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CLUSTER APPROACH TO SUSTAINABLE WASTEWATER MANAGEMENT FOR SMALL COMMUNITIES

Master Thesis

For the Master of Science Degree in Natural Resources Management and Ecological Engineering

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"(…) in the process of taking too much, we waste too much.

(…) The environment can absorb waste, redistributing and transforming it into harmless forms,

but just as the earth has a limited capacity to produce renewable resources,

its capacity to receive waste is similarly constrained."

(Paul Hawken)

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ABSTRACT

In the last decade, as a result of increased environmental awareness and focus on sustainable development, a fundamental change in the approach to wastewater management has been observed. Recently, decentralized systems appear to be a more feasible and sustainable solution to wastewater management, especially in low density areas.

The identification of adequate wastewater management for small communities is a complex problem as it demands integration of data from different sources, such as community needs, receiving environment, landscape, or available and affordable wastewater treatment technologies. However, decentralized wastewater management can successfully address the challenge of providing effective wastewater treatment systems for rural areas.

This study presents a strategic approach to wastewater management for small communities through decentralized wastewater management – cluster approach, based on water conservation, pollution prevention and minimization, treatment and reuse, and controlled disposal and rain-water harvesting. What is more, to be effective, this approach recognizes stakeholder interest in wastewater management. The focus is on cluster approach as the best solution to sustainable wastewater management in low density areas, and best alternative to conventional centralized systems. Different components of cluster wastewater management are discussed here, taking into consideration residents' needs and issues.

For this purpose, questionnaires assessing community attitude towards wastewater management were designed and a survey was undertaken in the small settlement Upper Hakatere Huts, located at the Ashburton River Mouth in New Zealand. The characteristics of settlement used in the survey process and results of questionnaires, allowed to select treatment alternatives with technical environmental justification, as well as reasons for discarding, favoring and disadvantaging options. Due to that analysis, evaluation of different potential feasible solutions to sustainable wastewater management through cluster approach for that area was possible. Additionally, some innovative ideas contributing to water savings and thus to prevention of wastewater, as well as nutrient recycling were suggested.

Keywords:

Decentralized wastewater management, cluster approach, wastewater treatment, small communities, sustainable approach

ZUSAMMENFASSUNG

Ein gesteigertes öffentliches Interesse an Themen wie Umweltschutz und nachhaltiger Entwicklung, hat im Laufe des vergangenen Jahrzehntes dazu geführt, dass sich die grundsätzliche Herangehensweise an das Management von Abwässern grundlegend geändert hat. Der aktuelle Trend geht hin zu dezentralisierten Systemen, die es ermöglichen, insbesondere in dünnbesiedelten Gebieten, nachhaltige Lösungen zu konzipieren.

Das Design von adäquaten Strategien zum Abwassermanagement in kleinen Gemeinden gestaltet sich jedoch nach wie vor sehr komplex und unterschiedliche Faktoren, wie spezifische Anforderungen der Gemeinschaft, eventuelle Umwelteinflüsse, landschaftliche Gegebenheiten und technologische Machbarkeit, müssen berücksichtigt werden. Trotzdem ist die dezentralisierte Abwasseraufbereitung eine geeignete Methode, um Abwassermanagement in ländlichen Gegenden effizienter zu gestalten.

Die, in dieser Studie vorgestellte, 'Cluster' Methode, bietet eine strategische Herangehensweise an das dezentralisierte Abwassermanagement, basierend auf Wasserersparnis, Prävention und Minimalisierung von Verschmutzungen, Aufbereitung und Wiederverwendung, sowie kontrolliertem Abfluss und Auffangen von Regenwasser. Zusätzlich wird in der vorliegenden Studie die Partizipation aller Beteiligten als wichtiger Pfeiler eines effektiven Abwassermanagements anerkannt. Die Bestandteile der Methode werden unter Berücksichtigung von Anrainerinteressen diskutiert und `Cluster` Abwassermanagement als beste Alternative zu zentralen Systemen in dünnbesiedelten Gebieten vorgestellt.

Eine Umfrage in 'Hakatere Huts', einer kleinen Ansiedlung an der Mündung des Ashburton River in Canterbury, Neuseeland, wurde durchgeführt, um die Ansichten der Anwohner zu der Abwasseraufbereitung anhand von Fragebögen zu erfassen. So konnten nicht nur umwelttechnische Aspekte, sondern die Meinungen der Betroffenen bei der Auswahl und Evaluation der verschiedenen Möglichkeiten eines nachhaltigen Abwassermanagements durch die ´Cluster' Methode berücksichtigt werden. In weiteren Ergebnissen der Studie werden innovative Ideen zum Thema Wassersparen und Recycling von Nährstoffen vorgeschlagen.

Stichwörter:
Dezentralisiertes Abwassermanagement, Cluster Methode, Abwasserbehandlung, kleine Gemeinden, Nachhaltigkeit

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1. Introduction

Nowadays, sustainability challenges us to reflect on wastewater treatment differently. Instead of focusing on the end-of-pipe approaches for emission prevention, finally attention shifts towards optimal resource utilization, favoring the development of decentralized systems (Balkema et al, 2002). As the origin of wastewater production is water consumption, the need to develop and implement sustainable management strategies to control both water and nutrient flows with additional benefits such as cost reduction is necessary. To solve the problem, deterioration of natural resources has to be controlled through effective and feasible concepts of water management. Thus, available highly efficient technologies have to be infused into well-thought out and systematic approach for the sustainable resource management (Nhapi and Gijzen, 2005). In addition to that, recently, the development of innovative, holistic and sustainable approaches to wastewater management, has been the subject of initiatives on a political level such as the Dublin Principles, Agenda21, Vision21 or the Millennium Development Goals (Cosgrove and Rijsberman, 2000; King, 2000; WHO/UNICEF, 2001).

The idea of innovative and integrated water concepts is based on the principle of separating different water flows according to their characteristics. The prevention of wastewater has become a priority, and water re-use contributes to large water savings and less wastewater generation. Innovative decentralized systems can change the current ways of wastewater management, and together with new interesting sustainable energy supply technologies, such as solar or hydrogen sources which could power wastewater treatment structures in the future, can lead to integrated sustainable wastewater management.

Over recent years, the shortcomings of conventional systems, have led to development of a series of new alternative technologies, characterized by a small-scale, decentralized structures and a source control approach. In the past, the centralized systems, undoubtedly, were able to solve many hygienic problems and enabled far-reaching ecological improvements however, they were focusing on solving mainly only one problem at a time (Nhapi and Gijzen, 2005). Today, these systems are increasingly criticized, referring mainly to ecological issues, such as accumulation of persistent harmful substances in the bodies of water (Panebianko et al., 2006). Moreover, they generate high costs by non-productive transport, and utilize disadvantageous approach by mixing different wastewater streams, what makes recovering of resources such as water, nutrients or energy, more difficult; and do not lead to an integrated solution. In addition, dilution of wastewater requires more complex treatment and higher levels of resources, like money, energy or space, while posing pressures on the environment in the form of emissions.

To improve the traditional approach, water supply and wastewater management have to be closely interconnected so that water is used with minimal withdrawal from, and the discharge to the environment can be reduced. It includes prevention and reduction of wastewater production, treatment and recovery of wastewater components, and safe disposal of any wastewater component that is not recycled or reused (Davidavicius and Ramoskijene, 1996; Naphi et al. 2003). These options for intervention are the concept of decentralized wastewater management, which aims at minimizing the required resources, and treat and reuse the different substance flows in the adaptive way at an early stage in the purification process (Panebianko et al., 2006). Thus, technology can be adapted to the particular pollutants and to the demand on the quality of the purified water. What is more, decentralized approach is clearly perceived as sensible alternative in regions where no central wastewater infrastructure exists, providing the best starting point for designing innovative systems. Especially in rural areas with low population densities the costs of integrating scattered households into one central sewage system are not feasible. Additionally, it represents and enhances alternatives in situations where high investments are needed to reconstruct or expand the existing infrastructure due to capacity problems or malfunctions.

Cluster approach, as one of the concepts of decentralized wastewater management, can overcome the shortcomings of the conventional system, address wastewater issues and provide effective wastewater management for small communities, in more restrictive environments, and with more cost-effective solutions (Ferguson et al., 2003). Instead of managing hundreds of on-site systems that serve several hundreds homes, cluster system is encouraged due to the increased efficiency in land use and the ability of the technology to support more diverse interests. This alternative utilizes advanced and innovative technologies and requires more sophisticated management to solve wastewater problems. Moreover, it supports rural character and provides for local and regional management that protects water supplies, valuable water resources, public health and the environment (Crites et al., 1998). Followed by management skills of rural water districts, many water consumers can have access to the same level of reliable sewer service as urban dwellers.

In addition to this, cluster approach utilizing advanced solutions will help achieve sustainability goals (e.g. by minimizing wastewater generation, by conserving water, or recycling nutrients);

and will drive the expansion in use worldwide, as the current practices of consumption, diversion and use, are still depletive and destructive.

The increasing pressure to develop rural and coastal land areas, leads to search for more sustainable and affordable alternatives to wastewater management, meeting the needs of communities living there. There is a broad variety of technological solutions to decentralized approach that can address wastewater issues, however, technology itself is not enough, and social dimension has to become a part of planning and management processes, as specific solutions have to be provided to specific situations (Panebianco at at. 2006). Moreover, as the legislation has largely focused on the environmental and technological dimensions that sets limits to or prescribe the incorporation of new technologies, the inclusion of human dimension is valuable in supporting the introduction of new elements into planning processes in resource management, particularly if major changes in the socio-technical system are to be implemented; such as transformation from centralized to decentralized concept. It is observed that the number of communities that use effective community decision-making processes and decentralized technologies increases resulting in making most cost-effective, optimal sustainable decisions (Jones K., 2003).

The aim of this research is to describe a progressive approach to providing a new, different type of wastewater infrastructure for small communities. This approach facilitates sustainable wastewater management through the use of managed cluster systems. Moreover, it presents a case study community, the Upper Hakatere settlement in New Zealand, facing wastewater system choices; choices that many small communities are facing nowadays.

2. Decentralized wastewater management concept

Many years ago, development moved towards a single dominant design - centralized approach to wastewater treatment. As a result, nowadays, it is not easy to introduce basically different alternatives, especially as decentralized approach used to be tolerated as temporary solution. That was partly responsible by the way decisions regarding decentralized wastewater systems were made over decades (Etnier C. et al., 2005). However, recently, technical progress led to advanced purification capabilities of small-scale treatment plants. Hence, they are increasingly recognized as alternative solutions especially for areas with low population density. The United States Department of Commerce reported that 25% of all American households and 40% of new developments rely on decentralized wastewater systems nowadays (US Department of Commerce, 1997).

Decentralized wastewater management is shorthand for the centralized management of dispersed, single family and cluster on-site wastewater treatment systems in a small community (Hoover, 1997). That indicates that advanced decentralized technologies require a more sophisticated management approach than has been traditionally used for conventional solutions.

In addition to that, the current world population estimated on 6.1 billion, with the annual average growth at about 1.2% (UNFPA, 2001) results in increased energy, food and material demand. This is why sustainable development and focus on sustainable management of resources is of high importance nowadays.

2.1 The beginnings of wastewater management

Over the last hundred years, wastewater systems were thought, built and managed as if they were separate from the natural ecosystem (Ferguson et al., 2003). The focus was on health issues, while overflows into waterways were not of concern. Individual systems were often considered as temporary solution to be used only till public sewerage became available. When it came to choosing among options, many people used to consider on-site solutions as a less desirable choice for approaching wastewater (US EPA 1997). However, conventional wastewater management utilizes a disadvantageous approach by mixing different flows. In the past it has solved some hygienic problems in the houses, while polluting water resources used for drinking water supplies at source, leading to epidemics. A good example is the major epidemics of cholera and typhoid fever, primarily caused by improper disposal of wastewater. It was discovered by Dr. Snow, know as the father of epidemiology, during devastating cholera epidemic in London in 1854, that the city's water supply was being contaminated by improper disposal of human waste. This resulted in the desire of transporting of wastes away from the towns and passing them to the bodies of water. Another example of such epidemic is Hamburg, Germany in 1892 (Evans, 1991). The problem of disease was solved by technical development, although, reasonable alternatives existed, they were not considered in the past. Expansion of flushing toilets took control, however, the knowledge of epidemic infection pathways was still lacking (Otterpohl et al., 2002).

Moreover, the environmental effects were ignored and forgotten and management of waste was seen as independent from natural systems. As there was no requirement to think about water quality, pollution of rivers and coastal areas increased. From 1950s, concern about effects on the ecosystem, and on amenity and recreation, forced the treatment of wastewater, to a level that tried to minimize some adverse impacts on receiving waters (Ferguson et al., 2003). This approach improved the attitude to wastewater management, as the effects on natural system started to be considered.

Up till 1960s and 1970s, small communities (e.g. in New Zealand) continued to use individual systems (Ferguson et al., 2003). As controls on expansion and development became more common, some of them invested in outfalls for untreated wastes. From 1970s, subsidies led to improvement in systems' conditions, but also brought development pressures, and extra costs. Increase in the towns' sizes led to better understanding of waste as a source of disease.

Together with the passage of the Clean Water Act in 1970's in the United States, it was announced that it was only a matter of time before centralized sewerage facilities would be available to almost all residents (Tchobanoglous et al., 1998). However, after many years, it was finally recognized that complete sewerage of the country was not possible or desirable, due to economic and geographical reasons. From that moment it became clear that decentralized wastewater management is of great importance to the future management of the environment.

The historical development of wastewater (Figure 1) has been characterized by efforts to solve mainly one problem at a time; sanitation during the first half of 20th century followed by eutrophication of receiving water and, for past 10 years recycling of nutrients (Nhapi and Gijzen, 2005).

However after the Dublin Conference on Water and the Environment, water management was discussed in a more holistic manner, than before (ICWE, 1992). Recent water related conferences such as UN WaterConference (Mar Del Plata, 1977), Dublin Conference (1991), UN

Conference on Environment and Development (Rio de Janeiro, 1992), Bonn Consultation (2001), Johannesburg Summit (2002), the three World Water Forums (Marrakech, 1977, The Hague, 2000; Japan 2003), emphasized integrated approaches to water management. Additionally, the need for ecological responsibility has evoked different by governments and municipalities. Moreover, stricter regulations have resulted in huge investments in tertiary wastewater treatment (WHO, 2000; WHO/UNICEF 2001).

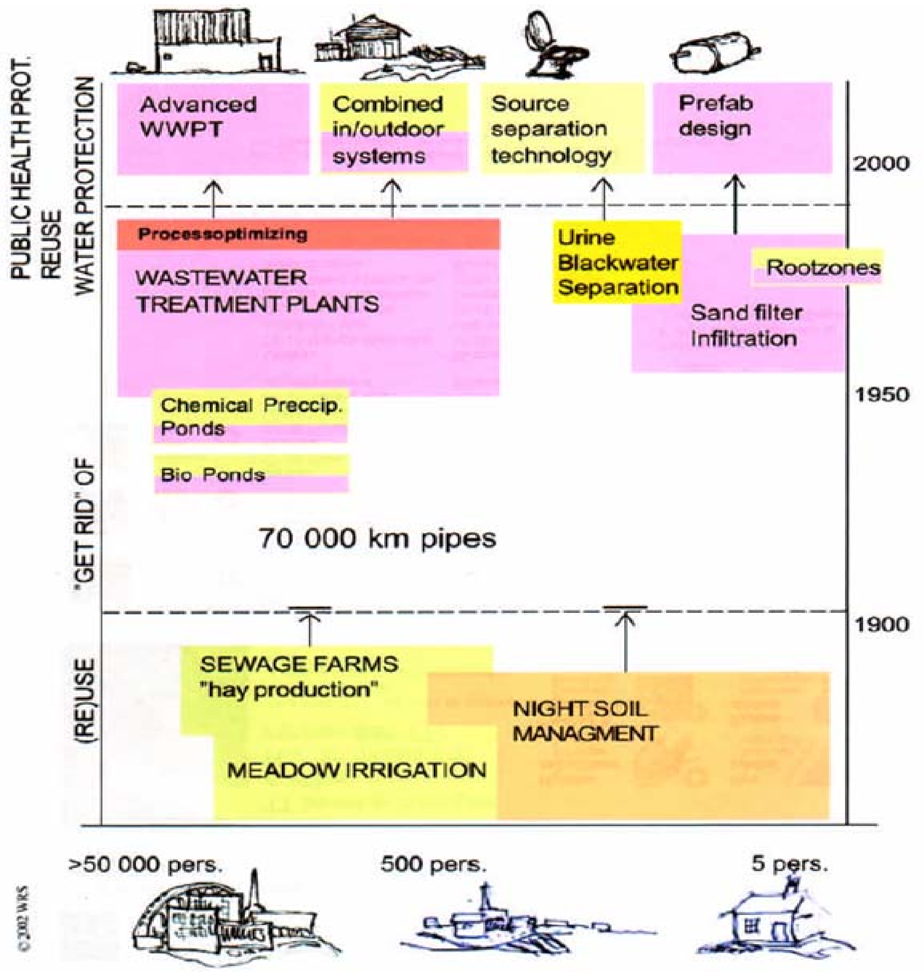


Figure 1: Development scheme of wastewater management (Noren 2006)

Nowadays, the historical error of mixing faeces with large amounts of waters is still not being addressed openly, and, furthermore, it is being repeated all over the world. Basing on WHO figures, about 5 million deaths per year are caused by water born diseases (WHO, 2000). For example in developing countries, the situation is more desperate as the investments have been more focused on clean water provision than on sanitation services (WHO, 2000), because the cost of disposing 1m^3 of wastewater is higher than the cost of producing 1m^3 of potable water

(Gunnerson and French, 1996). The wastewater management is globally very poorly spread, while innovation potential is very high (Otterpohl et al., 2002).

2.2 Wastewater systems

A wastewater management system is a human-designed and created system to manage wastes, while wastewater treatment and disposal technologies are the technical engineering solutions that might be used within that system (Ferguson et al., 2003). The processes occurring within and between different technological components, people, their actions and behavior, as well as natural ecosystem processes within which the technologies operate, are also a part of the wastewater system.

Depending on the scale, whether the solution deals with one house, a business, farm, a group of sites or a whole community, three general categories of wastewater systems can be distinguished, and these include (Lombardo 2004):

- ***On-site wastewater systems*** collect, treat and disperse or discharge wastewater from a single dwellings or buildings. Moreover, they are associated with low-density communities, rural-residential and small commercial developments (e.g. village centers). These systems generally consist of a treatment device (e.g. a septic tank) and a subsurface dispersal system, but they can include other components, such as secondary and tertiary treatment systems, and drip dispersal systems (Figure 2). Conventional methods as well as alternative technologies that provide advanced treatment may be used.

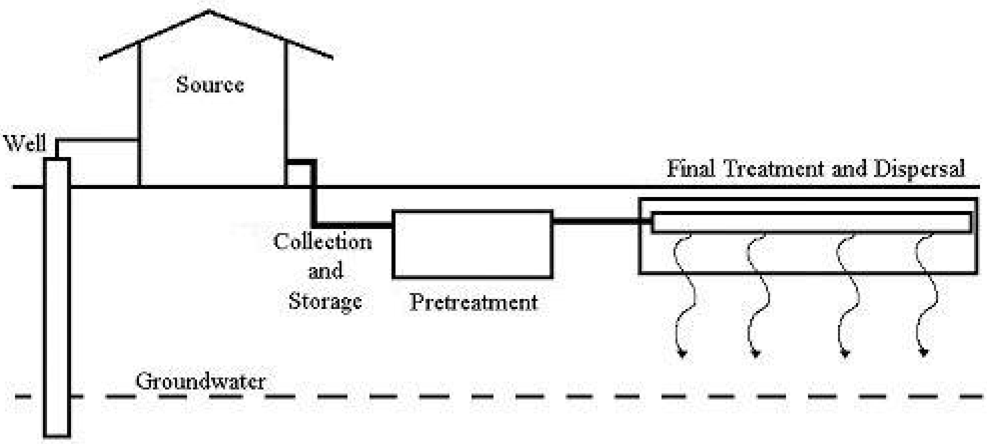


Figure 2: Example diagram of onsite wastewater system
(http://texashelp.tamu.edu/005-agriculture/onsite-waste-water-treatment-systems.php)

- ***Centralized Wastewater Systems*** are associated with high-density communities and developments such as cities and commercial areas. They generally consist of collection system that gathers and transports wastewater from multiple points of generation to one, or more, large centralized treatment facilities. These systems transport treated effluent to one or more point of dispersal, where it is typically returned to surface or ground waters (Figure 3).

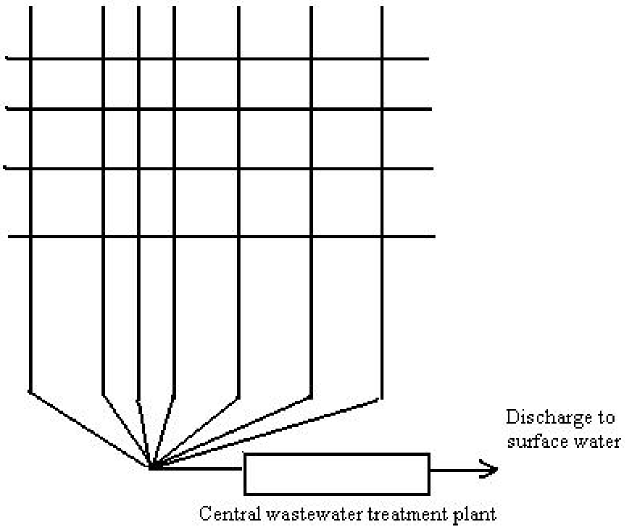


Figure 3: Example diagram of centralized wastewater system (Ferguson et al., 2003)

- ***Cluster Wastewater Systems*** can serve a small to large number of connections (two to hundreds homes) (Figure 4). Smaller clusters serving a few structures resemble onsite systems, while large cluster systems serving hundreds of structures tend to resemble centralized systems.

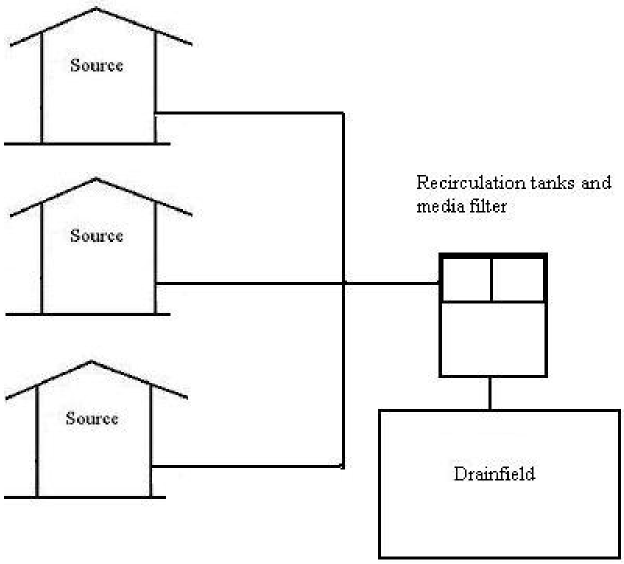


Figure 4: Example diagram of a cluster wastewater treatment system (Ferguson et al., 2003)

Clusters generally disperse wastewater in subsurface dispersal systems, although surface discharge or water reuse is also practiced. Each system can consist of many combinations of wastewater collection, treatment and dispersal/reuse technologies. While on-site systems serve an individual household or property and centralized systems serve large, high density communities (community refers here to a group of people living in close proximity), cluster systems serve an intermediate number of structures with more than one and as many as hundreds of connections.

