable sources.
	1.2 Minimise embodied energy in key components *(kg/p/d)*	2	HDPE tank, effluent pumps (stainless steel, thermoplastic, fibreglass), control panel and float switches; (high tech plastic) effluent filters	2	Key components: fibre-glass basin filled with engineered textile material and moulded plastic. These are relatively high embodied energy materials, however the unit is relatively small; Other components include control panel, program timer, telemetry unit made from high embodied energy materials.	1	mercury arc lamps; reactor; ballasts.
	1.3 Minimise consumables during operation and maintenance *(kg/p/d)*	4	filter cartridges, however replacement rate is very low (ie XX years); pumps last more than 25 years. Materials are durable and corrosion resistant.	4	filters are washed and generally replaced after 10-15 years	2	replacement of UV tubes at least each year.

Objective	Criteria	/5	INNOFLOW interceptor tank with filter	/5	ADVANTEX textile filter	/5	UV disinfection
2. Minimise waste and by products	2.1 Maximise beneficial reuse and recycling of nutrients (N, P, C) *(kg/p/d)*	-	Potential, however independent of interceptor tank technology. sludge pumpout separate from effluent	-	Nitrification/denitrification. ie some N is lost to atmosphere; P potentially available. High quality effluent facilitates reuse.	-	
	2.2 Maximise beneficial reuse and recycling of water *(kL/p/d)*	-	Potential, however independent of interceptor tank technology. Further treatment likely necessary	-	High quality effluent facilitates broad range of reuse.	-	
	2.3 Minimise waste (solid, liquid or gaseous) throughout lifecycle *(kg/p/d)*		Requires desludging every 8-12 years; Anaerobic digestion gases captured in activated carbon filter.	4	Small, pre-cast pods; in-ground, small volume of displaced soil; aerobic gases released to atmosphere.	2	Used UV tubes.
3. Maintain ecological function	3.1 Nominated indigenous terrestrial and aquatic ecosystems to be protected such that they continue to operate, or are enabled to operate, in perpetuity		although not necessarily relevant at this stage of treatment, the STEP system is watertight and has flexible pipes, thus less likely to crack and leak partially treated effluent into the local environment.	4-5?	High water quality of treated water discharged; steady flow throughout the day rather than intermittent high flow discharges.	-	-

Objective	Criteria	/5	INNOFLOW interceptor tank with filter	/5	ADVANTEX textile filter	/5	UV disinfection
4. Satisfy utility and maximise performance efficiency	4.1 Maximise short-term flexibility (ability to handle load fluctuations)	5	Can withstand and modulate peak hydraulic flows (the outlet pipe has 3 3/8inch diameter holes which restrains/regulates peak hydraulic loads due to tanks' reserve capacity - 24hr emergency back up); watertight; the filter would help reduce biologcial loads associated with SS.If pumped, then have control over outflow (if telemetry, then get alarm signals)	4	Can withstand hydraulic shock loads; has 24 hour emergency storage; has recirculated/blend tank; diverse microbiological ecology; requires same standard of robustness in pre-treatment.	1	highly sensitive to concentration of colloidal and particulate matter in wastewater.
	4.2 Maximise long-term flexibility (ease of modifying capacity)	1	fixed capacity	4	Flexible; can increase capacity by adding more cells in series and/or parallel. Each pod is physically small and easy to plumb.	5	
	4.3 Technology risk assessment: a) Probability of risk occurring	4	Possible but very unlikely due to good system design to prevent risks from occurring. Failure can occur by: 1. Odour if not designed and installed properly (ie. If pressure sustaining valves in collection lines allow air pockets and thus odourous gases can form) ; 2. Failure	4	Possible but very unlikely due to good system design to prevent risks from occurring.	2-4	(note: UV tubes can vary in lifespan from 6 months to several years).

Objective	Criteria	/5	INNOFLOW interceptor tank with filter	/5	ADVANTEX textile filter	/5	UV disinfection
			of control panel and/or alarm to alert owner of system failure; 3. Premature failure of parts due to incorrect design, installation and/or use of low quality parts (eg Effluent pumps can have useful lives of 13 months to more than 20 years depending on quality).				
	b) Severity of consequences		System is alarmed so risk is for short-term, one-off events, rather than long term.		System is alarmed so risk is for short-term, one-off events, rather than long term.	2	Failure can occur by: a. fouling of UV tubes
	4.4 Minimise operation intervention	5	Annual inspection	3	Minimal intervention	2-3	b. increased concentration of colloidal/particulate matter (TSS) can render UV disinfection ineffective
5. Contribute to amenity	5.1 Maximise amenity: a) Odour	5	Carbon filter	5	designed to be negligible	4	Exposure to UV radiation in low-pressure and high-intensity lamps (unlikely to occur under normal operating conditions
	b) Noise	5	pump (if necessary) runs for just several minutes/day	5	designed to be negligible	3	Not as significant at this stage of treatment (ie effluent quality is higher than at 'primary/secondary'