2.3 Decentralized versus centralized approach

Small communities have a wider range of wastewater systems available to them than larger cities, and the choice will depend on understanding the possible effects of different systems on the communities' vision of where they want to be in the future. Moreover, it will also depend on the local soils and water tables, closeness to the streams, rivers, lakes and the coast, and how overall ecosystem works (Ferguson et al. 2003). Additionally, the decision will be influenced by economic and social change. Summing up, two general approaches to wastewater management can be distinguished (Olson et al. 2002):

- **Decentralized** - an onsite and/or cluster wastewater treatment system that treats and disperses or discharges small volumes of wastewater, generally from dwellings or buildings that are located relatively close together. Decentralized wastewater management is the collection, treatment, and disposal/reuse of wastewater from individual homes, clusters of homes, isolated communities, industries, or institutional facilities, as well as from portions of existing communities at or near the point of waste generation (Tchobanoglous et al., 1998).
- **Centralized -** (conventional/septic system) consists of conventional or alternative wastewater collection system (sewers), centralized treatment plants, and disposal/reuse of the treated effluent, usually far away from the point of origin. While decentralized systems maintain both the solid and liquid fractions of the wastewater near the point of origin, although, the liquid portion and any residual solids can be transported to a centralized point for further treatment or reuse (Tchobanoglous, 1996). The centralized approach is well suited for highly populated areas (e.g. Auckland) where the large costs can be recouped from the population.

A graphical representation of centralized and decentralized approach to servicing a given area is presented in Figure 5. TP indicates centralized or cluster wastewater treatment plant.

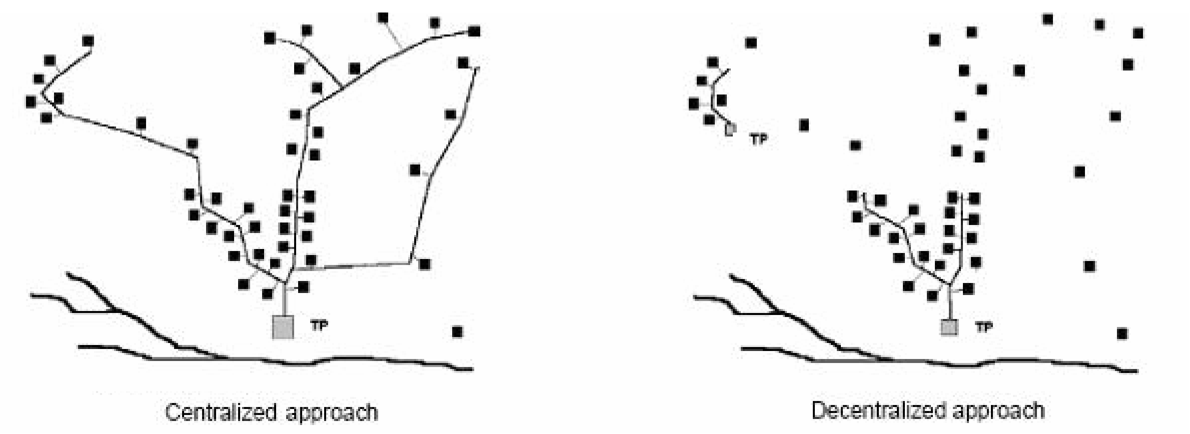


Figure 5: Comparison of centralized and decentralized approaches to wastewater management (US EPA 2003a)

To better understand decentralized and centralized approach to wastewater management, a diagram presenting wastewater scale continuum is used (Figure 6). For example, it can be seen that cluster system reflects centralization relative to onsite systems, while a regional wastewater treatment plant (WWTP) serving multiple municipalities reflects a higher degree of centralization than a number of centralized but smaller or community-scale WWTPs (Hamilton et al. 2004).

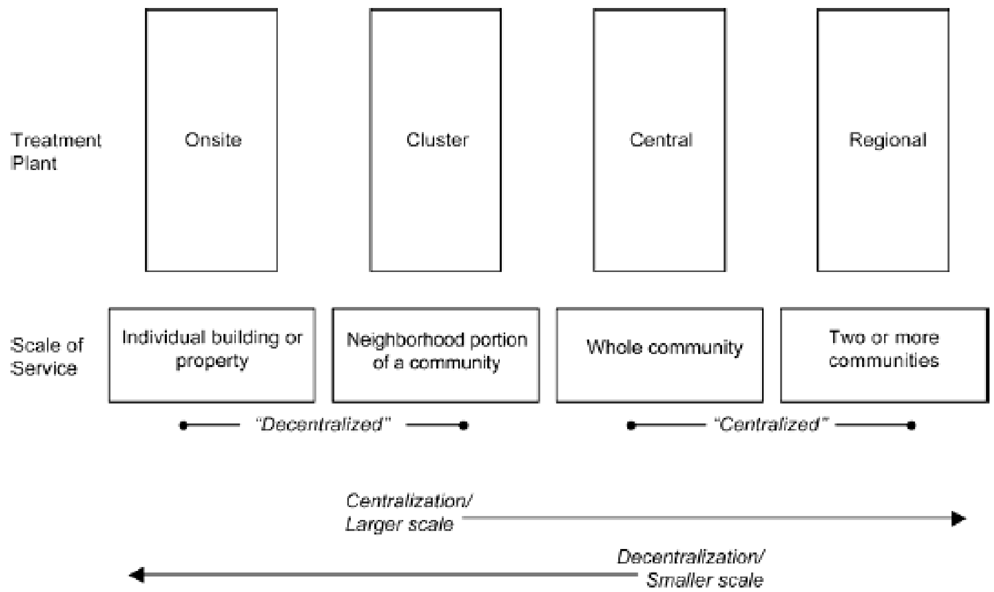


Figure 6: Wastewater scale continuum (Hamilton et al. 2004)

Decentralized systems may help communities avoid or resolve the problems mentioned before or address many other issues raised by centralization of wastewater services. The line between decentralized and centralized systems becomes vague when some cluster systems are considered. Differences between two approaches are presented in Table 1.

Table 1: Differences between centralized and decentralized systems (Hamilton et al. 2004)

	Centralized (typically)	**Decentralized**
Volume	Huge volumes of water	Treat 'relatively small volumes of water' (USEPA 1997)
Sewer type	Conventional gravity sewers	Alternatives: small-diameter pressurized pipes, small-diameter gravity and vacuum sewers, often with on-lot setting tanks and/or grinder pumps
Treatment type	Activated-sludge processes	Alternatives: sand filters, trickling filters, etc.
Discharge method	To surface water body	Infiltration into soil
Ownership	Publicly owned	Owned by developer, homeowners' association, or other private entity
Relative scale	Intended to serve entire community or substantial areas of large communities	Serve only a portion of a community (but less than entire community)

Decentralized vs. centralized, or degrees of centralization refer here to physical characteristics. Physical decentralization does not necessary imply anything about institutional structures for managing wastewater systems (Hamilton et al., 2004). As for example, maintenance of such systems can be overseen by centralized management entity such as a special district or utility, as assuring appropriate management is of high importance.

Small and rural communities often cannot afford expensive facilities, and their population may be too spread out or too low to take centralized approach. Moreover, some already existing on-site system functioning effectively, do not need to be replaced. In such circumstances, decentralized wastewater treatment is be the best solution for wastewater management, as it involves a combination of treatment technology options, both traditional and innovative, where they are most appropriate in community.

The centralized system nowadays is criticized due to difficulties in complete elimination of pollutants. Mixing different qualities wastewater originating from domestic and industrial use being discharged into one facility makes it difficult to treat and reuse (Hamilton et al. 2004). Additionally, the best water quality is provided for all utilizations irrespectively of particular demands, and the permanent withdrawal of water affects the local and regional resource cycles. It is expected that over next 25 years, only in Auckland, New Zealand, the water needs will increase by 30 percent to 468,000 m^3 a day (Struneski, 2001).

Considering economic point of view, high investment is needed to build and maintain infrastructure, and the major share of their expenditures is needed for transporting the wastewater into sewers, and not for purification processes (Panebianko et al., 2006). In addition to this, only in New Zealand, an estimated NZ$5 billion of investment will be required over the next 20 years to upgrade water, wastewater and storm water infrastructure (Strunski, 2001). That is why, communities have to become aware of the role decentralized systems can play, if properly designed and managed.

What is interesting, sanitation experts, who serve developing countries, universally do not accept that conventional centralized wastewater treatment is the standard towards which developing countries should aim (Hamilton et al., 2004). A good advice is presented in World Bank report on sanitation and disease in the developing world:

"Those whose job is to select and design appropriate systems for the collection and treatment of sewage in developing countries must bear in mind that European and North American practices do not represent the zenith of scientific achievement, nor are the product of history that started about 100 years ago when little was known about the fundamental physics and chemistry of the subject and when practically no applicable microbiology had been discovered. … These practices are not especially clever, nor logical, nor completely effective – and it is not necessarily what would be done today if these same countries had the chance to start again" (Feachem et al. 1983)

In New Zealand, developers are constrained by Local Authorities consent to connect into conventional systems where possible. In some cases, difficulties arise while connecting to a conventional system under gravity, which leads to utilization of expensive pumping systems and results in higher costs and less viable development. Moreover, new connections increase the pressure on the treatment station with fixed capacity, resulting in the need of upgrading and higher maintenance. Such activities may influence the quality of the wastewater at the outfall and costs of operation and maintenance, which may affect environment. In Dunedin, for example, the sewer outfalls is off Lawyers Head at St Clair Beach causes problems by polluting beaches and leading to increased algae bloom (Archer, 2004).

Traditionally, the choice of wastewater infrastructure for a community fell into one of two extremes - poorly maintained onsite systems or highly maintained centralized sewer systems; nowadays, however, there are more options available to address wastewater issues in small communities, and decentralized approach is an environmentally friendly alternative.

To support that statement, some of the problems connected with centralized wastewater systems are presented below (Hamilton et al. 2004):

- ***Centralized systems are unaffordable for many communities.*** They are too expensive to build, as small communities have fewer people to support large wastewater investment.

For example, a conventional wastewater treatment facility (not counting sewers) can cost a community of less than 1,000 people NZ$20,000-25,000 (EUR 10,000-13,300) per connection, compared to NZ$8,000 (EUR4,000) per connection for a community of 10,000 or more people (English et al.1999). What is more, even if the funds are obtained, often the technologies prove to be difficult and costly to maintain given the limited technical and financial capacity of most small communities (Kreissl et al. 2000).

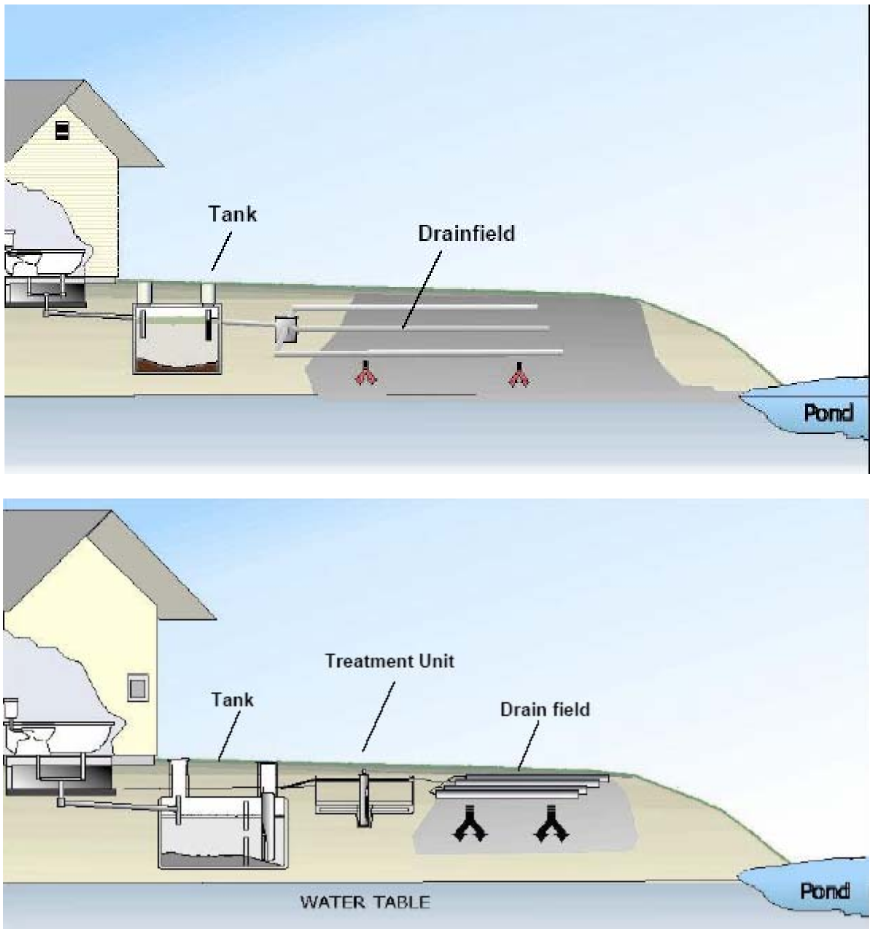
- ***In some places centralized systems have been overbuilt, resulting in crushing debt burdens for citizens.*** For example, Hillsborough County in Florida built a very large sewer system in the expectation of rapid growth. When the growth is not materialized, the high debt load could not be supported by population, and it struggled financially for years (Hamilton et al. 2004).
- ***Sewer systems can impact hydrology of watersheds***. Infiltration of groundwater into sewer is a substantial problem, as well as, wet weather sewer overflow. Too much groundwater is drained away, robbing streams of base flows. In some places, such as Ipswich River in Massachusetts, this has contributed to the drying out of some stream segments (Pinkham et al. 2004).
- ***Sewers can leak into streams and groundwater.*** For example, a study in Albuquerque, New Mexico, concluded that leakage of wastewater from sewer pipes amounted to 10% of average daily wastewater flow, which equaled five million gallons (22,730,000 liters) per day (Amick and Burgess, 2000). Moreover, leaking sewers may be a great source of ground and surface water contamination.
- ***Centralized systems have a huge backlog of deferred maintenance.*** The US EPA has determined that the gap between what cities are spending on maintenance and upgrades of collection and treatment systems (as well as drinking water infrastructure) and what is actually needed (USEPA 2002b). Communities cannot afford to spend more than they have to on new infrastructure when the needs of the existing infrastructure are so great.

Summing up, these are some of the reasons why alternative ways of providing wastewater service in suburban, low density areas are gaining increasing attention. Additionally, the shortage of resources in wide areas of the world makes the development and implementation of innovative methods a necessity.

2.4 Opportunities

Optimal scale for wastewater system is not a technical issue, but a matter of community needs and resources. Wastewater can be treated to any existing regulatory standard, e.g. to drinking water quality standard, at a scale ranging from plants that treat the wastes of individual homes to ones that serve millions of people (Hamilton et al., 2004). In a 1997 report to US Congress, the US EPA found that adequately managed decentralized systems are a cost effective and long term solution for many communities (US EPA, 1997).

Decentralized wastewater systems allow flexible wastewater management, moreover, parts of the system may be combined into treatment trains (Figure 7), or series of processes to meet treatment goals, overcome site conditions, and to address environmental protection requirements.



a)

b)

Figure 7: Examples of onsite systems: a) A conventional septic system with septic tank and trench drainfield; b) An alternative and innovative system treatment train (Hamilton et al. 2004)

A treatment train is an arrangement of treatment components in a sequence, where the additional treatment step enables advanced treatment systems to achieve consistently high results.

As alternative and innovative systems (advanced systems) are general terms for any wastewater treatment system that is different than the conventional model. This may refer to a complete treatment system or just one component within a system, influencing treatment performance and space requirements. The feature that sets alternative treatment systems apart is that separate treatment unit located after the septic tank treats the effluent before discharge to the drainfield (Figure 7). The septic tank and leachfield perform functions similar to a conventional system, except different types may be used. The components of decentralized wastewater systems include a tank, filter, reactor, and disposal/reuse method. The disposal method is the final step, and the effluent has to be filters before it leaves the septic tank.

Opportunities of decentralized wastewater systems, if properly managed, may be as follows (Butler and Maccormick 1996, Hamilton et al. 2004):

- ***Decentralized systems can achieve high pollution removal rates.*** Most centralized wastewater treatment plants meet secondary treatment levels, which are generally defined as removal of greater than 85% of the biological oxygen demand (BOD) and total suspended solids (TSS). Advanced secondary treatment (AST) is achieved when greater than 95% of these constituents is removed. It was shown that onsite wastewater treatment systems with at least 0.6m of unsaturated soil between the leachfield infiltrate surface and the water table, can meet AST standards and provide greater than 99% fecal coliforms removal. Various advanced onsite and cluster wastewater technologies can also remove substantial amounts of nitrogen (N) and phosphorous (P), some to levels approaching advanced wastewater treatment standards of 90% N and P removal (Anderson and Otis, 2000).
- ***Decentralized systems are often much more affordable for small communities.*** For example, in 2000, Willard in New Mexico, faced costs of NZ$2,12milion (EUR1.06million) for sewers and facultative ponds, compared to NZ$1.3 million (EUR650,000) for clustered reticulation sand filters and advanced onsite systems (Hamilton et al., 2004).
- ***Effective management can maintain decentralized system reliability at low cost.*** Decentralized systems provide a tool for large urban or suburban wastewater service providers. For example, the water and sewer authority for Mobile, Alabama is building and operating cluster wastewater systems to serve new subdivisions outside the city limits and on the opposite side of topographic ridge from its gravity sewershed. The utility has found that the systems are a good match with its strategic objectives of

avoiding large capital expenditures for a new treatment plant in another watershed or new force mains to serve the area, avoiding political battles and new flows in its already capacity-limited gravity sewers, providing cost-effective service to developing areas around the city and environmental stewardship through higher levels of treatment, generating new customers and a positive image for the utility, and competing with other local water providers for water service to new development.

- ***Decentralized approach to serve an isolated pocket of the city that still uses septic systems.*** This approach will probably be less expensive than extending sewers to the area.

Too few communities take advantage of these and other opportunities that decentralized wastewater systems can provide. Wastewater system planning is often carried by force of habit and familiarity, however communities can do better, as there are many alternatives to conventional, centralized wastewater systems.

2.5 Sustainable Wastewater Management

US EPA has encouraged small communities to integrate risk assessment of air quality, solid waste, toxic waste, and other problems, in order to proceed with high-priority, high-impact, cost effective projects. In addition to this, management of such systems is of high importance and involves considering the total physical wastewater system, from the source, to return of the wastewater to the environment (Figure 8).

That offers more sustainable and economic approach, and means that any wastewater management system, whether it deals with industrial, domestic wastewater or both (combined), consists of four stages and these include (Ferguson et al., 2003):

- Managing wastewater at source (including water conservation and recycling)
- Collection and treatment
- Re-use of treated water and sludge
- Re-entry of treated wastewater into ecosystem

First of all, the level of water consumption defines the amounts of wastewater generated, what later defines the investment needed in collection and treatment infrastructure. The reduction in water generation contributes to conservation of both resources and energy (Nhapi and Gijzen, 2005). Therefore controlling consumption through waste avoidance and reduction measures has to be a part of resource management (water, nutrients and energy). That is why, waste minimization involves planning and implementation of environmentally friendly management practices.

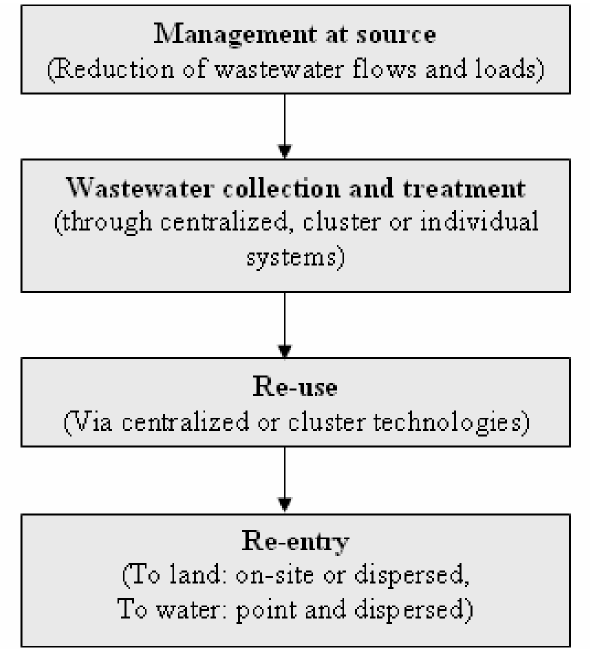


Figure 8: Relationship between servicing options and wastewater management process (Ferguson et al., 2003)

Secondly, the focus is on technologies that collect and treat wastewater, so it can be reused. These technologies have to be rational, cost effective and sustainable. Options to use valuable wastewater components include for example, converting COD into energy (Nhapi and Gijzen, 2005), or using effluent as water for aquaculture and agriculture, parks, recreational centres, golf courses, fire protection or toilet flushing. Moreover, the quality of wastewater and type of reuse defines the levels of treatment required.

When the options of prevention or reduction of wastewater production, as well as, treatment and recovery of wastewater components have been found, safe disposal of any wastewater components that are not recycled or reused is considered. If some unmanaged nutrients still remain in the effluent, the aim is to reduce pollutant concentrations and exposure risks by promoting self purification in receiving environments (Nhapi and Gijzen, 2005). The idea is to boost the self purification capacity of receiving water body so that it can cope with pollution load. In Cartagena, Colombia, outlet doors were constructed to allow water inflows and outflows to be controlled by tidal pressure, which improved water quality in the Bay as dilution occurred and self-purification was enhanced (Moor et al., 2002). The management of wastewater has also considered different land uses (residential, commercial, institutional, industrial, agricultural, etc.) in towns and apply different solutions for different areas.

Summing up, management based on wastewater prevention reduces water consumption and waste generation, additionally, treatment and optimal reuse of nutrients and water at the smallest possible level, as well as treatment technologies making the best use of the side products via reuse, all lead to cost savings and sustainability (Figure 9).

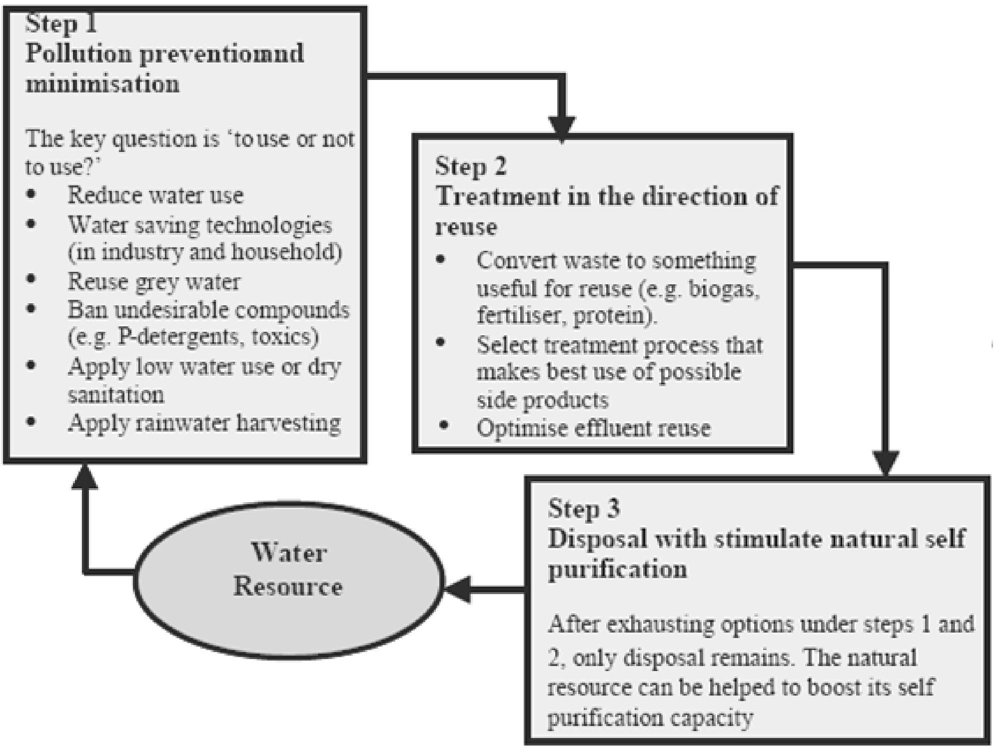


Figure 9: Schematic representation of the 3-Step Strategic Approach to wastewater management (Nhapi and Gijzen, 2005)

These principles are presented and explained in the work of Nhapi and Gijzen, as a 3-Stage Strategic Approach (Figure 9), which strongly focuses on sewage management, but also considers water supply, nutrient uses and other material flows associated with the water cycle (Nhapi and Gijzen, 2005).

Once first stages are addressed to the maximum, the remaining waste flows could be safely discharged into the environment, enhancing the self-purification capacity of receiving environments. To achieve this, systematic implementation together with appropriate planning, legal and institutional responses are required. Moreover, stakeholders' interests have to be recognized to find the optimal options for decentralized wastewater management.

Additionally, the sustainable management of water requires establishment of effective water institutions, the development of low water usage (or even dry) sanitation systems, rain-water harvesting, and the extensive use of resource recovery and reuse techniques for wastewater (Otterpohl et al., 1997; King, 2000; Lens et al., 2001). That approach sees waste as a resource, and the management to be linked to water resources and nutrients. Moreover, resource recovery and reuse approaches, next to the water savings, could result in financial incentives, which could be used to cover part of the cost of wastewater treatment (FAO, 1999). Additionally, water and waste management could be addressed from a cleaner production approach (Gijzen 2001; Nhapi and Hoko, 2004), as this approach has been successful in the industrial sector, it could be applied also in the domestic sector (Table 2).

Table 2: Cleaner production principles and current water management practices (Nhapi and Gijzen, 2005)

Principle	Practice
To use lowest amount of input material, energy or other resources per unit of product	The supply of drinking water per day is between 130-350L/capita/day, while less than 2L are actually used for drinking
Not to use input materials of a higher quality than strictly necessary	Water purified to drinking water standards is used to flush toilets, clean floors, wash cars or irrigate gardens
Not to mix different waste flows	Already at the household level various wastewater flows are combined (urine and faecal matter, grey and blackwater). After disposal into sewer this waste is mixed further with industrial effluents and with urban runoff. This makes reuse of sprecific components less attractive and less feasible.
To evaluate other functions and uses of byproducts before considering treatment and final disposal	Domestic sewage is discharged into open water resources either with or without prior treatment. Only few examples of wastewater reuse or (by-) product recovery from wastewater exist.

That is why by evaluating current water management from a cleaner production point of view, the need to re-think current practices and concepts in the case of sustainability becomes evident (Nhapi and Gijzen, 2005). The concept of cleaner production developed over the past two decades, has brought some innovative environmental thinking into the industrial sector, especially in terms of waste avoidance and reduction, as well as use of substitutes (Nhapi and Gijzen, 2005).

Managed decentralized wastewater systems are able to address and implement cleaner production principles, and manage wastewater in a sustainable manner. Moreover, they are viable, long term alternatives to centralized wastewater treatment facilities, particularly in small and rural communities where they are most cost-effective.

2.6. Current practices

The current trends in the United States give directions for the future of decentralized systems, as USA is one of the leaders in this field at the moment. Over the past two decades, the US EPA has put a lot of effort in developing, implementing and promoting many innovative advances for decentralized wastewater management (US EPA, 2002). As a result, many countries, including New Zealand, follow the research done in the USA. Moreover, many of their guidance materials is recognized internationally and adopted worldwide.

However, the US is not the only country placing a strong emphasis on decentralized wastewater approach. In Europe, Asia or Australasia, decentralized approaches have been developed and implemented (US EPA, 2000).

2.6.1 New Zealand example

Recently, the need is to integrate the wastewater into natural system, because, it is no longer sufficient to manage only the end effect, as it was done during last 30 years (Ferguson et al. 2003). That former non-system approach was focusing on the treatment and disposal of the treated wastewater, moreover, engineering and technology applied was to meet minimum regulatory standards, which resulted in inefficient use of resources and human effort.

However, the integrated wastewater management approach is not new and has been used for centuries. Actually, it forms the basis for Maori waste management thinking (Tiakiwai et al. 2004). For example many small communities use on-site systems which closely fit that approach. As Dr Steven A. Esrey from UNICEF stated, *linear approaches to problems, in which resources are used and converted into wastes, only to be disposed of, represent a failure in human ingenuity and a flaw in technology design* (Esrey, 2001).

At present there is a major focus on creating a circular process which involves re-use, rather than linear process from use to disposal. Circularity is one of the key principles of sustainability. If a system is to be sustainable, matter and energy removed from the system cannot exceed matter and energy put into the system (Hunt, 2004). To maximize the benefits or services derived from the system, inputs must remain in service until they are degraded to the point where they are no longer usable and at a rate which allows for replacement on a continuous basis. The approach is to evaluate the whole system in relation to social, cultural, economic and ecological environment within which it exists. Changes in environmental standards and community goals have led to thinking about all wastewater pressures on the local environment and trying to manage them as a whole.

Based on The New Zealand Waste Strategy (2002), the goal is to change the way in which wastes are approached. This Strategy sets national targets to bring wastewater treatment systems to standards by the year 2020. Cutting down the amount if waste generated and discarded by the country is the long term challenge. What is more, problems concerning wastewater management have to be addressed and alternative optimal solution identified and applied in order to fulfill the requirements. In 2001, the Parliamentary Commissioner for the Environment in New Zealand, identified opportunities for progress such as:

- Demand management and least cost planning: economic instruments and community awareness and education programmes;
- Integrated catchments management;
- Integrated design and management of water services – building efficiencies measures, recycling, and linkages with allied services; in particular the three waters, potable water supply, stormwater and wastewater.

Sustainable wastewater management through decentralized systems has started to dominate in approaches to wastewater handling in small communities. What is more, a trust has been created towards the use of decentralized technologies such as alternative and innovative small community cluster systems that can frequently make more use of limited economic resources in rural and suburban areas.

The conventional paradigm of water and wastewater management was characterized as supply driven, centralized, large-scale development (Al-Jayyousi, 2003). Such approach led to over-exploitation or even depletion of renewable water resources, mining of groundwater resources and deterioration of water quality. The collection and disposal mind-set prevailed because of concerns over public health protection. Water-intensive sewer systems were built to remove wastewater from immediate environment of the communities using water as a transport medium. This paradigm is inadequate for sustainable water management. A shift to decentralized approach is necessary in order to ensure optimum utilization of the resource.

Decentralized wastewater management offers more opportunities for maximizing recycling opportunities. New innovations in wastewater management will eventually lead to substantial changes in lifestyle. Decentralized treatment will open up opportunities for, used to be believed impossible, wastewater re-use (Butler et al., 1996).

In New Zealand, decentralized system offers several advantages in terms of environmental protection, culturally and fiscally. Unfortunately, because of poor performance of individual wastewater treatment systems, the public attitude towards decentralizes approach is still seen as experimental alternative. And development of decentralized systems within New Zealand is improving slowly.

At the moment, at least 20% of the county population is serviced by on-site wastewater systems (AS/NSZ 1547:2000). Among that number, about 10-30% is likely to be performing poorly, posing environmental and public health risk (USEPA 2000; Rodney District Council, 2002(a)). However, these systems if properly designed, installed and maintained, produce the same or better level of effluent than of conventional treatment plants.

Basing on the report The Water and Wastewater Market in New Zealand, Local Authority water and wastewater infrastructure is valued at approximately NZ$ 7.5 billion (EUR3.75 billion) annually, moreover, approximately NZ$ 600 million (EUR 300 million) is spent on operational costs each year (Struneski 2004). New Zealand has an abundant resource of water, and the quality of water infrastructure is of high standards, however, due to draught conditions, there are areas in which there is a tight competition for the water resources. At present New Zealand is facing a number of problems in order to reduce the use of water, resulting in production of wastewater. These problems include increasing water consumption, inefficient water use, excessive water extraction, and uncontrolled or poorly maintained storm water drainage and wastewater disposal. The New Zealand water consumption is 2,000 million m^3 per year (Struneski, 2004). Additionally, a number of issues e.g. recognition of Maori values with respect to water has made water management in New Zealand more complicated.

2.7 Summary

Managed decentralized systems bridge the two existing infrastructure extremes, poorly maintained conventional septic systems and cesspools on one hand, and highly maintained public sewers with central wastewater treatment plant on the other, with a range of wastewater treatment options that can protect human health and the environment. What is more, nowadays, cluster wastewater management approach utilizing advanced innovative solutions will help achieve sustainability goals of minimizing wastewater generation, water conservation, or nutrient recycling; and will drive the expansion in use worldwide.

3. Integrated wastewater planning for small communities

Decentralized wastewater technologies are emerging regularly, however, the variety and number of alternatives, sometimes makes decisions process more complex (Joubert 2004). Especially, when choices define where and how the community will develop. That is why the selection of wastewater management technologies should be a part of community planning process, as that approach ensures choosing the most appropriate wastewater treatment system for a particular community.

Decentralized systems are not a panacea, as proper siting, maintenance, management, and regulatory oversight is necessary to ensure their reliability (Ferguson et al., 2003). Only by adequately evaluating the benefits and costs of a full range of wastewater system options and community needs, an optimal solution can be determined. Especially as usually the costs have receiving more attention then potential benefits of wastewater systems while choosing a way of wastewater handling. What is more, up till now, wastewater facility planning have been too narrow in scope, that is why more integrated wastewater planning should be applied as it would be a more comprehensive and representative whole-system approach. Technologies more applicable to large urban systems have been recommended to small communities, while more affordable technologies such as community sand filters, pressure collection systems, cluster systems, and remedial onsite upgrades have been given little attention (Kreissl and Otis 2000). What is more, inadequate consideration has been given to wastewater reuse, groundwater recharge, wellhead protection, and other watershed needs and values. In addition, alternative means of reducing risks of water pollution, e.g. including stormwater remediation, repair of leaking sewer pipes, point-source upgrades, improving farming practices etc., have not been typically addressed in the planning process.

The idea is not simply to put centralized versus decentralized approach, but try to compare all alternatives, and selection of wastewater systems or mix of systems that best meets the objectives of the community.

3.1 Goals and issues – decision-making dependencies

Accountability in wastewater treatment decisions includes three major dimensions, protection of public health and the environment, community needs and preferences, and practicality of feasibility (Ferguson et al., 2003). Communities need whole-system, life-cycle analysis to make right the decisions. First, a discussion on setting of goals for the facility planning should be undertaken, next, several management strategies have to be considered, and the pros and cons of each discussed (Table 3). Then options for collection, treatment, and dispersal system technologies are reviewed, pointing out the strengths and weaknesses of each in the context of the various management strategies. Moreover, consideration of the regulatory requirements regarding treatment quality and the regulatory acceptability of various technologies is necessary. Usually there are at least two types of goals that have to be formulated and against which any options must be evaluated (Table 3) (Panebianko and Pahl-Wost, 2006).

Table 3: Types of goals (Panebianko and Pahl-Wost, 2006).

Community goals	**Environmental quality goals**
Growth management - encouraging, accommodating, discouraging, thwarting Cost sharing arrangements - who pays versus who benefits Ability to pay - level of public sector assistance with private sector contributions Level of public sector involvement - level of tax or fee derived revenue Level of public sector involvement - degree to which pubic sector intervenes/participates in historically private sector activities	What needs to be protected How well does it need to be protected Address current failures only, or protect against future failures

Additional issues to be considered include (Ferguson et al, 2004):

- ***Ecosystem and ecosystem services*** (Important factor in deciding on the solution, as there may be tensions between managing health risks and managing the effects of point discharges to the environment.).

- ***Health impacts*** (Sometimes technical engineering solutions are necessary, e.g.the reduction of the volume of wastes, may reduce health risks; some water conservation solutions may have their own health risks (re-use of greywater).

- ***Cultural issues*** (Statutory requirement in New Zealand requires particular attention to Maori cultural values, concerns and processes (e.g. the need to keep the local settlement small and casual; or issues concerning mixing water from different sources).

- ***Cost funding and social impacts*** (Cost of new system is usually a problem, however, the focus is still on the cost of buying the system and not on the long-term social impacts of wastewater decision. Even with grant assistance (e.g. Ministry of Health in New Zealand provides a grant to support poorer communities to make changes) the wastewater system can impose high long-term costs.

In addition to that, each community has its vision for future development, and any wastewater decision will impact the future direction of a community. For example, in Castlepoint, a historic beach settlement in the Wairarapa, New Zealand, by the 1990s' there was an increasing concern about beach pollution. Some sites had long drops, while others onsite systems (Ferguson et al. 2003). The central treatment system was chosen with oxidation ponds to address issues however the implications for development were never discussed as part of the options. The contamination problems were solved, but the pressure to develop this quiet seaside settlement has increased. Smaller lots have been created, and a rapid increase in population as well as property values has been noticed. These changes were unanticipated at the time, as the opportunity to think through both wastewater and development issues was passed over.

Another example is a small coastal community Riversdale, New Zealand struggling with such process at present. There are about 230 houses, and the permanent population is 90 people. However, during summer time, that number doubles. The lagoon used for swimming is no longer usable, and there is a probability that groundwater is contaminated by septic tanks. Because of that, the potential for future development is limited, however, if new system was put, further land could be developed, as the community has started to broaden their focus to look at water issues and implications of decisions for the future development of the settlement (Ferguson et al. 2003).

Before decision is made, a watershed factors (e.g. susceptibility to nitrogen or pathogen inputs) and individual site factors (site specific characteristics) have to be assessed. In addition to this, the cost and general system consideration have to be taken into account, together with design, installation, operation and maintenance costs, over a given life cycle. Sometimes lower initial capital costs may result in much higher operation and maintenance costs, and in overall, these systems may cost more than others.

Some general system considerations include (Joubert 2004):

- Regulatory issues and constraints (e.g. as some regulations may not support the use of alternative treatment technologies)
- Legal and administrative costs (e.g. maintenance costs for tanks and drainfields)
- Site conditions for excavation of collection lines (e.g. shallow water table)
- Factors that reduce the cost of shared systems (e.g. reduced design flow - with shared systems not all households are likely to generate maximum flow simultaneously)
- Waste type, strength and quantity (e.g. high-strength wastewater – high BOD and grease - multifamily structures tend to be higher strength even when occupancy is low; they may be an opportunity to reclaim or reuse treated wastewater in case of high or variable flow)

- Lot size and usable space (e.g. larger developments may be suitable for cluster systems; adequate space may be necessary for alternative future leachfields)
- Site suitability (e.g. depth to water table, soil permeability, location from wetlands and surface waters)
- Site design (e.g. site accessibility for maintenance, aesthetic concerns)
- System design (owner level) (e.g. costs, maintenance frequency, reliability and longevity of the system)
- Site alteration (e.g. alteration may be necessary to install the system; extent of disturbance, excavation or filling, trees removal, modification of drainage patterns, increased runoff)
- Site limitations (e.g. high water table, proximity to wells, streams and wetlands)

All of these should be taken into account by a community, especially as the choice of wastewater system scale may result in varying benefits and costs. (Hamilton et al. 2004). Moreover, the relationship of the community to the natural surrounding environment in which it exists and how it relates to that have to be considered, moreover, the choice of technologies that might be preferred for the composition of the community's infrastructure, socioeconomic questions of acceptability to the public of technological change in an infrastructure.

In order to apply such integrated approach, the community wastewater planning has to include needs assessment, development and screening of alternatives (particularly regarding problem areas or areas of special concern), and integrated evaluation of alternative plans and their area-specific sub-plans. A final recommendation would be then based on a showing that the selected plan is the most economical means of meeting the applicable water quality and public health requirements, while recognizing environmental and other non-monetary considerations (Arenovski and Shephard, 1996).

The lack of knowledge and public misperception, legislative and regulatory constraints, lack of management, liability and engineering fees, and financial problems are still the barriers to decentralized wastewater systems (Jones K., 2003).

Choosing a wastewater treatment system requires working out the number of economic and sociopolitical issues, moreover, it requires energy, time and expense. That is why, it is important to build support for better wastewater management in the community, using motivation factor or an incentive, to enhance community to spend time and resources to address wastewater needs. Some of the motivating factors may include (Joubert 2004):

- Protecting high-quality resources (e.g. by showing what might be lost if no action is undertaken)
- Restoring impaired waters (e.g. by showing that resources are restorable and improvement can take place)
- Protecting public health from serious failures (e.g. improvements protect property and family’s health)
- Complying with regulations to remediate failures
- Allowing full use of property (e.g. wash laundry at home)
- Maintaining the strengthen property values
- Bringing properties to modern standards
- Being fair (e.g. where most property owners already takes care of septic systems – maintenance and upgrading - while others are not)

Without a motivation, it may be difficult to reach an agreement on shared wastewater improvements, even when incentives include financial support (Joubert 2004). It may be difficult to force all homeowners to abandon their individual and connect to a community treatment system. What is more, for most communities, change can be difficult to accomplish. Despite that, human nature leads people to fall into comfortable routines and try to stay with tried and true technologies, however, designers may become familiar with advanced technologies and favor those. There is a need to learn from other communities that have already applied wastewater management systems.

3.1.1 Cultural issues

Many cultures hold a spiritual belief in the environment. The nature of this belief varies across and between the cultures. The issues of wastewater management can bring these issues to the surface. Especially the focus on physical effects can deny a view that there are principles of behavior that should be considered in wastewater management. This is an important issue in New Zealand and many Maori (indigenous people of New Zealand) have a very clear view of the world, which goes beyond a purely physical focus (Ferguson et al. 2003). That is the reason why decisions about environment may be based more on the relationship between the human and environment, rather than effects.

In New Zealand, Maori world view involves a belief in a spiritual dimension that permeates physical world, binding all things together (Harmsworth et al. 2003). Maori considers human-derived wastewater to be spiritually defiled, until cleansed by passage through the earth (Tiakiawai et al. 2004). It means that polluted water need to pass through the earth to be purified and to have its mauri (life force) restored. This is considered necessary, whether treatment to remove or dilute pathogens, chemicals and metals has occurred. As a result, the issue is the process undergone for treatment, as much as the removal of pollutant. Because of that the focus is on how wastewater and sludge should re-enter the ecosystem. Land re-entry appears to be the preferred approach, with wastes entering the soils before they become absorbed by plants.

There are seven main groups of people in any wastewater systems decision process in New Zealand, and these include local community (residents and business people), local government, tangata whenua, central government, developers, individual land owners and interest groups.

It must be sure that there is a partnership developed with local iwi or hapu and that these groups are involved in the process. Maori communities are no exception, as the role of Maori in any wastewater management initiative extends beyond that of being a stakeholder, because of the recognition in law of their traditional kaitaki (guardian, caretaker, trustee) and environmental management roles. The Resource Management Act (RMA) 1991, which sets out various resource consent processes, gives particular recognition to the Treaty of Waitangi and the role of Maori in environmental management issues.

As required by section 8 of the RMA (RMA 1991), when preparing plans and implementing the resource consents process, local authorities must recognized the principles of the Treaty of Waitangi. This means that local authorities need to be vigilant in ensuring that any proposal for development has properly considered Maori concerns. The Treaty of Waitangi represents an agreement in which Maori gave the Crown the right to governed and developed British settlement, while the Crown guaranteed Maori full protection of their interests and status and full citizenship rights. These issues are important for wastewater management, as wastewater has a potential impact on resources, on development vision and on relationships between groups. If the community is non-Maori, people will have to be aware that iwi (people, tribe) and hapu (subtribe) will often be keen to explore these concepts in the area of wastewater management. However, if it is mainly Maori, the rights and responsibilities under the Treaty have to be known.

Within this context, proper management and treatment of wastewater becomes an important facet of environmental guardianship, or kaitiakitanga (uardianship), spects of which include protection of sacred places (wahi tapu), and traditional food sites (wahi kai, maitaitai, mahinga kai), as well as maintenance of spiritual and physical well-being for Maori communities (mauri, waiora, mana) (Tiakiwai et al. 2004). These aspects have beenidentified in iwi managementplans, which recognize the customs andrites (tikanga, kawa) pertaining to human waste discharge and which state that such discharge into aquatic environments is an unacceptable activity (e.g. the Ngati Tuwharetoa Environmental Iwi Management Plan, 2002).

Choosing a wastewater system for a community can take years; from starting to thing about it, setting up the process, doing the investigations, looking at technologies, getting funding and building the system (Ferguson et al. 2003). It is a complicated process, with attention put on the communities attitudes to growth, their understanding the technical options, environmental conditions and standards, different ways to fund and how the rating system works as well as how the resource consent process works.

3.2 Cluster versus individual system

In decentralized wastewater management, the choice between individual and cluster system is highly site-related, as well as the technology is (e.g. if homes to be served are located at a higher elevation than the final treatment facility, than small diameter gravity sewers might be the most cost effective technology). Moreover, shared systems may cost more or less then several individual systems. There is a variety of factors that can help determine which system would work best; and some of these are listed below (Joubert 2004):

- If a reduction in design flow will be allowed with a shared system; in case of individual system, enough capacity must be provided for the worst case – maximum flow scenario; while with the same homes on one system, the probability that all units will experience maximum flow at the same given time is low, so design flows may be lowered (reducing peak flows increases cost-effectiveness)
- If the lot is too small for a system, a cluster system with a neighbor would be an option
- When more than five or six houses are connected, there is a potential for greater water savings due to reduced design flow, a single treatment unit and potentially fewer pumps
- If public property is available for common treatment and drainage area, as it makes a shared project much more cost effective
- If private wells are located within 100 feet (30.5m) of soil infiltration system, upgrading to advanced treatment to protect drinking water quality has to be considered
- If shallow wells are located within 100 feet (30.5m) of wastewater treatment system, installation of drilled well should be considered

- Collection systems for alternative cluster systems serving anywhere from two homes to a whole village all require piping to carry wastewater from homes to the shared treatment units and drainfields (typically small diameter pipes 5-8cm) are used
- The cost of septic tank effluent gravity collection system versus individual system repair should be compared
- If local regulation allow connection of small diameter effluent sewers to a nearby gravity sewer should be determined, rather than installing a conventional (more costly) traditional pump station
- In areas of large lots with good soils and were advanced wastewater treatment is not essential to protect human health or environmental quality, the conventional treatment systems using gravity flow should be relied on
- The use of active systems should be justified with measurable improvements in health and the environment (Tyler, 2000). Active systems providing only minimal improvements (reduced BOD and TSS and reduced drainfield size) should be carefully evaluated
- Electrical costs, which add up over the life of a system should be analyzed, as well as offset and minor savings in initial installation cost (especially in island locations where electricity costs are generally much higher)
- When selecting advanced treatment systems of comparable complexity, reliability and cost, it makes sense to choose the simplest technology

Wastewater servicing system can be linked to ecosystem services such as water supply, stormwater, and food and fibre production (via the nutrient cycles), as well as social and cultural services such as education and research (Etnier et al. 2005). These interrelated issues can make the process of selecting the best option very complex. Each site will have certain characteristics that will eliminate particular options. Evaluating the different options for wastewater technologies and wastewater system is extensive and site specific, that is why it is important to have clear objectives in relation to the need for wastewater system, set certain criteria for evaluation different wastewater options and choose indicators that would enable ongoing monitoring of the chosen system.