Objective	Criteria	/5	INNOFLOW interceptor tank with filter	/5	ADVANTEX textile filter	/5	UV disinfection
							treatment phase. However, If UV is ineffective, systems potentially allows viruses, spores and cysts to be transmitted to receiving land and/or water body;
	c) Unsightly visual obstructions	5	most parts are flush to ground with only access port exposed.	5	Can be flush to ground	4	a. should be picked up through regular maintenance.
6. Minimise whole of life cost to the community	6.1 This cost is the sum of capital, operating, and maintenance, decommission and asset renewal of infrastructure and management programs for wastewater treatment and reuse and/or disposal	4	Capital costs: installation time is shorter, small diameter pipes are 'inexpensive' , a smaller unit is required due to avoided inflow and infiltration (all compared to conventional system); Operation and Maintenance costs: minimal as service time averages 30mins every 5 years. Materials are durable and corrosion-resistant.	4	Low capital and operating cost; easy installation, low maintenance.	3	b. requires effluent quality checks, likely to be sporadic

Table D-6: Option 4 ratings (*ACRON NOBLE* AWTS; UV disinfection).

Objective	Criteria	/5	*ACRON NOBLE* AWTS	/5	UV disinfection
1. Minimise resource use	1.1 Minimise operations greenhouse gases *(kWhr/p/d)*	2	Aerate, pump, mix	1	Requires significant amount of energy to transfer electromagnetic energy from mercury arc lamp to an organism's genetic material. It is assumed the energy supplied will be from non-renewable sources.
	1.2 Minimise embodied energy in key components *(kg/p/d)*	1	plastic tanks, pipes, pumps, control system components (wiring, timers etc).	1	mercury arc lamps; reactor; ballasts.
	1.3 Minimise consumables during operation and maintenance *(kg/p/d)*	3?	possibly coagulant and disinfectant?	2	replacement of UV tubes at least each year.
2. Minimise waste and by products	2.1 Maximise beneficial reuse and recycling of nutrients (N, P, C) *(kg/p/d)*		N, P	-	
	2.2 Maximise beneficial reuse and recycling of water *(kL/p/d)*		High quality effluent facilitates broad range of reuse.	-	

Objective	Criteria	/5	*ACRON NOBLE* AWTS	/5	UV disinfection
	2.3 Minimise waste (solid, liquid or gaseous) throughout lifecycle *(kg/p/d)*	3		2	Used UV tubes.
3. Maintain ecological function	3.1 Nominated indigenous terrestrial and aquatic ecosystems to be protected such that they continue to operate, or are enabled to operate, in perpetuity	-	-	-	-
4. Satisfy utility and maximise performance efficiency	4.1 Maximise short-term flexibility (ability to handle load fluctuations)	2	more sensitive to hydraulic and microbiological loads: lower residence time, less diverse ecology; less robust/stable.	1	highly sensitive to concentration of colloidal and particulate matter in wastewater.
	4.2 Maximise long-term flexibility (ease of modifying capacity)	2?		5	
	4.3 Technology risk assessment: a) Probability of risk occurring	2-3	Possible, but not probable. (this AWTS has improved design over existing technology AWTSs, thus reducing probability of failure); Requires more complicated alarm/control system.	2-4	(note: UV tubes can vary in lifespan from 6 months to several years).

Objective	Criteria	/5	*ACRON NOBLE* AWTS	/5	UV disinfection
	b) Severity of consequences	3 4	Would only be picked up through regular effluent checks, so could be long term. However short term malfunctions also possible. could also be short term malfunction.	2	Failure can occur by: a. fouling of UV tubes
	4.4 Minimise operation intervention	3		2-3	b. increased concentration of colloidal/particulate matter (TSS) can render UV disinfection ineffective
5. Contribute to amenity	5.1 Maximise amenity: a) Odour	3-5	?	4	Exposure to UV radiation in low-pressure and high-intensity lamps (unlikely to occur under normal operating conditions
	b) Noise	3	Aerators and pumps	3	Not as significant at this stage of treatment (ie effluent quality is higher than at 'primary/secondary' treatment phase. However, If UV is ineffective, systems potentially allows viruses, spores and cysts to be transmitted to receiving land and/or water body;
	c) Unsightly visual obstructions	1-3	All above ground, many unit operations.	4	a. should be picked up through regular maintenance.
6. Minimise whole of life cost to the community	6.1 This cost is the sum of capital, operating, and maintenance, decommission and asset renewal of infrastructure	2-3	moderate capital costs, moderate operating and maintenance costs.	3	b. requires effluent quality checks, likely to be sporadic

Objective	Criteria	/5	*ACRON NOBLE* AWTS	/5	UV disinfection
	and management programs for wastewater treatment and reuse and/or disposal				