As centralized wastewater system is an excellent solution in larger densely populated areas, since the cost of municipal sewage system is lower if it can be distributed over a larger number of users. However for small communities, non-discharging decentralized treatment system - cluster system - should be carefully considered.

Nowadays, new technologies are becoming more cost-effective then conventional systems, moreover, they can remove nitrogen e.g. may be required in nitrogen-sensitive coastal waters, as well as protect groundwater resources or phosphorous-sensitive freshwaters. On new or existing lots with failed systems and limited space an alternative and innovative systems would be an option.

Some regulatory programs recognize the higher levels of treatment achieved in alternative systems. As a result, these systems maybe preferred to conventional, due to reduced costs, convenience, space savings, and all the benefits they provide. For example, improved biochemical oxygen demand (BOD) removal, as well as total suspended solids (TSS) content may make a smaller drainfield size feasible.

Additionally, in areas with high water table, the use of advanced systems can help avoid impacts of fill systems, moreover, preserve natural character of the neighborhood, or protect water quality more effectively (e.g. shallow drainfields or bottomless sand filters may be used for final dispersal to the soil as an alternative to fill or mound leachfield) (Joubert 2004).

What is more, alternative systems employ components that help achieve consistent treatment performance, which is dependant upon maintenance and management. All systems require various levels of operation and maintenance to ensure systems longevity, however many users do nothing to their systems, which affects the performance. The innovative systems may include tanks for advanced treatment systems, treatment units or alternative drainfields etc., and examples are described in Chapter 5.

3.3 Example – Vadsbro, Sweden

The case of Vadsbro in the south of Sweden is an example of the planning process for sustainable wastewater management for small community (Noren 2006). The process here was based on comparison of different options from the Best Available Technology (BAT) and the Polluter Pay Principle (PPP), and the use of Open Wastewater Planning Method (OWP), which consists of six stages (Noren 2006):

1 – Site conditions:

- Number of people, future loads
- Natural and prerequisites
- Existing infrastructure
- Environmental sensitivity and risk assessment
- Ambitions and local regulations

2 – User and owners ambitions and economical capacity, regulation and local policies

3 – Set up terms of requirements (T&R)

- Levels of environmental protection from what is economically and practically reasonable)

4- Investigate at least three different options

- Options must have potential fulfil T&R and they should be at detail level that is obvious they can be implemented

5 – Evaluate and compare options

- Use T&R as the evaluating tool

6 – Decide

Further investigation or implementation

Among technologies, the whole wastewater system has to be considered, together with private (safe, comfortable and affordable sanitation for the users) and public goals (protection of public health, recycling of water and nutrients, protection of water recipients). The question was to develop existing system or to construct a new one, additionally, to focus on targets and ambitions or to consider reasonable costs?

Site Conditions:

- Issues:
    - Old and obsolete plant and collecting system
    - High consumption of chemicals and electricity
    - Weak and uncertain treatment results
- The site:
    - Rural area, farmland, forest, lake nearby
    - Local water well in the middle of the village
    - Existing pipe system and two pump stations
- Number of people: designed for 145, now 125
- Wastewater flow: average 45m^3/day (320l/preson/day)
- Nutrient and organic matter flows (based on Swedish standards):
    - Phosphorous 110 kg/year
    - Nitrogen 700 kg/year
    - BOD7 2450 kg/year

Terms and requirements:

- Hygiene:
    - To avoid sanitary nuisances (e.g. odour)
    - Infectious disease control (effluent is either bathing water quality or excluded from direct exposure to human until it has achieved that water quality)

- Recipient:
    - Phosphorous reduced >90% (general requirement).
      In Vadsbro, at most 0.1kg/person annual discharge and <0,1 mg/L
    - Nitrogen reduced >50% (general requirement)
      In Vadsbro, at most 2.5kg discharge per person per year, discharge as nitrate
    - BOD reduced >95%
- Recycling:
    - Phosphorous >75% recycled
    - Other resources valuable for agriculture
- Economics:
    - Cheaper than construction of a completely new system (e.g. maximum NZ$5,200 (EUR 2600)/household)
    - An average operation cost for small treatment plants (e.g. ~ NZ$330 (EUR170)/household)
- Technical function:
    - A proven robust system that gives few surprises, as they can lead to inadequate treatment and/or extra expenditures
- Fitting in with the local situation
    - Goals of land owners and residents near the treatment plant, land use, the potential for re-use of resources from wastewater on-site (e.g. agriculture).
    - Goals of other affected parties (e.g. low energy consumption and/or reduction in other resources use, multi-use facilities that combine wastewater treatment with open water and wildlife habitat
    - Use existing infrastructure when feasible
- Responsibility and control:
    - New systems may require new divisions of responsibility between municipal wastewater engineers and farmers
    - Discharge monitoring may be more challenging, and could require new methods for monitoring

Assessment of options available included measures at the point of origin (source separation and on-site treatment and at the 'end of pipe'. Six different options were found possible to implement:

- Forest irrigation
- Precipitation pond
- Trickling filter and biofilter ditch
- Wetland/agriculture rotation system
- Open sandfilter
- Compact treatment plant

Final evaluation and comparison of alternatives:

Indicators were chosen such as: economy, reduction, potential for recycling, hygienic safe, local adaptation, responsibility/control to evaluate alternatives. Basing on these, the most efficient, cheap, flexible and robust solution was chosen – trickling filter and biofilter ditch, together with drainage beds for sludge treatment (Noren 2006).

4. Cluster Approach

Decentralized wastewater management is defined as the integration of onsite, cluster and centralized systems in an economically and environmentally manner within a sustainable management framework that is consistent with land use and growth plans (Lombardo 2004). Cluster systems play an important role in decentralized wastewater plans by enabling an optimal mixture of onsite, cluster and centralized systems to be achieved in area-wide (town, county, and other local areas) wastewater management.

At present, the increased demand for homes in small communities and lower density areas makes it difficult to provide drainage. Only where very rapid growth or high density development occurs, such investment is affordable. Additionally, prime agricultural land suitable for conventional septic systems is becoming rare (Dix, Infiltration Systems Inc.). If utilities are faced with very costly, land intensive and often complex onsite systems that must be managed; additionally have to pay for the total cost of sewers, deal with aging and failing infrastructure or terrain barriers, other options became cost effective alternatives.

That is why cluster wastewater management approach can bridge the gap and provide a means to develop in more restrictive environments and with more cost-effective solutions that can be managed economically. Instead of managing hundreds of on-site systems that serve several hundreds homes, cluster system is encouraged due to the increased efficiency in land use and the ability of the technology to support more diverse interests in low density areas.

Clusters are community systems for more than two dwellings, and are generally much smaller in scale than a centralized system (Ferguson et al., 2003). The size is a function of development patterns and environmental limitations, while the cost of collection and ease of recharging or discharging effluent favor a smaller size cluster unit. The wastewater from each cluster may be treated on-site or may be re-circulated off-site to a local treatment and ecosystem re-entry location.

Clustering is preferable where the development density is high and receiving environments such as streams, rivers or sounds, do not have the capacity to assimilate the additional waste load that could come from wastewater treatment plant (Hoover, 1997). This approach may encourage a denser distribution of homes and business, what is more, it may be appropriate and cost effective than single family individual on-site systems or traditional sewers, regardless the development and lot sizes.

4.1 Cluster systems within various contexts

Locating a cluster system in a rural site may open possible options to meet community wastewater treatment needs. For example, existing homes in the vicinity that may have substandard of failing systems could be allowed to tie into the system. This shared solution is potentially more cost-effective than repairs or the system replacement individually, especially if site conditions are difficult. Another land use option could take advantage of the wastewater capacity of a shared system to increase density of development. Development rights for critical open space land could be purchased and directed to increase density within the new development supported by the cluster system.

Moreover, the farmland could be protected by development at the allowable density, so the land protected by transfer of development anywhere else within the town. This method is used in New Jersey Pine Barrens to protect critical aquifers while directing development to appropriate growth areas (Joubert et al, 2004).

Cluster systems can be used in a variety of contexts including (Lombardo 2004):

- ***Community-wide wastewater management.*** Cluster systems enable communities to develop wastewater solutions that optimize economic and environmental objectives and avoid difficulties and adverse impacts of centralized or onsite options.
- ***Parcel development.*** Cluster systems enable communities to optimize environmental and economic issues associated with land development. Many communities have regulations that encourage cluster development for land use purposes and provide incentives for cluster system use.
- ***Defined wastewater needs solution.*** Cluster system can be a solution where onsite systems are not technically variable, while sewers are too expensive, not available, or not desired due to unfavorable impacts.

Some people view cluster systems as a threat as they may enable development of previously unbuildable land. Cluster systems are an opportunity for improved land use planning, moreover, they can enable development to occur in a more environmentally and economically favorable manner (e.g. they can open up land that was considered unbildable or allow higher densities). However such growth stimulation could be a significant issue for some communities. Examples of cluster system application are presented in Chapter 6.

4.2 Planning process for cluster approach

The initial phase of cluster system planning depends on whether the system is being developed for an existing community, a parcel development, or a defined wastewater need, etc. (Figure 10). Management plans for such systems begin with the development of a community profile based on the socioeconomic, demographic, water resources, soils, geologic, political, and other data (Lombardo, 2004). Existing land-use plans should be considered, as well as compatibility of wastewater planning. Such integrative planning approach has been described in Chapter 3.

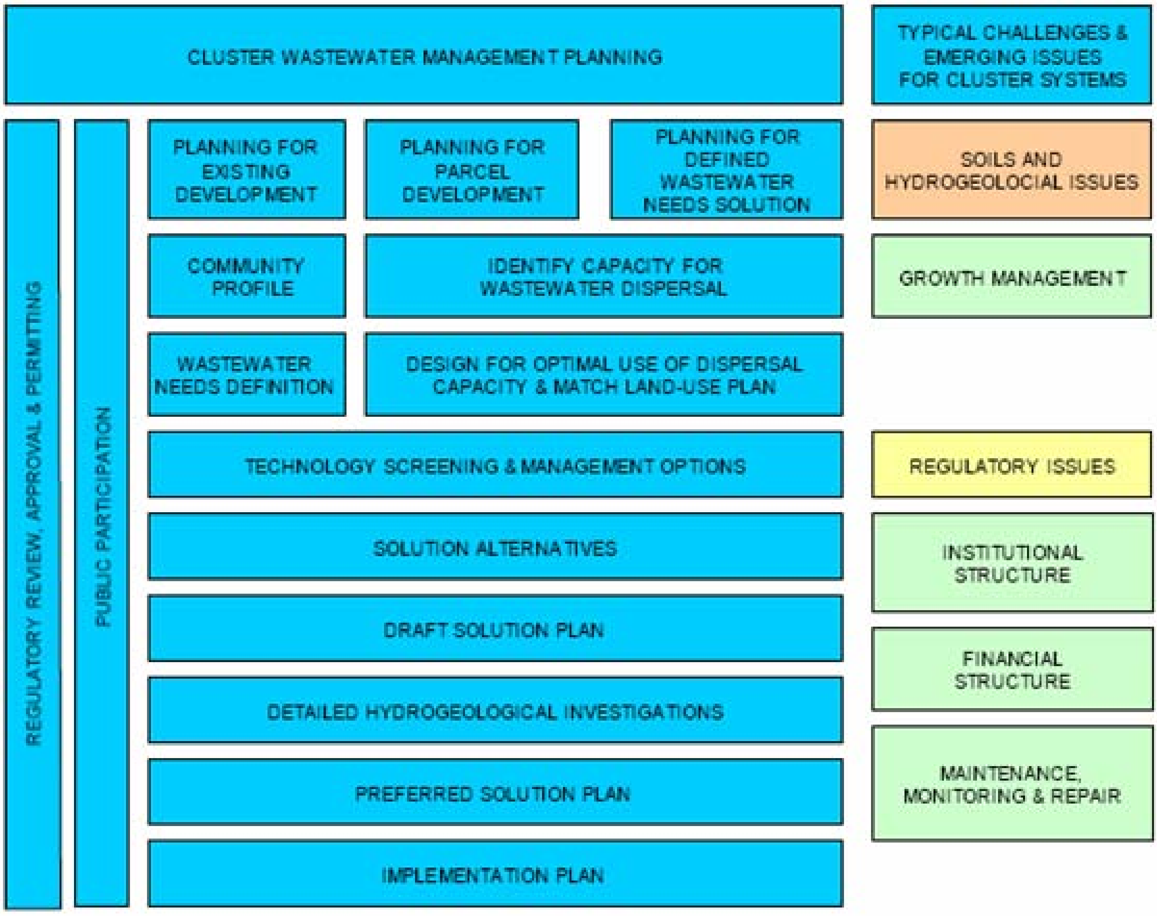


Figure 10: Cluster wastewater systems planning process (Lombardo, 2004).

Many land-use plans are developed when only onsite and centralized sewer options are viable, however, revising plans might be appropriate to allow cluster wastewater systems. Assessment

of wastewater needs involves a detailed lot-by-lot analysis. This process identifies properties that require off-site solutions, which means minimum areas requiring sewers (Lombardo, 2004).
In the new parcel development the initial planning step consists of determining wastewater dispersal or disposal capacity and designing the parcel development to optimize dispersal capacity. In case of planning for defined wastewater needs, finding a solution involves additionally considering water reuse and expansion of the area of concern. Moreover, at all stages of planning, as well as during implementation, the participation of public is needed, as communities and private entities must develop and maintain public awareness of wastewater issues and planning efforts in order to sustain support for the necessary wastewater solutions.
Additionally, consideration of regulatory issues is critical throughout the planning process. In addition to health department and environmental regulatory agency requirement, the location and the size of a cluster system may require compliance with other regulations (e.g. associated with wetland buffers, near historical sites, or protected areas). What is more, systems may require preparation of environmental assessment reports. Regulatory requirements for cluster systems (especially for public health protection) may limit the location and option for dispersal. In some places cluster systems can be used to correct existing wastewater needs.

There are public, private and combined options for wastewater management. Traditionally, onsite and cluster systems have been managed privately, with some general public oversight. The lack of management of cluster wastewater systems was a major cause of their performance difficulties in the past (Lombardo, 2004). Consequently, nowadays, long term operation and maintenance programs are required.

Historic development practices, unplanned growth, and changing usage patterns for existing development all make it difficult and costly to resolve wastewater management problems and define wastewater needs. Moreover, the implications, of existing land-use plans for wastewater planning, need to be considered. Planning for parcel development tends to be more straightforward than planning for communities since development patterns can be better optimized to the physical constrains and capabilities of the land. Planning for large areas and new communities presents an opportunity to develop a comprehensive wastewater management plan that matches the physical capacity of the land and water ecosystem with the planned development patterns of the community.

When a community faces wastewater problems, a successful outcome is often more dependent on the process the community follows to address the issue than it is on the wastewater treatment technologies available to them. Involvement of the community in the early decision-making process leads to the best solution and encourages responsibility.

Communities that succeeded in finding technically effective, economical and socially acceptable solution have understood their current situation before they started looking for solutions, realized that only they can make the best decision for their community, and took responsibility for the problem (Lombardo, 2004). Moreover, they had strong leadership from within, clearly defined mission and goals, took time and energy to examine all options before taking action, kept all affected parties involved and informed, identified and used set of criteria (Lombardo, 2004). Moreover, steering committee representing diverse interests must work with the entire community. The process usually takes from three to seven years. This process stimulates to learn, understand differences, negotiate compromises and come to a conclusion that everyone can live with. Once the community understands its situation and resources, it must examine options for treatment, legal structure and financing available to them, work with professionals to find solution that best fit the community's needs.

Many small communities begin to address their sewage treatment needs by thinking that all they need to do is to find 'recommended' treatment option and install it. However, numerous treatment technologies are available, and each has its advantages and limitations. There is no recommended technology that meets the specific conditions and treatment objectives of every community.

4.3 Advantages and challenges

There is a great scope of advantages in cluster wastewater management both for small and bigger communities. However, among advantages, challenges have to be faced.

Advantages

Some of the advantages of cluster system application include cost, maintenance, flexibility in land use and environmental protection. Cluster systems concentrate flows through small pipes, lift station or treatment plant, implying less environmental damage from a mishap. Any bypasses, leaks and overflows remain small, decreasing environmental impact. Carrying only liquid effluent to dispersed treatment centers, the collection system consists of shorter runs of smaller pipes containing fewer openings, providing less opportunity for infiltration, exfiltration or overflows (Gross and Dietzmann, 2003). Installation of cluster systems causes less environmental disturbance, as e.g. smaller collection system pipes are installed at shallow depths and are more flexibly routed. The environmental disturbance can be minimized over the long run, because lines do not need to be upgraded. Additionally, expansion can be accomplished by adding new treatment centers rather than by routing more flow to existing centers. Generators can be required to implement treatment methods specific to wastewater characteristics and beneficial reuse opportunities, as domestic wastes are separated from industrial stream, which makes treatment less complex.

A major advantage of cluster systems is the cost savings, as no large interceptor mains and few if any lift stations are needed. As the infrastructure costs are reduced, resources can be redirected to appropriate treatment and beneficial reuse opportunities. Moreover, reuse of water can deliver additional financial benefits, both to individual users and community. In addition costs of maintenance can be lower, as little or no infiltration and inflow would enter effluent sewer systems, decreasing collection maintenance costs and peaking loads on plants (Gross and Dietzmann, 2003). Reuse of water can become more cost-efficient as the effluent would be available near to points of use, decreasing the costs of reclaimed water distribution system. Landscape irrigation, toilet flush supply or cooling tower makeup can be served with reclaimed water. Reduced wastewater flows resulting from water conservation measures would not cause clogging problems in the collection system. Additionally, cluster approach would be easier to plan, with management needs considered directly and implemented independently. Such system can be designed and installed in a growth-neutral manner, responding to development only as it occurs.

Another advantage of cluster systems is the increase in water customers. As developers build in rural and suburban areas, they can take advantage of the opportunity to increase lot density not afforded by using individual on-site systems (Gross and Dietzmann, 2003). More lots and homes lead to more water customers for the rural water system. Moreover, cluster approach helps to protect district’s territory. Eliminating the source of contamination is one way to protect groundwater or surface water quality, as poor source water quality means more extensive and more expensive treatment. By providing high quality, reliable and properly managed cluster system, the source of contamination of the water supply is eliminated. In addition to this, as water district have already a customer base for providing safe drinking water, and customers are already living in the district, providing additional service – cluster wastewater treatment, the rural water district can generate additional revenue stream (Gross and Dietzmann, 2003).

Challenges

There are a number of challenges and issues emerging for planning and implementation of cluster systems. Some of these include soil and hydrogeological issues, growth management and land use planning, public participation, regulatory issues or indirect water reuse and nutrient impact, etc. The goal is to understand these and consider technology for addressing them in a positive, practical and beneficial manner. The failure to gain acceptance as effective and permanent facilities is due primary to shortcomings in management programs. Regulating and managing such systems is a part of environmental pollution control issues (USEPA, 1979). In 1990's the focus on the development of adequate monitoring and comprehensive management systems started to dominate, and basing on that, in 1997, US EPA stated that *adequately managed decentralized wastewater systems are a cost-effective and long term option for meeting public health and water quality goals, particularly in less densely populated areas*. Management programs are imperative and enable communities to control the effectiveness of wastewater treatment and help ensure public health, improve water quality, and sustain the environment (Knowles, 1999). What is more, management plan must be based on the local culture and philosophy. For an older established community, moving in the areas of environmental sensitivity makes sense when people come to understand that they are at risk.

There are five major barriers found by US EPA that continue to inhibit the full utilization of cluster systems (US EPA, 1997), and these include:

- Lack of knowledge of benefits and potential uses of cluster systems
- Legislative and regulatory constraints which inhibit optimum use of these systems
- Lack of management programs that can optimize the performance of technologies
- Liability and engineering fees that discourage consideration of these alternatives
- Financial barriers that inhibit the application of cluster systems

To overcome these barriers requires significant effort on the part of regional and local regulatory authorities and the management entities developed to support them. Some actions to address these issues are essential, including improvement in knowledge of technical practitioners; improvement in regulatory programs based on the system performance; and development of effective management programs to ensure that performance requirements are met (Hudson et al., 2004). At present, the technology and tools allow to manage and maintain any cluster-designed wastewater systems.

4.4 Management

Water resources face competing demands from uses to support human health, economic development, and environmental services. Water is the perfect example of a sustainable development challenge – encompassing environmental, social and economic dimensions. Reconciling these three aspects through appropriate water/wastewater management is a significant policy challenge for governments (OECD, 2003). While water/wastewater management practices need to be tailored to suit local circumstances – the competing demands for water, etc., appropriate management is necessary. Poor water management will be one of the major factors limiting sustainable development during the next few decades (Hunt, 2004).

As mentioned in Chapter 2, cluster wastewater management system consists of: management of wastewater at source, collection and treatment systems, ecosystem re-entry, and reuse systems. Appropriate operation and maintenance of the system has to be provided in order to ensure the proper functioning of the system. Cluster management must assure that appropriate technologies are implemented on each site and that they are properly operated and maintained. Functions of cluster management have to include planning, site evaluation, system design, installation supervision, operation and maintenance, system inspection, financing, water quality monitoring, public education, and program coordination. All these activities must occur to properly manage cluster system in order to avoid water quality degradation as well as to maximize the cost efficiency of the system.

What is more, cluster wastewater system management requirements can be minimal, such as for small cluster systems, or complex, for cluster systems serving many customers with a large collection system. There must be someone responsible for ownership, monitoring, operation, maintenance, and finances of wastewater treatment systems (Lombardo 2004). A responsible management entity providing technical skills, legal authority and administrative capabilities is necessary.

The functions of the cluster wastewater system management include (Lombardo 2004):

Ownership describes entity that has legal responsibility, liability, and authority regarding all aspects of cluster wastewater system, and falls into three categories: public, private for profit, and private non-profit. Usually clusters have been owned and managed privately with public oversight, however today, they have been successfully implemented using other innovative ownership structures (Table 4).

Table 4. Cluster ownership option matrix (Lombardo 2004).

Ownership Institution	Infrastructure	Centralized	Cluster	Onsite
Public	Health Department Department of Public Works Independent public entity	Traditional	**Innovative**	**Innovative**
Combination Public/Private	Combinations	**Innovative**	**Innovative**	**Innovative**
Private	Private individuals Special purpose entities For-profit corporation Non-profit corporation	**Innovative**	**Innovative**	Traditional

The cluster systems can be managed by local authority or by a corporate entity. The management regimes for cluster servicing are well established and may be administered by local authority or regional authority, council controlled organization or private servicing company. In case of a small subdivision in a rural area, sometimes a sewage package plant is an acceptable solution to the local authority. This requires legal agreement between the benefiting parties to provide for maintenance and management.

Administrative functions include: ownership management, program management and capital improvements, use regulation, regulatory compliance reporting, customer service, billing, and collection, user-charge system, and financial function.

Ownership management can consist of oversight of the activities of others to whom all activities have been outsourced, the performance of all activities by the owner's manager directly, or a variety of combinations. At a minimum, it maintains records on the cluster system and submits required compliance performance reports to regulatory agencies, and educated system users.

Program management for capital improvements. There is a need for management of the proposed system's capital facilities implementation, during cluster system creation and during major expenditures.

Use regulation. All cluster wastewater systems are regulated regarding authorized use, and adoption of special regulations on prohibited use and practices may be necessary (e.g. disinfecting chemicals and floor cleaning products toxic to wastewater treatment systems leading to malfunction, as the lower flow in cluster systems does not provide dilution that would mitigate the toxic effects). Additionally, pretreatment requirements may be needed to protect wastewater collection and treatment systems.

Regulatory compliance reporting requirements increase. As cluster systems increase in size and proximity to environmentally sensitive areas, owners must provide for gathering and transmission of the required regulatory compliance reporting information.

Customer service, billing and collections. The issues range from responding to odor complaints to change of use, including service termination and the addition of new service connections. Billing and collection, as well as enforcement actions for non-payment of fees are managed by responsible management entity.

User charge system. The primary cost categories for user-charges associated with cluster wastewater systems are capital costs (total installation costs, including engineering (design and construction management), land, financing and capital improvement program, administration and construction costs), administration, operation and maintenance (annual cost of operation and maintaining the system, e.g. electricity costs, labor, chemicals, etc.), repair funds (to pay for small equipment, repair or replacement when fails or on a regular basis to avoid damaging impacts), and replacement-depreciation funds (funding of future replacement of major capital equipment).

Financial issues include budgeting, accounts payable and accounts receivable, and capital resources procurement. The owner needs to establish a budget to determine user-charges, for revenue and expenses. It may involve both government financing options (grants and loans), and local options (including community-wide charges like taxes, user-charges and connection fees). An innovating means of community-wide financing is the use of a specialty tax (e.g. the town which hosts many tourists could dedicate a portion of its room tax to wastewater fund).

Affordability guidelines. In 1995, US EPA has developed guidelines to assess the affordability of wastewater fees, based on indicators like median household income, unemployment etc. For low income families and the elderly, grants are available in the USA (US EPA 1995).

Operation management includes monitoring, maintenance and repair activities for cluster systems, and these are dependant on the system capacity (Table 5). Maintenance and repair activities are influenced by the equipment and monitoring requirements are dictated by permits.

When the systems, that has not been maintained properly, fails, the homeowner or community has to cover the costs to replace it. Additionally, some hidden costs may arise including costs of contaminated surface and groundwater, overall water quality degradation, which may lead to reduced property values. In some cases it may appear that there is no place to put another new system, e.g. in case of lakeshore properties and small communities that were platted in the 1970s or earlier (Lombardo 2004).

Table 5. Typical responsibilities for cluster systems (Lombardo 2004).

<table>
<tr><th>Activity</th><th>Onsite systems</th><th>Small systems <2,000gpd</th><th>Medium systems 2,000-10,000gpd</th><th>Large systems 10,000-50,000gpd</th><th>Very large systems >50,000gpd</th><th>Centralized systems</th></tr>
<tr><td>Maintenance</td><td colspan="2">Periodic residuals removal</td><td>Treatment, collection system</td><td>Treatment, collection, dispersal system</td><td colspan="2">On-going treatment, collection, dispersal system</td></tr>
<tr><td rowspan="2">Monitoring</td><td colspan="2">Periodic inspections</td><td colspan="2">Regular inspections, sampling; on call personnel</td><td colspan="2" rowspan="2">Regular inspections, sampling; full-time personnel, SCADA system</td></tr>
<tr><td></td><td>Remote monitoring systems</td><td>Remote monitoring systems</td><td>SCADA system</td></tr>
<tr><td rowspan="2">Repair</td><td colspan="3">Components repair as needed</td><td colspan="3">Preventative repair and replacement program</td></tr>
<tr><td colspan="2"></td><td colspan="2">On-call personnel</td><td colspan="2">Full-time personnel, redundant systems</td></tr>
<tr><td rowspan="2">Administration</td><td colspan="2" rowspan="2">Varies by degree of oversight (education, permit applications, inspections, etc.)
System use regulation</td><td colspan="4">Discharge permit, compliance reporting
System use regulation</td></tr>
<tr><td></td><td>Main customer service</td><td colspan="2">Full customer service</td></tr>
</table>

Another important question to be answered by community is: what is the capacity of individual households or community to manage a wastewater system in the long term. This will show if there is a need to manage the system by an external agency (e.g. local council) or whether it will stay within local responsibility.

Nowadays, all wastewater must be delivered to an effective treatment facility, and all treatment facilities must be well managed.

5. Components of cluster systems

At present, there is a variety of innovative technologies and systems that have entered the market for wastewater collection, treatment, disposal, and reuse that can be used within cluster approach to wastewater management. Thus, more options are available for advanced wastewater management. However, there is still a need for technology improvements, e.g. the nutrient removal requirements in environmentally sensitive areas remain the most challenging technical issue (Lombardo 2004). Innovative technologies for small flow system can avoid extensive collection infrastructure and can lead to significant cost savings.

An overview of wastewater management technologies available for collection, treatment, dispersal, and reuse (Figure 11) for cluster system applications is presented in this Chapter.

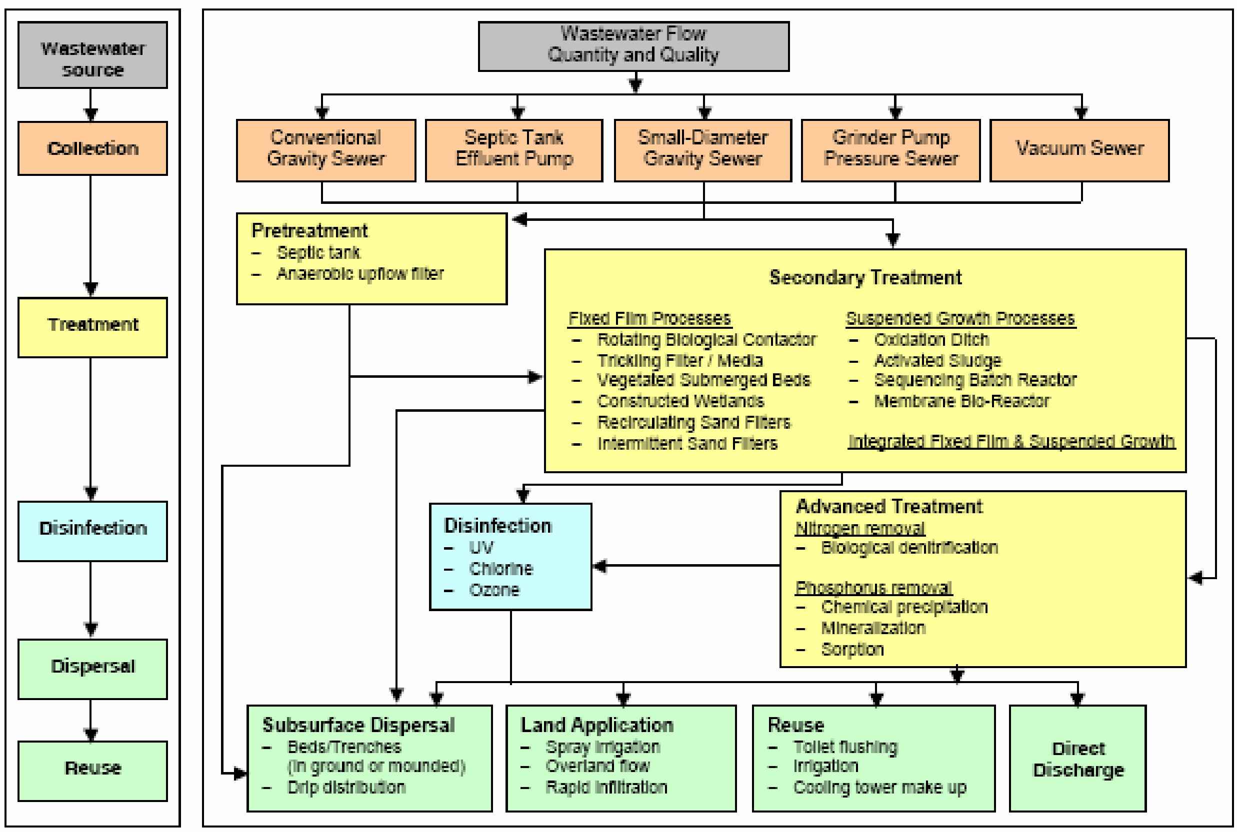


Figure 11: Overview of technologies suitable for cluster wastewater systems (Lombardo 2004).

Each alternative technology has to be evaluated for a given site in terms of its appropriateness in solving the problem (including overall life cycle cost with both construction and long-term maintenance), as well as its environmental impact. Additional factors to consider include housing density, road frontage, the size of the project and the volume of the wastewater to be collected, topography and sensitive natural resources, depth of groundwater and bedrock, as well as distance to the cluster treatment and dispersal site (Lombardo 2004).

5.1 Collection

Collection systems are used to collect and transfer wastewater to treatment unit from one or more discharge locations (Joubert et al. 2004), moreover, they represent the major portion of the total capital cost associated with cluster wastewater management (up to 70%). Selection of appropriate sewer system will depend on the unique properties and the characteristics of the community to be served.

In situation where wastewater treatment is off-site, the effluent generated has to be collected and transported by pipeline or network of pipelines (sewers) to the cluster treatment plant (Ferguson et al. 2003). Energy to transport the wastewater may be by gravity, pumping, or combination of both, depending on topography, layout and economics. In systems involving some on-site pretreatment (septic tank or grinder pump), reticulation is often done by pumped small-bore pressurized pipeline systems; while other options include vacuum collection and transport systems. The collection systems for cluster approach include (Lombardo 2004):

- Conventional gravity sewers
- Modified conventional sewerage (MCS)
- Septic tank effluent gravity (STEG) system (or small-diameter gravity sewers)
- Septic tank effluent pump (STEP) pressure system
- Grinder pump pressure sewer system
- Vacuum systems

5.1.1 Sewer collection systems

5.1.1.1 Conventional gravity sewer

Conventional gravity sewer or conventional sewerage (CS) is a network of large diameter pipes that use gravity flow (Figure 12). The idea is based on the downhill flow of water (Angelakis and Spyridakis, 1996), and building sewers are connected directly without any pretreatment. In such system, household on-property sewer lines (100mm diameter) connect to street sewer lines (minimum 150mm diameter), which are reticulated in straight lines between manholes (access ports) that provide access at all changes in direction.

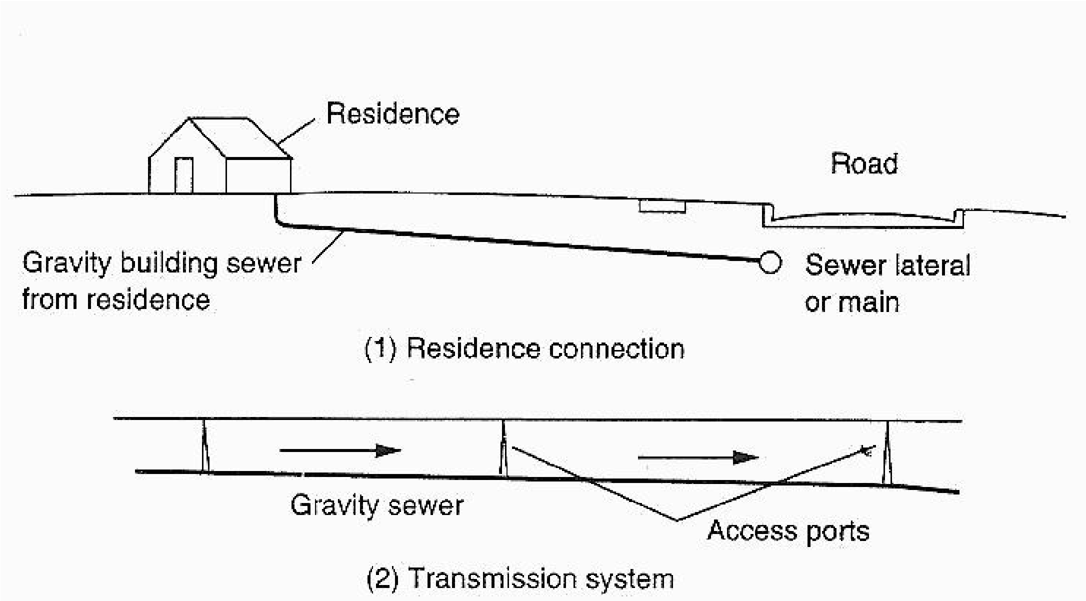


Figure 12: Conventional gravity sewer (Crites and Tchobanoglous 1998).

Manholes are used at all street reticulation connections to main collecting sewers, and where trunk connections are made (Ferguson et al. 2003). Access port spacing varies from 90 to 150m, depending on available sewer cleaning equipment and maintenance method (Crites and Tchobanoglous 1998). Manholes are a point of weakness in reticulation systems, as the connection often cracks due to ground settlement and traffic impact, with groundwater infiltration entering the sewer lines, diluting the wastewater flow and diminishing treatment process performance (Ferguson et al. 2003). Moreover, groundwater diversion lowers water tables and can seriously impair stream habitat and water quality. Additionally, excavation costs are high because of the size of the lines, the great depth needed to maintain gravity flow, and pump stations at intervals to pump up to a higher point.

5.1.1.2 Modified conventional sewerage (MCS)

MCS´s are suitable for smaller communities converting from on-site to cluster approach. Numbers on manholes can be reduced through the use of rodding inlets, and pipeline gradients (Ferguson et al. 2003); alignments can better fit the topography, which decreases construction costs; minimum line diameters can be reduced from 150 to 100mm, depending on the number of connection; self-cleansing gradients can be reduced due to the smoother pipe material, producing construction economies; moreover, infiltration is reduced, decreasing hydraulic impact on the treatment plant processes (Lombardo, 2004). In addition to this, gravity sewer can bypass properties in low-lying areas, which are then connected to the sewer through a grinder pump unit and on-property rising main (Cities and Tchobanoglous, 1998).

5.1.1.3 Grinder pump pressure collection

Pressure sewerage provides full-off site transfer of all household wastewater by injection of grinder-pumped wastewater flows into pressurized reticulation network (Ferguson at al. 2004). Instead of septic tank, discharge pump is located in a small pump basin and equipped with chopper blades that cut up the solids in the wastewater so they can be transported under pressure in a small diameter pipeline to a treatment facility (Figure 13) (Crites and Tchobanoglous, 1998). As a result, higher solids, oil and grease concentrations are encountered.

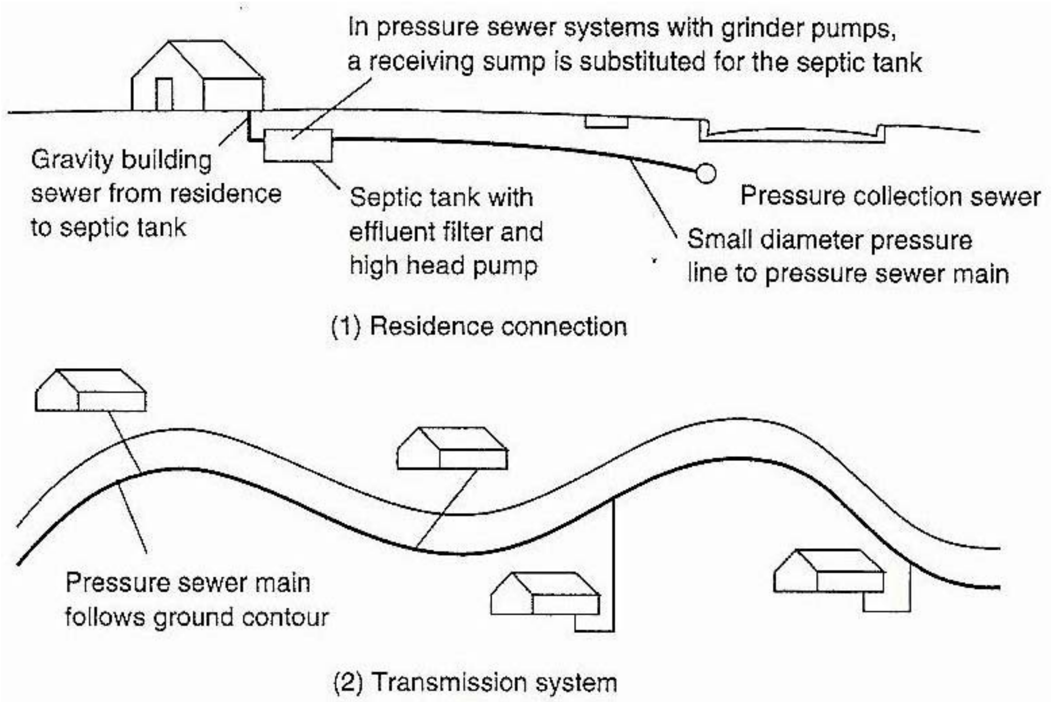


Figure 13: Grinder pump pressure collection system (Crites and Tchobanoglous, 1998).

The system can follow the natural ground profile at a shallow depth, including undulating and steep terrain, and can be directed around or over topographical obstacles, which eliminates the need for deep excavation. Effluent is anaerobic (no air surface is present) and special venting controls are required at the treatment plant discharge point (Crites and Tchobanoglous, 1998). Grinding solids tends to wear out components, so maintenance needs are higher than effluent pumps. Large prefabricated treatment units, often use this method rather than separating solids with a septic tank at each site. Where large flows include high-strength commercial waste, blending wastewater flows from various sources can keep overall waste strength low, which improves treatment efficiency. As solids are not retained in a septic tank, treatment units will generate relatively large amounts of sludge, which must be separated, dewatered, and disposed of regularly (Joubert et al., 2004).

5.1.1.4 Septic tank effluent gravity and pressure collection

Septic tank effluent gravity (STEG) (called Gravity Effluent Drainage System (GEDS) in New Zealand) tanks trap and retain solids at the point of discharge and transfer by gravity flow relatively clear effluent to the next treatment stage (Figure 14). Septic tank effluent pump (STEP) tanks (called Pumped Effluent Drainage System (PEDS) in New Zealand) perform the same, however, they pump the effluent, due to different elevation. Both of these methods can move only relatively clear effluent, and keep solids in tanks for additional decomposition and processing.

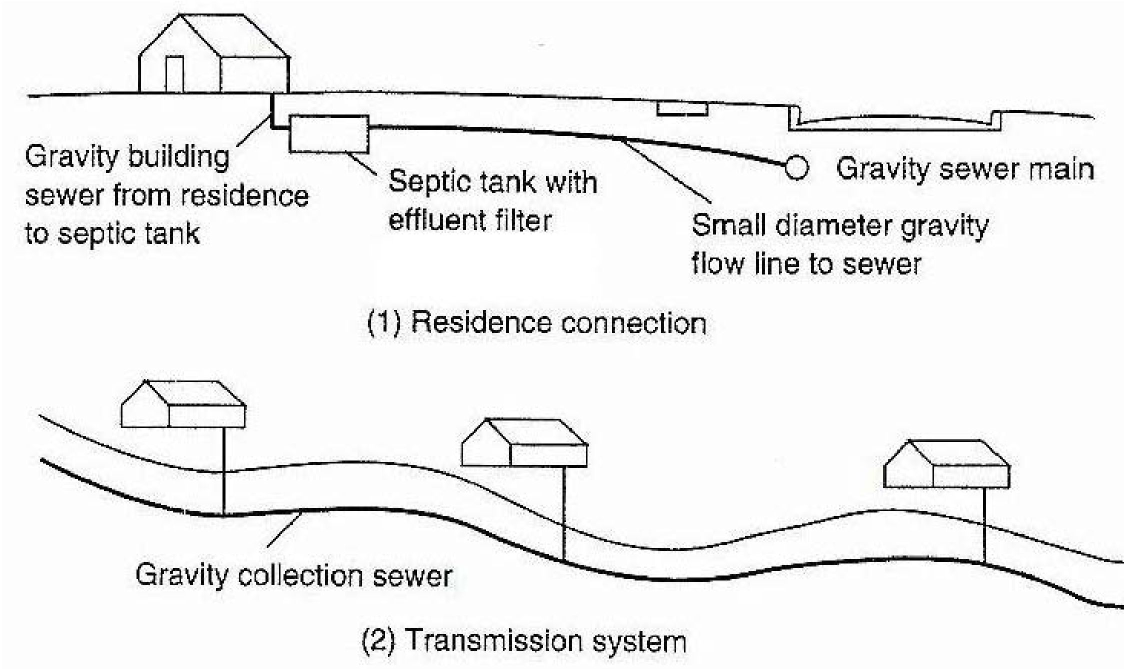


Figure 14: Septic tank effluent gravity system (Crites and Tchobanoglous 1998)

Septic tank effluent systems offer significant economies in reticulation and overall scheme costs, particularly in retrofitting sewer lines into unsewered smaller communities in difficult topography. Moreover, pumps reduce maintenance needs, while on-lot solid decomposition decreases amount of organic matter be processed at the wastewater treatment unit. With small cluster systems, segregating flows using individual tanks provides better control in pre-treating waste and solids removal, often at a lower energy cost (Lombardo et al., 2004).

In STEG systems, a small-diameter (25-50mm) plastic pipe is used to convey the effluent from the septic tank, equipped wit an effluent filter to a small-diameter collection system (Figure 14) (Ferguson et al. 2004). As there are no solids to settle in the collection system, it can be laid below the ground surface (e.g. 0.9m). Many systems are designed as a combination of STEG and STEP to take advantage of the topography.

In the modern STEP systems, a high-head turbine pump is used to pump screened septic tank effluent into a pressurized collection system (Figure 14). The size of the discharge line from septic tank effluent to a pressurized collection system is 25-38mm, and the minimum plastic pipe size for the pressurized collection main is a 50mm-diameter. STEP sewers are usually placed below the frost penetration depth, and they can follow the terrain due to applied pressure. Because of the shallow burial depth, construction problems resulting from high groundwater and rocky soil can be avoided (Crites and Tchobanoglous 1998).

The components of septic tank effluent systems include (Ferguson et al. 2004):

- Retention of existing (or provision of new) septic tanks on each lot;
- Low-diameter modified sewer lines (75mm) for collection of septic tank effluent; special odour-venting controls on the lines; and pump units designed for septic effluent handling;
- A modified cluster wastewater treatment plant designed to handle inflow of septic effluent, of reduced size to the input of partially treated wastewater (the primary effluent from the septic tanks)
- A centralized operation and management system that oversees septic tank maintenance, treatment plant and final effluent land disposal.

There are several schemes, operating in New Zealand, efficient in initial construction costs when sewering existing communities with on-site effluent management problems (Ferguson et al., 2003). These systems, and the scaled-down cluster treatment plant comprise the publicly funded scheme, which benefits property owners with newer septic tanks, and disadvantages those with older once. However, where the condition of existing septic tanks in a community requires substantial upgrade or renewal, the MCS are a feasible option.

Depending on the flow, more than one dwelling could be connected to the same STEG or STEP, and these tanks can flow to a variety of treatment options, ranging from conventional to advanced technologies. These collection systems commonly used with cluster systems, save space, and are a cost-effective means to move wastewater from one point on the landscape to another. What is more, cluster systems served by STEP or STEG collection systems tend to become more cost-effective than individual systems where flows range from 22,700 to 68,100 liters per day (University of Minnesota Extension Service, 1998).

5.1.1.5 Modified effluent drainage servicing (MEDS)

This is a small-bore version of effluent drainage servicing EDS for carrying filtered septic tank effluent from each property to cluster treatment. It is based on variable grade sewer (VGS) technology (Ferguson et al. 2004). Each on-lot septic tank has a large-capacity single chamber, and is fitted with an effluent outlet filter. The solids control enables 30mm on-property collection lines to pick up the septic tank effluent and transfer it to 50mm sewer lines, which increases to 75mm as more properties connected. The lines can be installed by continuous-shallow-trenching machines at constant depth and following the natural lie of the land, reducing construction costs. Special design is necessary to deal with odour control, pump-station and sewer line maintenance. Sewer lines can flow up-hill, as long as properties connected in the vicinity of uphill sections are elevated above the hydraulic grade line (HGL). If properties are below that line, the effluent pump can be installed.

The MEDS approach can benefit existing communities as well as new developments. It eliminates infiltration by providing totally sealed system from the on-property improved septic tanks to the treatment plant. In addition to this, in 1995 a survey of City and District Councils was carried out in New Zealand to obtain information on alternative sewerage schemes (Ferguson et al. 2004). That survey resulted in identifying 14 operating schemes with three collection alternatives: Effluent Drainage Servicing (EDS), where septic tank effluent is reticulated via 75mm sewer lines off-site treatment and disposal; Modified EDS (MEDS), where 50mm variable-gradient sewer lines were used; and Pumped EDS (PEDS), where everything is pumped into a pressurized reticulation system.

In cases where local councils managed the total system, maintenance problems did not occur (Ferguson et al. 2003). Treatment of the reticulated septic tank effluent was best achieved by oxidation ponds and wetlands. These could be purpose-built as a cluster treatment plant, or the effluent could be transferred to an existing community treatment plant. Mechanical aeration plants based on the activated sludge principle were not satisfactory, due to lower organic strength of septic tank effluent resulted in operating problems and poor maintenance. Overall, scheme costs showed variable savings relative to conventional sewerage schemes, with PEDS system showing greater savings (35-40%) compared to EDS (12-40%) (Ferguson et al., 2003). However, costs were site-specific, with alternative sewerage offering advantages in locations with difficult topography and soil (e.g. rock) conditions.

5.1.1.6 Vacuum sewers

A central vacuum source is used to maintain a 380-500mm vacuum of mercury on small-diameter collection mains to transport the wastewater from individual homes to a central location (Figure 15) (Crites and Tchobanoglous 1998). Infiltration is not an issue, as the collection main is watertight.

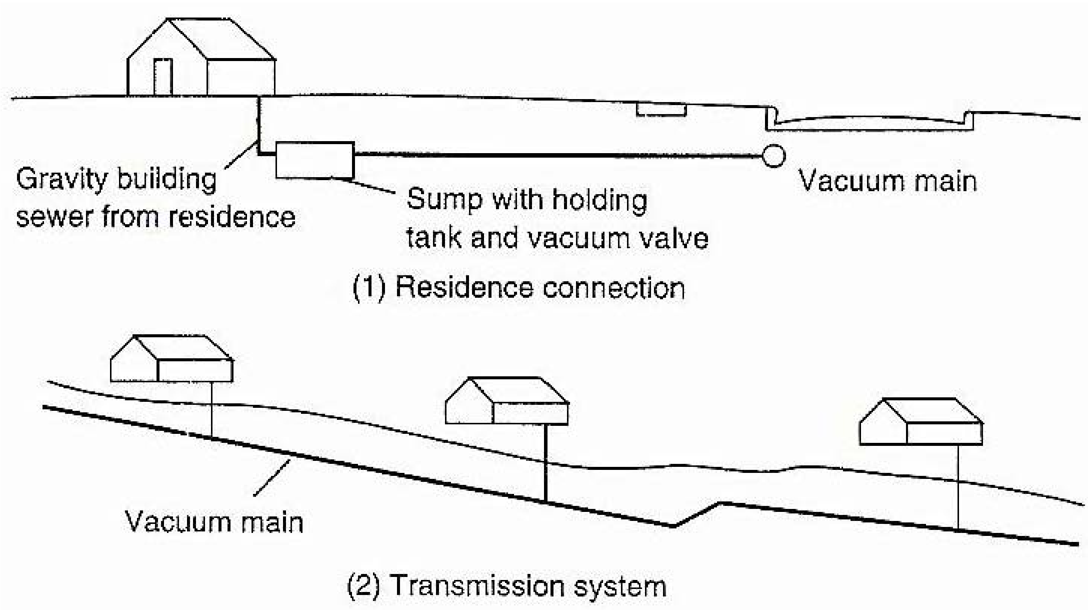


Figure 15: Vacuum sewer system (Crites and Tchobanoglous 1998)

These systems can operate in conjunction with vacuum toilets (with very low flush), or normal low-flush toilets, as well can pick up all other household wastewater flows for vacuum conveyance. They are most suited to flat topography, and are very useful in high water table locations e.g. around lake edges or coastal strips. Vacuum lines have to be provided with regular low points to facilitate plug flow between dwelling vacuum holding tanks and central collecting tanks. Because flow is continuously mixed with air, it does not remain anaerobic.

5.1.2. Conventional sewers versus alternative sewerage

The main problem with conventional sewer systems is the level of occurring infiltration due to groundwater and surface water flows leaking into the sewer system during wet weather. It is almost impossible to eliminate, as manholes used for maintenance create points of potential leakage in the sewerage system unless the lids are sealed or bolted to the frame. On the other hand, many of the alternative collection systems enable fully sealed pipes with secure access and inspection points to be constructed, so as to eliminate infiltration (Crites and Tchobanoglous 1998).

The alternative systems have a number of common features, such as the use of lightweight pipe buried at shallow depths. All have suffered from misuse and misapplication in early installations, as have most developed technologies. A comparison of different alternative sewer types and combinations is presented in Table 6 (Crites and Tchobanoglous 1998).

Table 6: Characteristic of alternative sewer systems (Crites and Tchobanoglous 1998)

Sewer type or combination	**Ideal topography**	**Construction cost in rocky, high groundwater sites**	**Sulfide potential**	**Minimum slope or velocity required**
Conventional gravity	Downhill	High	Moderate	Yes
STEP	Uphill, undulating	Low	High	No
STEG	Downhill	Moderate	High	No
Grinder pump	Uphill	Low	Moderate-high	Yes
Vacuum	Flat	Low	Low	Yes
STEP-STEG	Undulating	Low-moderate	High	No
Conventional-GP	Undulating	Moderate-high	Moderate	Yes
Conventional-vacuum	Undulating	Moderate-high	Low-moderate	Yes

Basing on the Crites and Tchobanoglous (1998), the highest cost for conventional gravity sewers is where undulating terrain, high groundwater, or rocky conditions exist. While the use of STEP, STEG, or a combination of the two, can be cost effective. Vacuum sewers are suited to flat terrain, such as around lake, or in marinas and harbors. Where the population density is low, but growth is expected, there should be a consideration for system operation compared to ultimate flow rates. STEP and STEG, due to their relative freedom from minimum velocity requirements, can handle a wide divergence between initial and ultimate design populations. Additionally, STEP systems can alternate doses into the collection system when the system approaches capacity. Grinder pump require minimum scouring velocities to be reached daily, therefore, a low ratio of initial-to-final design population requires special facilities for flushing the mains.

The treatment of wastewater in cluster treatment plant is undertaken due to economics, decisions on wastewater reuse locally, and to avoid centralized treatment system. As communities grow and expand the distances from new development to existing wastewater treatment plant do not make the connections cost effective. Instead, alternative collection can be used to allow for local reuse of treated wastewater, as in small residential development Stonehurst in California, the combination of STEP and STEG system was implemented (Crites et al., 1997).

5.2 Treatment

Treatment processes aim to remove contaminants from the water used to transport the wastes, and produce treated water and sludge. Moreover, the goal is to reduce the amount of water in the remaining sludge/biosolids to landfill or reuse them more easily. Different stages of treatment can be used to reduce the content of pollutant (Table 7) however options are dependant on the kind of pollutants in the waste, people's values, or the ability of receiving environment to absorb the waste (Ferguson et al. 2004).

Table 7: Stages of wastewater treatment (Ferguson et al., 2003)

Treatment stage	**Waste constituents treated***				**Remaining Waste**
	Organic material (BOD)	**Suspended solids (organic)**	**Bacteria and viruses**	**Salts: nitrates and phosphates**	
Primary (setting)	Up to 35% captured	Up to 65% captured		Not removed	'Raw' sludge and primary effluent
Secondary (aerobic bacteria growths)	Can be reduced to $20g/m^3$	Can be reduced t $30g/m^3$	Some removed	Not removed	Biological sludge; secondary effluent with some salts, metals and bacteria, etc.
Tertiary (various techniques)	Can be reduced to $15g/m^3$**	Can be reduced to $10g/m^3$**	Can be disinfected to remove	Can be treated to reduced salts	Tertiary effluent and solid residues with metals, etc.
Land (septic tanks and soil soakage)	Will reduce total amounts of organic material, salts, bacteria and viruses – levels depending on system design				Remaining scum and sludge (septage) with metals, etc.
Treatment of sludge	Takes primary and secondary treatment sludges and uses anaerobic digestion to convert them to 'humus solids', known as biosolids, plus methane gas				Methane gas; biosolids with metals, etc.
Treatment to produce reclaimed water	Further treatment for non-potable purposes				

* other waste constituents that are not removed by standard treatment processes will need to be assessed to determine whether there is a tertiary technique(s) that can be used to treat them. If there is no applicable process available, the method of ecosystem re-entry used will have to address the environmental risks associated with those substances not managed through the treatment technologies
** sometimes better tertiary quality than this can be achieved

Each stage removes only certain kinds and levels of pollutants. Sludge from primary treatment is smelly, grey-black, semi-solid and contains high concentrations of bacteria and other microorganisms, as well as large amounts of biodegradable material, which means that dissolved oxygen in the water will be used very quickly. Secondary treatment produces secondary sludge made up of micro-organisms that have eaten the original wastes. It contains high levels of disease-causing pathogens, as well as material that will decay and cause odour.

5.2.1 Types of treatment systems

Advanced treatment systems can be sized to treat wastewater from clusters of two homes or an entire neighborhood, while using soil-based leaching systems for final treatment and dispersal. These advanced systems can achieve high levels of treatment and recycle effluent to the same watersheds, therefore replenishing groundwater supplies, and maintaining stream flows. Treatment options for cluster systems are presented in Table 8.

Table 8: Wastewater treatment technology options for cluster systems vs. design flows (Lombardo 2004).

Pretreatment needed	Technology*	Design Flows (Litres/day)			
		<7,500	7,500-37,500	37,500-75,000	75,000-190,000*
Pretreatment					
	Septic Tank**	٧	٧	٧	٧
٧	Anaerobic upflow filter	٧	٧	٧	٧
Secondary treatment					
Fixed film growth					
	Rotating biological contractor		٧	٧	٧
	Trickling filter***	٧	٧	٧	٧
٧	Subsurface wetlands – vegetated submerged beds	٧	٧	٧	٧
٧	Constructed wetlands			٧	٧
٧	Recirculating media filters	٧	٧	٧	٧
٧	Intermittent media filters	٧	٧	٧	
Suspended film growth					
	Oxidation ditch				٧
	Activated sludge systems	٧	٧	٧	٧
	Sequencing batch reactor	٧	٧	٧	٧
	Membrane bioreactor			٧	٧
	Integrated fixed film – suspended growth	٧	٧	٧	٧
Advanced treatment					
٧	Nitrogen removal	٧	٧	٧	٧
٧	Phosphorous removal	٧	٧	٧	٧
* depending on methods of dispersal, disinfection systems may or may not be required ** tank may be part of collection system or located at treatment site *** various media, usually with recirculation					

Treatment technologies for clusters can be the same as for onsite systems although increased in size. What is more, for large clusters, the technologies tend to be those used in large centralized wastewater treatment plants, because as cluster system gets larger, more sophisticated treatment options may be preferable due to site constraints.

The key element of a modern cluster system is the pretreatment phase (Table 8), where much of the sewage is intercepted in a tank close to the source. It allows the remaining material to be treated effectively and reused or disposed safely (Crites and Tchobanoglous, 1998, p.8).

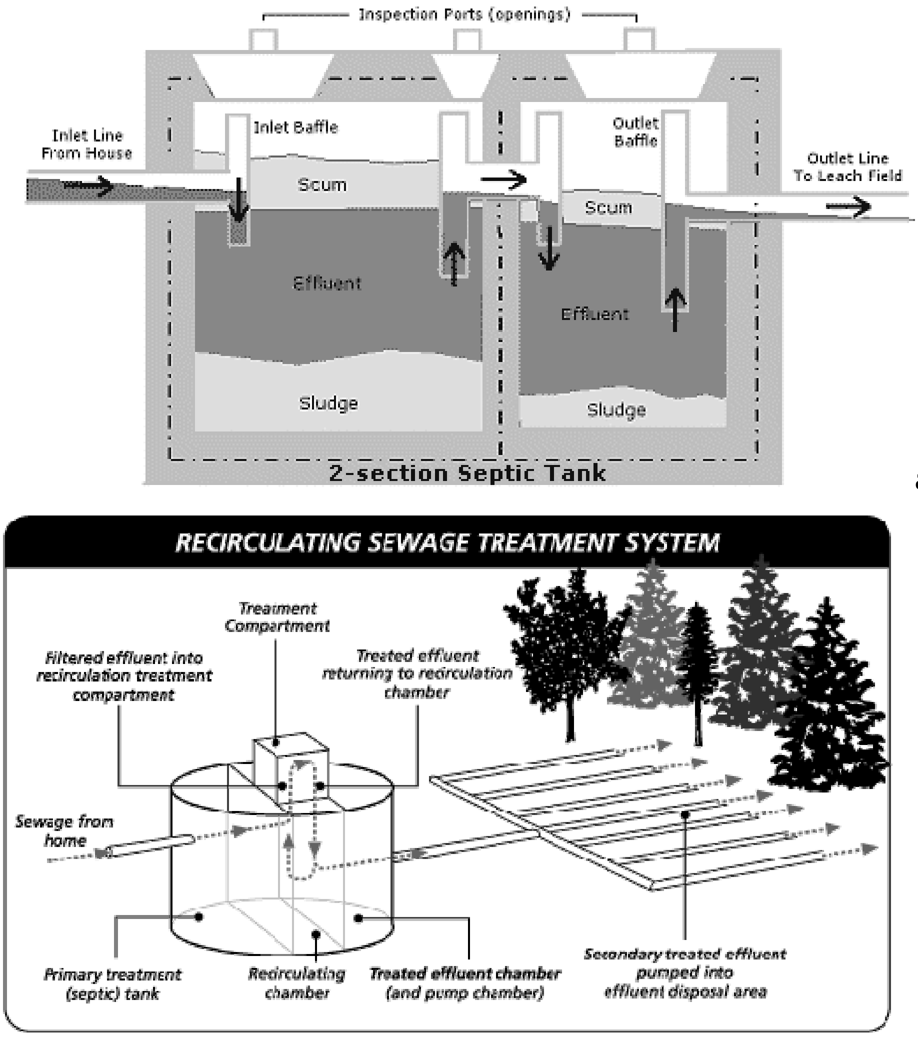
A number of conventional treatment units are available, if wastewater is collected for off-site treatment in a cluster wastewater treatment plant. These include either single process or combination of primary/secondary/tertiary treatment processes. In case of combined off-site/on-site treatment, the on-site component is usually septic tank or improved septic tank, and the resulting effluent in conveyed to the cluster plant for secondary treatment.

Septic tanks

Concrete and fiberglass septic tanks are used for advanced treatment systems, while polyethylene septic tanks may be used if structural issues are to be addressed (Crites and Tchobanoglous 1998). Other features include (Lombardo 2004):

- Two-compartment tanks (Figure 16), typically with a pump in a protective screen vault that filters wastewater before it is pumped to advanced treatment unit;
- Separate pump chambers
- Flow equalization tanks for shared or large systems, which accept and store effluent following the septic tank and before the treatment unit. Moreover, they help to moderate peak flows and provide a way to collect flow from different sources before treatment;
- Watertight tanks, which are important for all systems and essential for alternative and innovative systems

Primary treatment can be best accomplished in an Imhoff tank, as it provides a better and more reliable effluent quality than a large septic tank, is more economical to operate, due to its capacity to hold sludge and decrease its bulk via digestion.



a)

b)

Figure 16: Septic tank: a) Two-section compartment, and b) Potential application (http://www.septicyellowpages.com/SepticWork.html)

Anaerobic upflow filter

Anaerobic media filter (Figure 17) uses flocculation, sedimentation and absorption in removal processes, while anaerobic digestion occurs in the bed. These filters are usually filled with gravel, but other non-degradable media are also used. Following septic tank, upflow media filter can remove TSS, BOD5 and organic nitrogen. To improve nitrogen removal, aerobic treatment processes can be applied. Secondary treatment of the dissolved and suspended matter in the settled effluent from primary treatment is provided via a range of treatment options.

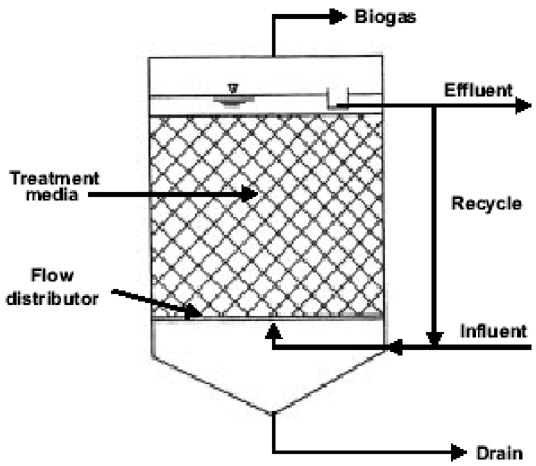


Figure 17: Anaerobic upflow filter (www.epa.gov).

Biofilter systems

Biofilter systems provide suitable secondary treatment for communities with a relatively constant population to maintain uniform loading and reliable treated effluent quality. All biofilter systems incorporate a secondary settling tank to capture the biological sludge that accumulates in the system (Ferguson et al. 2004).

In fixed-film reactor bacteria is growing on a surface medium suspended in the tank where the air is injected (Figure 18).

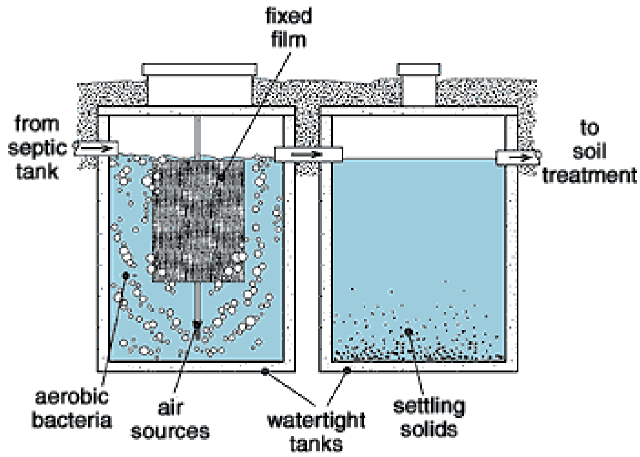


Figure 18: Fixed-film reactor ATU
(http://www.tyndallseptic.com/page_includes/septic/aerobic_003.gif)

Medium can be made of variety of materials, including plastic, Styrofoam, or gravel (Lombardo, 2004). Organic matter decomposes in the chamber, while settling and clarification occurs in a separate chamber. Treated wastewater flows from settling chamber to the draifield for final dispersal. Fixed-film reactors usually do not produce bulking or require return mechanisms, but they tend to be more expensive than suspended-growth systems (Ferguson et al., 2003).

Media trickling filters are tanks of uniform-size gravel or crushed rock, or plastic-spooked wheels, on which grow the aerobic bacteria slimes responsible for cleansing the settled wastewater, and through which air circulates continuously as settled effluent trickles slowly down through stone or plastic media filter (Ferguson et al., 2003). The slime growths slough from the system continuously, forming a biological sludge for collection and removal from the secondary settling tank.

Rotating biological contractors (RBC) consist of 2-3 meter-diameter thin plastic discs 80-100mm spaced on a rotating axle and turned slowly through a 'trough' of settled wastewater (Figure 19), so that the bottom third is continually being submerged (Crites and Tchobanoglous, 1998).

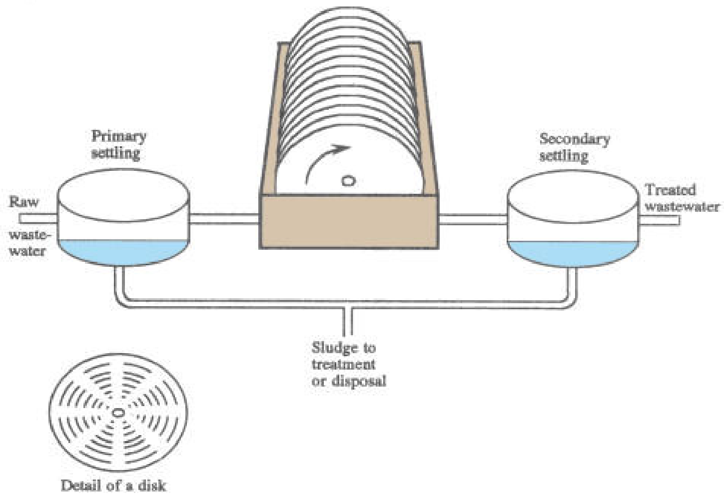


Figure 19: Rotating biological contractor (RBC) (Ferguson et al., 2004)

The intermittent submergence in wastewater and then exposure to the air creates aerobic bacterial slime growth on the plastic surfaces in the same way as the media filter. Rotating drum biological contractors provide for biosolids growth on the internal media surfaces of the drum unit.

Sand-filter systems

Different types of filter beds are used with various media to reliably treat wastewater to a high degree (Ferguson et al., 2003). Single-pass sand filters a proven technology for reducing pathogen organisms. Different variations of that filters have used solid granular media (e.g. crushed glass, and bottom ash – a by product of coal-fired power plants).

Packed bed biological reactors, or sand filter systems, use sand or packed media (e.g. crushed glass) to provide surfaces for bacterial growth, and voids for air circulation, bacterial storage, and physical straining. These systems cope well with varying population loading rates.

Intermittent sand filters are used as secondary treatment following community septic tank or Imhoff tank pretreatment. They can cope with fluctuating loadings more effectively than biofilter and activated-sludge systems, and produce much better effluent quality (Lombardo, 2004). Moreover, they reduce human intestinal bacteria numbers (coliform indicator organisms), as well as the significantly reducing organic matter and suspended solids. They must always be preceded by primary treatment.

Recirculating sand filters are more economical to construct than the intermittent types because of their reduced size, however pumping costs for dose loading are higher due to the recirculation process. *Recirculating textile filters* replace the sand by a synthetic woven fabric, resulting in a very compact treatment nit with high performance in organic matter and suspended solids removal, however are not as effective at bacterial removal (Ferguson et al., 2003).

To encourage more efficient movement of wastewater and gasses in the filter bed, absorbent media has been substituted with the non-absorbent granular media (Ferguson et al., 2003). The use of absorbent media promotes better treatment performance, in single-pass mode it includes peat and open cell foam, while textile media is used in recirculation filters.

In *media filter systems*, the general treatment train starts with the effluent being collected in septic tank. The effluent is pumped to the top of the filter and distributed over the media surface, which provides surface area for bacteria and other microorganisms responsible for treating the wastewater as it trickles down through the media (Lombard, 2004). The filter bed is never saturated with water and the presence of air promotes establishment of favorable microorganisms.

In *single-pass systems*, the treated effluent is collected at the bottom of the filter bed usually dosed to the drain for final treatment and dispersal (Figure 20).

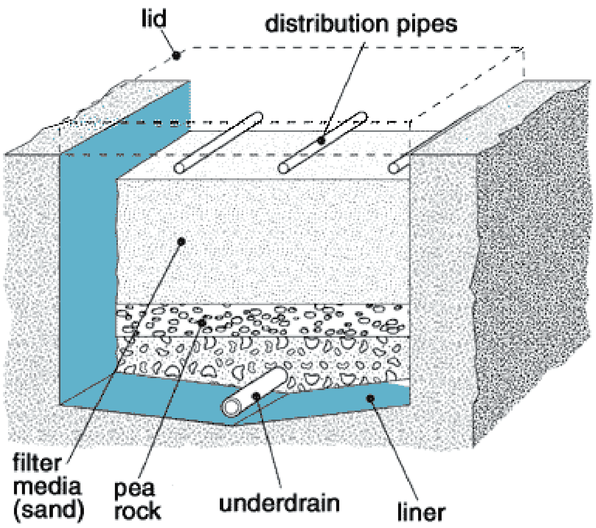


Figure 20: Single pass media filter (Lombardo 2004)

In recirculating designs, the partially treated effluent trickles down the media, is collected at the bottom of the filter, and recirculates between the tank (e.g. septic tank or separate recirculation tank) and the media filter several times before final discharge to the drainfield (Lombardo, 2004). In the recirculation process, a combination of aerobic treatment in the media filter and anaerobic conditions in the tank are required to convert nitrogen to N_2 gas. Recirculating sand filters have been used successfully and are generally accepted as a decentralized nitrogen reduction technology

Moreover, modular prefabricated and prepackaged media filters such as peat, foam and textile systems have advantages over other media filers that must be constructed entirely onsite. The challenge for new filer systems is trying to match the long-term treatment performance, low level of operation and maintenance, as well as robustness of sand filters. Additionally, storing peak flows and timing doses of wastewater helps minimize filter overload and keeps the system working twenty-four hours per day to treat stored wastewater.

Oxidation ponds

Facultative ponds are the most common full treatment systems in use in New Zealand (Ferguson et al., 2003). The aerobic liquid depth fosters waste stabilization via an algal-bacterial symbiosis, which matures incoming flow during a four- to six-week retention period. The anaerobic sludge layer on the floor of the shallow pond stabilizes and consolidates settled sludge and algal cells. Pond systems can accept widely varying input loadings due to the buffering action of their considerable storage volume and detention time.

Polishing ponds (tertiary treatment systems) are usually on a 21-day retention time at average daily flow to allow algal solids from facultative ponds to settle, and human intestinal bacteria to die off before discharge of effluent (Lombardo, 2004). Some polishing or maturation ponds consist of several cells in parallel, each cell with 5 to 10 days retention capacity. The cells-in-series configuration improves the efficiency of bacterial removal. Maturation ponds can provide tertiary treatment for effluent from any type of secondary treatment system.

Constructed wetlands (CWs)

There are two types of wetland systems: surface (free water surface) flow (SF or FWS) and subsurface flow (SSF) technology (Haberl and Langergraber, 2004). The sub-surface units involve effluent treatment via flow through a porous soil granular medium, some, but not all Maori Iwi accept that this meets their cultural objectives in handling human waste via soil treatment before the resulting water flow enters natural water (Ferguson et al., 2003). Subsurface systems can be subdivided into horizontal and vertical flow CW (Figure 21), depending on the direction of water flow through the porous medium (gravel or soil) (Haberl and Langergraber, 2004).

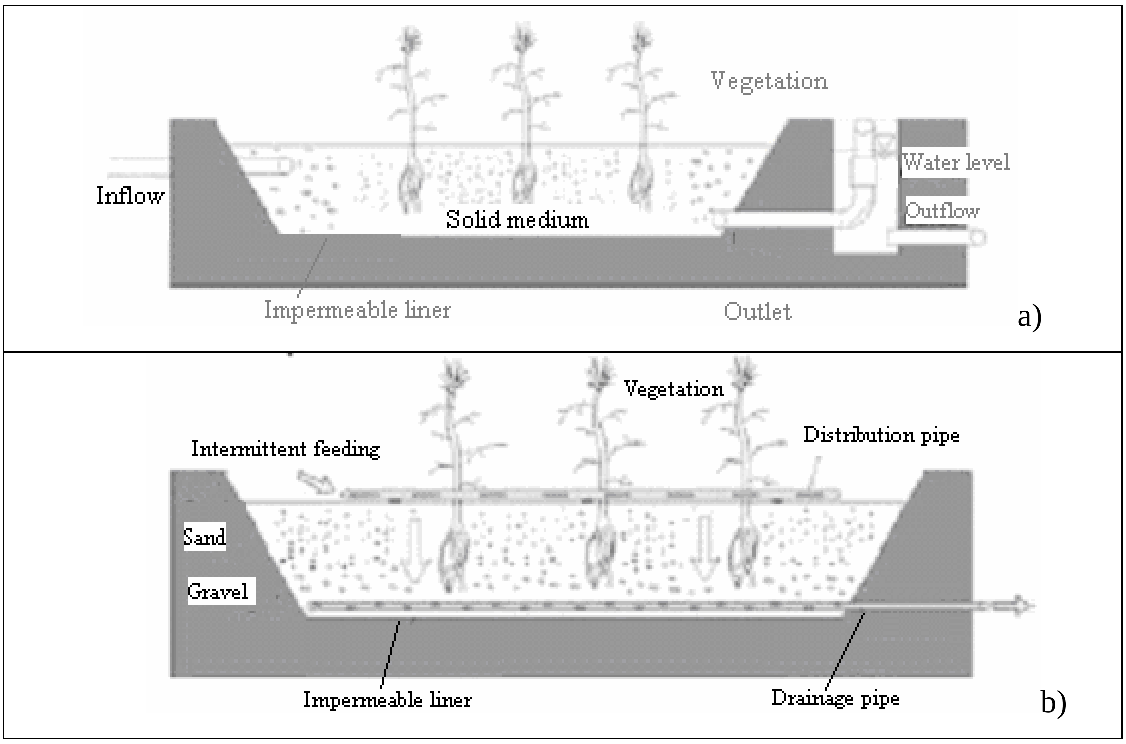


Figure 21: Longitudinal cross section of subsurface CW: a) Horizontal flow; b) Vertical flow (Langergraber and Haberl, 2004)

The treatment performance of wetland systems is nowhere as predictable as other treatment systems, and many wetlands are used as an environmental buffer treatment stage between the main treatment system and receiving water into which a point discharge is being made. CWs are applied for different qualities of water, domestic wastewater, rainwater and runoff management, agricultural and industrial wastewater etc. (Langergraber and Haberl, 2001).

Surface-flow wetlands provide either secondary or tertiary treatment over a 5 to 10 day-flow-through (retention period). Emerged wetland plants that are rooted in the soil on the base of the shallow pond in which they have been planted work well, through the settling and bacterial growth on plant stems, as well as aeration of the water by oxygen transfer processes. Septic tank effluent or effluent from secondary treatment processes can be treated.

Sub-surface flow gravel-bed wetlands are increasingly being used to provide a further tertiary treatment stage for facultative oxidation pond effluent flows. They are also used for combined secondary and tertiary treatment of septic tank or other primary effluent in smaller communities, and provide simple, affordable and sustainable technology (Haberl, 1999).

Activated sludge systems

Suspended growths of aerobic bacterial slimes are maintained by aerating the wastewater and suspended solids mixture by bubble aeration or mechanical mix aeration (Lombardo, 2004). The wash-out of active suspended solids is captured in secondary settling tank and recycled back into the activated sludge tank to continue cleansing the incoming wastewater. Activated sludge variations can provide either secondary treatment to pre-settled primary wastewater flows, or full treatment of raw wastewater by what is termed 'extended aeration' (Ferguson et al., 2003).

Package plants are factory-assembled activated sludge treatment units, ranging from single household size up to village size, which generally operate on the extended aeration basis (Crites and Tchobanoglous, 1998).

Sequencing batch reactors (SBRs) are a fill-and-draw system, which provides a simplified and economical alternative to the conventional extended aeration activated sludge approach. They can be operated to strip nitrogen nutrients from waste flows and hence well suited to residential areas in sensitive environments (Crites and Tchobanoglous, 1998). The Lake Taupo basin was the first application of SBRs for a small community in New Zealand (Ferguson et al., 2003).

In a seq*uencing batch reactor* (SBR), filling, aerobic decomposition, settling, and discharge proceses all take place in a single reactor (chamber or basin) in one complete system (see Figure 22). Incoming wastewater mixes with sludge remaining from the previous cycle during the filling step; air is injected into the wastewater and mixed during the decomposition cycle (Lombardo, 2004). After the settling stage the treated wastewater is discharged to the drainfield. This process is more consistent, however requires a controller and has a higher potential for mechanical, electrical, or operational failure due to many moving parts. This type is used for commonly for individual systems as well as for large-flow cluster systems.

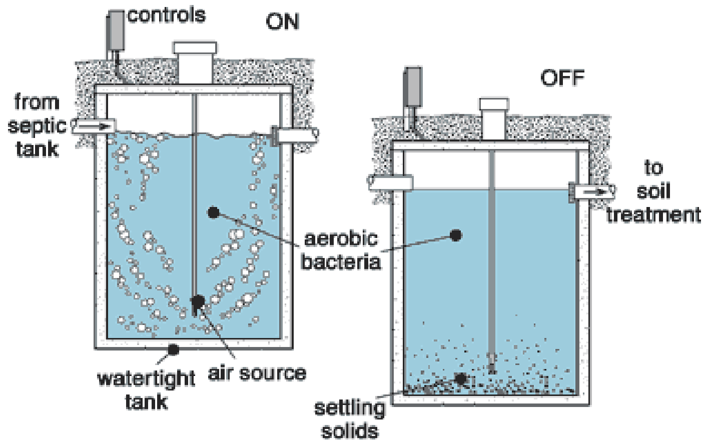


Figure 22: Sequencing Batch Reactor (Lombardo 2004)

Oxidation ditches are an extended-aeration activated-sludge system which uses a shallow oval, race track-shaped aeration basin aerated by a surface mechanical aerator, which maintains also a steady circulation of mixed flow in the channel (Ferguson et al., 2003). Overflows are settled to produce a final effluent and sludge, which is recycled to the plant inlet. Excess sludge biosolids have to be removed periodically.

Aerated lagoons are low-cost alternative to the extended-aeration activated-sludge system suitable for larger small communities. In some cases they can provide pre-treatment prior to oxidation pond systems. In New Zealand they have particular application in holiday area communities, where during winter season they operate as a simple oxidation pond followed by polishing treatment in the accompanying oxidation pond (Ferguson et al., 2003). In summer time, the system is changed back to an aerated lagoon/oxidation pond configuration by activating the aerators

Aerobic treatment units (ATUs) rely on air injection systems and blowers to create an oxygenated (aerobic) environment to help bacteria break down organic material (Lombardo, 2004). Usually there is at least one additional stage in the treatment process that enables solids and bacteria to settle out of the wastewater so that cleaner wastewater is distributed to the draifield. That produces an effluent lower in TSS and BOD, with some reduction in bacteria. The injection of air into the ATU agitates the wastewater so solids are kept and mixed with bacteria to digest the organic matter. Usually settled solids are returned back to the aerobic part of the tank for mixing and additional treatment. ATU consists of three basic operating modes, suspended-growth, fixed-film reactor, sequencing batch reactor.

All of these have solids removal step as the first process in their treatment process, either designed as a discrete compartment or separate tank positioned before the aeration step, where large solids are removed so that they do not hamper aeration process.

In *suspended-growth ATU,* bacteria are free floating in the main chamber (Figure 23). In the last chamber solids and bacteria settle out and are returned back to aeration, mixing and return back to the aeration chamber by either a portion on the bottom or by a recirculation pump. Clarified treated wastewater is piped to the drainfield. This type is likely to have bulking problems, where clumps of bacteria and some solids do not settle to the bottom but stay suspended and tend to clog the outflow pipe tot the drainfield.

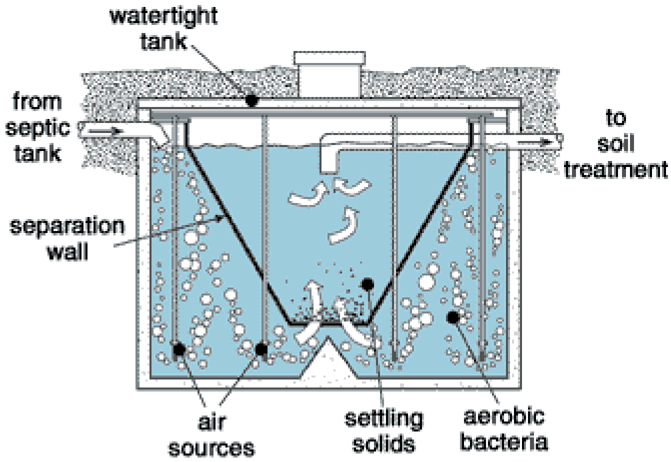


Figure 23: Suspended Growth ATU (Lombardo, 2004).

Membrane biological reactors (MBR) combine membrane-solid separation process with activated sludge treatment (Crites and Tchobanoglous, 1998). Membrane utilizes low pressure microfiltration or ultrafiltration and eliminated the need for clarification or tertiary filtration.

Integrated fixed film suspended growth systems involve addition of inert media into existing activated sludge basins in order to provide sites for biomass attachment (Lombardo, 2004). This combination of attached and suspended growth results in maintaining high density of biomass population and increase the efficiency of the system. Such systems can be used both with fixed or moving media (moving bed biological reactor).

Overland flow

Overland flow offers both treatment and ecosystem re-entry function. Treatment occurs within the topsoil mantle. To ensure that the aerobic renovation capacity of the soil is maintained, alternative cycles of load and rest are required (as in rapid infiltration) (Ferguson et al., 2003). Effluent to be treated is spread over the upper surface of a sloping, grassed plot and is treated via sheet flow as it moves down to a collection system at the lower edge of the plot. As the wastewater flows over the land, some will be infiltrated into the soil, achieving re-entry to the ecosystem. Flow that does not soak in is collected as polished effluent for appropriate disposal.

Advanced treatment provides a final stage to raise the effluent quality to the levels required before it is discharged to the environment or reused. Additionally, more than one tertiary treatment process can be used at treatment plant and it is usually called effluent polishing. Aditionally, advanced treatment operations and processes for reclamation and repurification include packed bed filtration, membrane filtration (micro-, ultra-, nano-filtration and reverse osmosis), chemical precipotation for phosphorous removal, disinfection with chlorine and ultraviolet radiation. Processes like carbon adsorpton are ocassionally used and are normally associated with large centralized treatment plants (Tchobanoglous and Burton 1991).

5.2.2 Combination of treatment systems

Treatment units can be specifically designed to treat certain types of contaminants (e.g. BOD, grease, and nutrients). For example, membrane filtration systems are capable of reducing nitrogen to levels as low as 2-3mg/l (Lombardo, 2004). Site design is also considered while selecting appropriate type of system to meet specific challenges, as some treatment units (e.g. rotating biological contractors) are typically placed in a garage or a barn, while others (e.g. sequencing batch reactor) can be located underground using little space but requiring deep excavation.

Basing on the research undertaken by Rhode Island Department of Environmental Management (RIDEM, 1998) for the period of 1995 through 2003, indicates that media filters and fixed activated sludge units are most commonly used for systems in the 3,700 to 18,000 liters per day range. Many of these are modular, which enables system sizing to accommodate present needs and the ability to incorporate additional units, moreover, these systems are commonly paired with alternative drainfields, using either shallow trench designs or bottomless sand filters for final wastewater treatment and dispersal. Considering 37,800 to 150,000 liters per day range, it was shown that recirculating sand filters and self contained treatment units are commonly used, including fixed activated sludge systems, trickling filters, sequencing batch reactors, and rotating biological contractors (Lombardo, 2004). At large flows a variety of alternative or conventional soil-based leaching systems may be used, including pressurized shallow trenches, conventional drainfield trenches, flow diffuser, and lagoons.

In New England, cluster systems of 75,000 to 300,000 liters per day are common, with a few approaching 750,000 liters per day (Lombardo, 2004). At flows of 375,000-750,000 and greater, advanced treatment systems supporting water reuse and recycling may become feasible (e.g. several commercial centers, resorts, and stadium complexes in New England take advantage of cluster systems to generate high-quality wastewater that is stored and reused for toilet flushing, thereby reducing both water demand and wastewater leachfield requirements). Although recycling systems have been used on arid areas more extensively, summer water shortages and growth pressures, combined with growing demands for clean water are making reuse and recycling systems increasingly cost-effective (Lombardo 2004). Treatment processes most commonly used for cluster systems are presented in Table 9.

Table 9: Examples of treatment system combinations (Ferguson et al., 2003).

Wastewater conditioning	Screening and grit removal			
Primary treatment	Imhoff tank Clarigester	Sedimentation (large capacity septic tank) Sedimentation with chemical addition	Oxidation ponds (primary treatment)	
Secondary treatment	Activated sludge: - Standard aeration - Extended aeration - Oxidation ditches - Sequencing batch reactors	Biofilters: - Trickling filter (biological filter) - Rotating biological filter	Sand filters: - Intermittent sand filter - Recirculating sand filter	Oxidation ponds (secondary treatment)
Tertiary Treatment	Sand filters (following activated sludge, biofilter or pond systems)	Disinfection (pathogen removal): - chlorination - UV - ozone	Oxidation ponds (maturation treatment)	Overland flow
Advanced treatment	Nitrogen removal: - Denitrifying sequencing batch reactors - Denitrifying sand filters - Zeolite filters	Phosphate removal: - Chemical stripping - Biological stripping - Amended soil absorption	Membrane filtration	
Sludge treatment	Septage: - Burial - Chemical treatment and landfilling	Raw sludges: - Anaerobic digestion - Digestion and compost treatment - Other treatment technologies	Biosolids: - Aerobic digestion - Digestion and compost treatment	

Advanced treatment may involve sand filtration to remove residual suspended matter, or carbon filtration to remove residual toxins. Lagooning may provide settlment and further biological improvement through storage in large highly aerobic ponds or lagons. As mentioned above, constructed wetlands may provide high degree of aerobic biological improvement and are often used instead of secondary treatment for small communities.

Since treatment plants for cluster systems would be small, they should employ technologies that will incur low operational and maintenance liabilities, moreover, these plants should be cost efficient to install at small scale. There are two treatment technologies - biofiltration systems (with sand filters) and constructed wetlands – that best meet these criteria. Biofltration is reliable, consistent high performance option requiring low area, and being installed in covered or sealed housings.

Wetlands require less labor to operate and maintain. If an irrigation reuse opportunity is available, evapo-transpiration during hot weather would reduce the amount of water available for reuse at the time when irrigation is most needed. Wetlands may be however a good low cost treatment method for systems that will discharge effluent to surface waters.

These two technologies are relatively easy to operate and maintain. Moreover, they consume less land than lagoons and are capable of consistently producing much higher effluent quality than lagoons.

An example of biofiltration treatment concept is presented in Figure 24. Granular media – sand – filters are most familiar however recently alternative types of media-textile and foam have been researched (Vanhuizen, 1991). These media can be loaded much more heavily, than a granular media filter providing to smaller and more cost efficient biofiltration bed. Such small scale systems serve cluster systems. An average design loading rate of 495 liters/m^2/day is used to size granular media filter bed, while with textile or foam media filters could be loaded at around 90 liters. This would significantly reduce the land area required to house such plant.

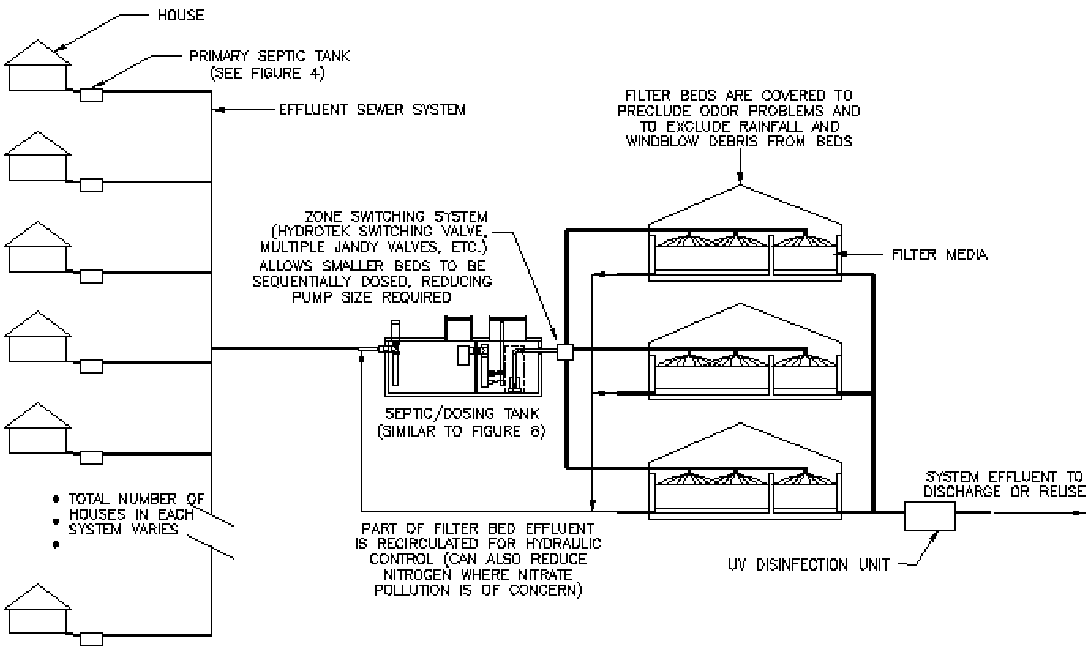


Figure 24: Biofiltration treatment plant system concept (www.vanhuizen-ww.com)

The filter bed should be designed to be covered rather than open to the air due to odor control, rainfall elimination and windfall debris control.

The wetland system concept would be actually similar as the biofiltration treatment system, with the wetland bed replacing the biofiltration bed in Figure 26. However, wetland would not employ recirculation concept, moreover, subsurface flow wetland would be preferred to minimize mosquitoes problems.

5.3. Disinfection

The treatment train approach to system design is flexible, which enables additional component to be added if necessary. Disinfection options for cluster systems include chlorine, ultraviolet (UV) and ozone (Cites and Tchobanoglous, 1998; Ferguson et al., 2003).

The use of chlorine for wastewater disinfection includes the use of tablets, gas, and chlorine dioxide. However, due to its harmful environmental effects, dechlorination may be required, since it created carcinogenic compounds, its use in environmentally sensitive areas is discouraged. UV disinfection operates by exposing the wastewater to a UV light source of sufficient intensity and time to kill infectious organisms in the wastewater. When separation distances to wells are inadequate, the unit, the UV disinfection unit is used, which is usually included in the pump chamber following treatment and before final discharge to the leachfiled. UV is effectively eliminating bacteria, however before it requires a high level of BOD and TSS removal. Ozone disinfection operates by bubbling ozone through the wastewater, as it is a strong oxidant and is highly toxic to organisms.

5.4 Water, nutrient and biosolids reuse

Communities across the world face water supply challenges due to increased demand, drought, depletion and contamination of groundwater, and dependence on single sources of supply (Miller, 2006). Wastewater reclamation, recycling, and reuse address these challenges by creating new sources of high quality water supplies. The future potential for reclaimed treated effluent is enormous however current practices in water reuse and reclamation constitute only a small fraction of effluent generated, and in order to meet growing water supply demand needs, people are considering other non-traditional sources of water such as agricultural return flows, concentrate and other wastewater streams, stormwater, co-produced water resulting from energy and mining industries, as well as desalination of seawater and brackish groundwater (Miller, 2006). Traditionally wastewater has been managed as a product that is a threat to human and ecosystem health, consequently the infrastructure design for handling such material was suitable to that approach. However at present the attention shifted to managing wastewater as a resource, with potential of water, nutrients and organic material reuse.

Reusable water and composted solids, that can be used for horticulture, as a soil conditioner, can be recovered nowadays. The focus is on how to reuse it in the most cost effective, practical and institutionally acceptable way. For example, wastewater could serve irrigation demands, or other non-potable demands like toilet flushing. What is more, the wastewater issue can be addressed as a resource with revenue potential.

There are different strategies that can be applied to beneficially reuse the effluent and some of these include (Venhuizen, 1991):

- Redistribution system back to the lots generating the flow – use of reclaimed water could be restricted to lawn and garden watering, or car washing. The level of post-treatment required would include biofiltration with additional polishing processes.
- Growing crops on land purchased (or leased) by the operating entity to serve as the distribution area. With biofiltration or wetland treatment system, effluent by drip or spray irrigation could maximize beneficial use of the resource.
- Selling water to adjacent property owner for agricultural irrigation reuse.
- Discharging effluent into a supply canal (instead of drainage canal), as this would allow the water to return to irrigation district. In such case, higher level of treatment might be required.
- Organizing the management system for a commercial center as a flush water recycling system, with any residual flow routed to drip irrigation of landscaping.

The important factor is if and how wastewater could be reused in a way that benefits could be gained. Other things to consider include regulations, topography, development density, type of land use and community desires in regard to land use, moreover, points of potential reuse and of allowable discharge. If a high quality effluent is produced, it should be possible either to irrigate or discharge, keeping in mind the need or absence of irrigation demand. Discharging effluent where there is no irrigation demand e.g. during wet weather and irrigating where practical is called opportunity reuse (Venhuizen, 1991). This strategy makes reuse more financially feasible as it obviate the need for expensive storage facilities. However, there might be some regulatory constraints, which have to be taken into consideration.

A number of technologies are used that utilize the resource value of wastewater, although this is fairly new area for cluster systems. Treated wastewater produces liquid wastewater and primary and secondary sludge – material that remains once the original water-borne waste is dewatered. Both these processes recover reusable water and composted biosolids (Table 10). Re-use of biosolids requires a higher level of treatment beyond what is achieved with the normal treatment of primary and secondary sludges.

Table 10: Alternative reuse strategies (Ferguson et al., 2003)

Biosolids reuse	Reclaimed water reuse
Bio-gas for energy via anaerobic digestion (organic component of primary and secondary sludges is converted to methane) Energy extraction using heat pumps Compost material	Irrigation (water with nutrients for biomass production) Wetland restoration (artificially pumping water back into a wetland to offset the loss of water from drainage of surrounding areas, and lowering water table) Use for non-potable purposes (garden irrigation, industrial processes)

Some options include recycling of treated wastewater, or greywater for non-potable uses such as toilet flushing and irrigation, or feeding landscaped wetlands, and the use of composting toilets and production of humus. Other practices include aquaculture, urine separation, and nutrient stripping for the production of nutrients. Moreover, water reuse can consist of treatment of total or solely greywater. It requires dual piping and is more practical for new construction.

That approach to wastewater management is relatively new however there is a wide range of technologies to be explored, like water management at source, biosolids and reclaimed water reuse. For example, in Golden Valley, Kuaotunu, Coromandel Peninsula, New Zealand, a new subdivision of 40 lots have been constructed with a pumped modified drainage effluent collection system (Ferguson et al. 2003). Filtered septic tank effluent is convoyed there to recirculating sand-filter treatment plant, and the very high-quality effluent produced is in part disinfected and returned to each lot as non-potable reclaimed water for toilet flushing. The remaining effluent flow is not disinfected, but pumped to an area of steep terrain, where it is irrigated by driplines into eucalyptus planted plots. Morover, a portion of the treated effluent is held in storage for firefighting purposes. In addition to that, the advantage of the recirculating sand media filter treatment system for this type of development is that it can be commissioned on a regular basis. Treatment capacity can be extended to match housing numbers as constructed over time, moreover, on a seasonal basis, modules can be started up and the shut down to fit the expansion and contraction of holiday occupancy, maintaining consistently high treatment performance (design-built-operate project) (Ferguson et al., 2003). The performance of the overall treatment system is done by locally trained people.

In New Zealand reuse of water is a new part of wastewater management. Moreover, it is more difficult than in other areas, as cultural concerns and believes of Maori about reuse and re-entry of wastes, including direct irrigation on food crops, and uncertainty of compost as an end use have to be considered here (Ferguson et al. 2003). For example, non-potable use is acceptable there, if it is not used for food production, however, the passage through soil has to take place first. Additionally, there is a community concern about some of these processes (e.g. heavy metals), as well as issues raised by health authorities concerning direct contact with pathogens in case of the system failure.

Nevertheless, a wide range of technologies suitable for certain community needs can be explored. Managing water use at source, biosolids and water-reuse have the potential to reduce the overall cost of wastewater system. For a smaller community it is worth to look how the waste streams, especially sludges to be converted to biosolids, might be combined with other communities in a centralized process.

Additionally, water reuse provides a wide range of benefits for communities, which results in creating immense value for the public and the environment. One of the most significant benefits is the value created by the inclusion of water reuse in integrated water resources planning and other aspects of water policy and the implementation of water projects resulting in the long-term sustainability of water supplies. These integrated concepts involve the convergence of diverse areas as governance, health risks, regulation, and public perception, and also present a significant challenge to water reuse.

5.5 Ecosystem re-entry

Having collected and treated wastewater, the systems and technologies for its re-entry to the ecosystem have to be considered. Till recently the way the wastewater re-entered the environment was not a major focus for communities. Untreated waste, especially sewerage, was often been discharged via sewer outfalls onto coastal areas. However with the improvement in treatment, the approach has changed, and treated wastewater may be returned through direct point discharge to a water body as river, lake, wetland or estuary, or sea. In this case, high discharge standards are required by regulations, for example RMA in New Zealand. Additionally, cultural issues may be an issue e.g. Maori values often prohibit direct discharge to natural waters (Ferguson et al. 2004). However, alternatively, the treated wastewater may be returned to land by various irrigation methods, such as flood irrigation, overhead sprinklers or sub-surface drippers. Usually towns close to the coastline tend to return the treated wastewater to the costal ecosystem, while inland treatment plants may discharge their treated wastewater to lake, river or to land via irrigation. The other waste product from treatment plant is the processed sludge (biosolids) and this may be disposed to a landfill site, spread on to land, composted, palletized or treated for use as a soil conditioner.

5.5.1 Wastewater residuals

There are four kinds of wastewater residuals that must re-enter the natural environment after treatment and these include (Ferguson et al. 2003):

Gases - ammonia, methane and hydrogen sulfide, odorous organic gases, which can re-enter at various points. If water turns septic from an overload of organic material or at the point, sludge is landfilled. Methane can build up within a site and will need to be managed to reduce risks to surrounding properties. Risk and site management plans for landfills to manage combustible gasses and odour are an important part of re-entry process.

Wastewater aerosols. Very small water droplets can carry pathogens and other contaminants. These aerosols are created by mixers and aerators, which disturb the surface of wastewater tanks and ponds, or by overhead sprinklers. The distance they can carry in winds and survival time of pathogens is variable and depends on the site. A risk management plan and regulation of where and how any treatment plant or land irrigation area is to be located is important.

Liquids. In the case of liquids, the characteristics of treated wastewater to be returned to the environment depends on the level of treatment, it has received.

Solids – sludge and biosolids - can be classified as semi-solids and semi-liquids depending on the amount of water left in them. Unprocessed solids from primary and secondary treatment processes are referred to as sludges. Local authorities invest significant effort into converting sludges to biosolids, and reducing the level of water in the processed solids, to improve handling problems when they are disposed to landfills.

For example, The New Zealand Waste Strategy calls, by 2007, for such wastes to be beneficially used or appropriately treated to minimize the production and leachate (Ferguson et al., 2003). Moreover, The Ministry for the Environment is placing strong emphasis on improving landfill management. Some landfills will not take biosolids. The Ministry is keen to promote re-use of biosolids, but there are issues with some processes in terms of available markets. The re-use of biosolids that have been composted is not straightforward because of concerns about the impacts of remaining heavy metals and other substances (Biosolids Guidelines, 2003)

This approach often utilizes land disposal, so the area needed will be determined by the number of dwellings serviced by that system. Moreover, cluster solution can allow a more managed land-based ecosystem re-entry, as the volumes of effluent treated are relatively small.

There can also be a linkage to centralized system, as some technologies allow mining of wastewater, by hooking up to wastewater mains pipes and removing some of the wastewater for processing. This provides reclaimed water for re-use and contribute to reducing the amount of wastewater going to a centralized plant.

5.5.2. Types of re-entry system

There are six main ways in which liquid and solid wastewater residuals re-enter the ecosystem (Table 11). The impact of wastewater re-entry is dependent not only on the quality and quantity of residuals released into them, but also on the sensitivity of the ecosystems and the relative importance of its goods and services.

Table 11: Types of re-entry system (Ferguson et al. 2003)

System	Residuals managed
Freshwater ecosystems (streams, lakes and wetlands)	Treated wastewater effluent (various levels of treatment)
Marine ecosystems (estuaries, harbours and ocean – coastal and offshore)	Treated wastewater effluent (various levels of treatment)
Land ecosystems (agricultural, horticultural, forestry or landscaped areas)	Some untreated wastewater (more rare)
Atmosphere	Treated wastewater effluent (various levels of treatment) Odour Gases (indirect and flaring of landfill gases) Wastewater aerosols (a by –product of treatment processes)
Landfills (closed systems)	Sludge and biosolids
Waste-to-energy plants (not used in New Zealand at present)	Dried sludge/biosolids

5.5.3 Technologies

Solids re-entry

Small community treatment plants using biofilter or activated sludge systems produce a range of sludges from the combination of both primary and secondary treatment processes. The degree of stabilization of these solids by anaerobic and aerobic processes in the treatment plant determines the volume of final biosolids to be managed by disposal or utilization onto land. Wet biosolids may be dried on special sand beds at the treatment plant before being collected as dried cake for trucking to land (or even to a solid waste landfill). Alternatively, in New Zealand, wet biosolids may be spread on land under the 1992 guidelines prepared by the Ministry of Health (Ferguson et al., 2003). A new set of national guidelines favours agricultural land uses, if biosolids are digested and are mature (have been aged since digestion), and can be placed by sub-surface injection into the soil. Forest land application provides an opportunity for the nutrients in the solids to enhance tree growth, and is a further beneficial use of biosolids.

Wastewater effluent re-entry

Effluent can enter both water and land. The main forms of effluent community wastewater effluent re-entry used in New Zealand are presented in Table 12.

Table 12: Main forms of wastewater effluent re-entry in New Zealand (Ferguson et al., 2003)

Forms of re-entry	Number of communities	%
Freshwater:		
- Stream flow	147	51.9
- Lake	4	1.4
	151	53.4
Marine:		
- Estuarine	7	2.5
- Harbour	13	4.6
- Coast	6	2.1
- Offshore outfall	29	10.2
	55	19.4
Land and other:		
- To land	59	20.8
- Land/excess flow to water	17	6
- Pipeline to another treatment plant	1	0.4
	77	27.2
Total	283	100

However, the cultural issues of Maori spiritual values, together with recognition that water re-entry systems often do not provide sound environmental performance, have led to new or upgraded facilities away from water re-entry, towards land re-entry. This new approach has been significant in particular for smaller communities, as the land areas needed, can be more readily found in rural areas, than can be found for a larger community. In the case of larger communities, upgrading their treatment and ecosystem re-entry systems, the use of constructed or natural wetlands has been accepted as appropriate buffer between the treatment plant and the natural water into which the final discharge diffuses.

Options for returning the treated wastewater to the ecosystem within the site boundaries (on-site disposal) depend on the site's characteristics, such as soil types, area and slope of land available, location of groundwater, and local climate, and these include seepage into the soil sub-surface, irrigation (surface and sub-surface) and evapo-transpiration.

There are three options available for subsurface dispersal and these include (Lombardo 2004):

Conventional subsurface dispersal technologies (trench, leaching beds, and other conventional methods like drainfields). Septic tank effluent or purified wastewater are discharged into a network of buried perforated pipes or chambers from which it enters the soil column and percolates downward until reaching the water table. The purified wastewater than merges with and disperses into the water table.

Mounded systems (trenches or beds). These systems import a select fill to provide the required separation to groundwater or a limiting layer. The purified wastewater than merges with and disperses into the water table.

Subsurface drip distribution systems. The purified wastewater here is dispersed within the root cone of vegetation (e.g. lawns, landscaping, etc.). These are shallow systems. The vegetation absorbs the water and some of the nutrients from the discharge, avoiding or reducing the need for other irrigation/fertilization application. Excess water flows into the soil column with the groundwater system as a conventional subsurface dispersal system.

There are two general options available for surface dispersal (Lombardo 2004):

Direct discharge system includes a discharge pipe/diffuser in a water body to mix the treated effluent with the receiving water body.

Created riparian wetland dispersal system is one in which a wetland is created along the shoreline of the receiving water body and purified effluent is discharged into the wetland, as in a subsurface from wetland, or in saline waters in a submerged aquatic vegetation wetlands.

Land options include *rapid infiltration, overland flow, and low-rate irrigation* by either *spray irrigation or drip-line irrigation.* Land treatment is the favoured method for achieving cultural objectives for human waste management by the majority of Maori Iwi (Ferguson et al., 2003).

Rapid infiltration can be both treatment and disposal (via discharge to groundwater some distance below the soil infiltration surface). Partially or fully treated effluent is soaked into the ground at a high rate for further in-soil treatment. Sandy soils are the only suitable for long-term use, moreover, the water table must be sufficiently deep, so that all human bacteria are trapped in the soil where they gradually die off and not contaminate groundwater. Other pathogens may not be removed.

Low-rate irrigation is a land treatment and disposal system that involves total effluent absorption via soakage and evapotranspiration through planted crop or vegetation ground cover. Application rates are few centimeters per week, which means that large application areas are necessary. The higher the level of pretreatment (secondary treatment is a minimum), the more effective the long term performance of the irrigated area in coping with the effluent load.

For *spray irrigation* systems, significant buffer distances (planted, non-irrigated boarders) are requires adjacent to any location where people may be present to avoid human contact with aerosol-carried bacteria in the spray drift.

Forrest irrigation is a common method of effluent spray irrigation management, with the advantage that nutrients and water enhance tree growth. Grassland spray irrigation is another method however dairy industry is not interested in using harvested crop for fodders as they say that overseas consumers are likely to reject dairy products from cows fed on human effluent-irrigated pasture. Where drip-line systems are used, buffer distances can be very small and horticultural use of the treated effluent nutrients and water becomes feasible.

In-land treatment via surface application and underdrainage lines for collecting filtrate that is subsequently disposed to receiving water or to a reclaimed water use is a variation on rapid infiltration. It can provide the advantages of irrigation for crop or pasture growth where table depths may restrict rates unless lowered by artificial drainage.

Alternative drainfileds used with innovative technologies will fit into landscape, treat wastewater more effectively, and last longer than a conventional drainfields. There are two (pressure dosed for uniform wastewater distribution) options typically used (Lombardo 2004):

Shallow pressurized drainfileds (placed in the upper soil layers for maximum wastewater treatment by natural soil processes e.g. microbial nutrient removal and plant uptake) (Figure 25). Pressurized flow lines are shielded with polyvinyl chloride (PVC) pipe cut lengthwise. Figure 25(a,b) shows a narrow draifiled following a recirculation media filter. Draifield is the area with greener lawn. Additional nutrient uptake is done here by plants. The drainfield helps protect local drinking water wells and coastal pond water quality. Another example of a shallow narrow drainfield that serves a restaurant, and retail and office complex that generated 10,100 liters per day of wastewater is presented in Figure 25(c). The lines shown are ready to be covered with 30.5cm native backfill.


a)


b)


c)

Figure 25: Shallow narrow draifield - installation and application (Joubert et al. 2004)

Bottomless sand filters (Figure 26) have been used to treat raw septic tank effluent with good success. Bottomless sand filters (Rhode Island, 1998) provide a raised bed for final wastewater treatment and dispersal of advanced treated effluent (which must meet BOD and TSS standards). These systems are easily installed with little site disturbance and maximize separation distance to groundwater.

Figure 26: Bottomless sand filter following a recirculating media filter for multifamily and commercial use (Joubert e al. 2004).

Shallow narrow draifields and bottomless sand filters are both alternatives for the raised gravel fill systems, and provide much better treatment with minimal site disturbance. In some cases, conventional, gravity-fed drainfields can be used with advanced treatment. Mixing and matching alternative technologies in a treatment train to achieve a desired treatment is not difficult, however the technologies must compliment whether components come before or after it.

5.6 Wastewater management at source

As nature is the source of water; therefore our ability to support additional human lives depends upon the protection of nature and the continued operation of the water cycle. The water cycle is the combination of natural, physical, chemical and biological processes that constantly recycle water, ensuring a steady supply to support life (Hunt, 2004). Uses that change the quantity, quality and timing of water flows to various parts of the ecosystem may introduce disruptions to the water cycle, which results finally in the reduction of good water quality. There are some things people can do at the source that can be adopted to ease or reduce the cost of the ultimate treatment and ecosystem re-entry requirements (Ferguson et al., 2003) and these includes:

- Water conservation (water-saving practices in and around the home)
- Pollution prevention (choice of household products that will enter the wastewater stream)

The amount of water use in a community is a major factor in deciding the size of wastewater system. Water conservation practices can reduce the amount of wastewater that needs to be dealt with (Ferguson et al., 2003). Additionally, the amount of toxic material, oils and greases, fats etc. that goes down the drain must be considered in order to design the final system. Different kinds of water are a part of each household system and these include water for drinking, washing, cooking (potable); for transporting wastes (non-potable); and for other uses e.g. watering gardens and washing cars (non-potable). Moreover, greywater from baths, washing machines, showers, sinks; blackwater - human wastes (urine, faeces and blood); and stromwater. The amount of water used for potable and non-potable purposes can be reduced, which as a result reduces greaywater and blackwater production, meaning less water to be treated, moreover, greywater and stormwater can be reused for non-potable purposes.

It is necessary first to estimate how much wastewater is being produced and how much of that can be reduced, before estimating how big the treatment processes should be. Summarizing, the amount of water used and possibilities to reduce it have to be known; opportunities for re-use should be estimated, as well as the amount of stormwater that gets into the system has to be known.

5.6.1. Water conservation

Data presented in Table 13 shows the information on wastewater production in the city of Christchurch, however, these information is typical of most communities on a public water supply (Ferguson, 2003).

Table 13: The amount of wastewater produced per day (Christchurch City Council, 2002)

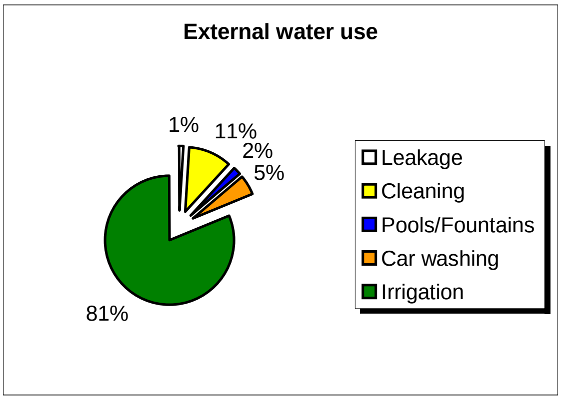
	Liter/Per person/Day
Urine	1.5
Total flushing water	30
Greywater	130

In the case when urine is diverted from the domestic wastewater, and greywater and toilet flushing is reduced by 50% by using more efficient water technologies in each home, the volume of domestic wastewater to be treated could be reduced by over 50%. As a result, nitrogen going to treatment would be reduced by 80% and phosphorous by 30% (Table 14). The amount of phosphorous and nitrogen produced has a major impact on the nutrient cycle and needs treatment.

Table 14: Amount of P and N produced in wastewater (Ferguson et al., 2003)

	Per person (kg/day)
Phosphorous from:	
Urine	0.001
Faeces	0.00082
Greywater	0.0013
Total	**0.00302**
Nitrogen from:	
Urine	0.0107
Feaces	0.00123
Greywater	0.001
Total	**0.01293**

Water consumption per person varies from town to town and through a year, increasing in the summer due to garden and lawns watering. For Christchurch City, peak daily per capita water consumption is up to 2,000 liters, while the minimum is 200 liters, with daily average around 450 liters/person (Ferguson et al., 2003). These numbers include water consumed by industry and commercial activities. For a small community in a rural area, industry and commercial uses will usually be quite small. The typical water consumption rate for household activities (excluding garden irrigation, car washing or swimming pool uses) is about 180-200 liters per person per day. Water use within the household is usually for internal and external (irrigation, car washing or swimming pools) purposes. Basing on the Christchurch City Council Water conservation Report (2002), the internal use accounts for 60% of the annual water use and 40% for external purposes (Figure 27). The major internal water consumers are toilets, laundry and showers (Figure 27), that is why these should be addressed first. Modifying individuals' behaviour concerning water use will result in reduced water consumption, and, thus, in reduced wastewater production. Not all water saving measures will reduce wastewater volume (e.g. garden watering), however fixing dripping water taps, reducing showering times and avoidance wasteful water practice (e.g. teeth-brushing) will lead to wastewater reduction.



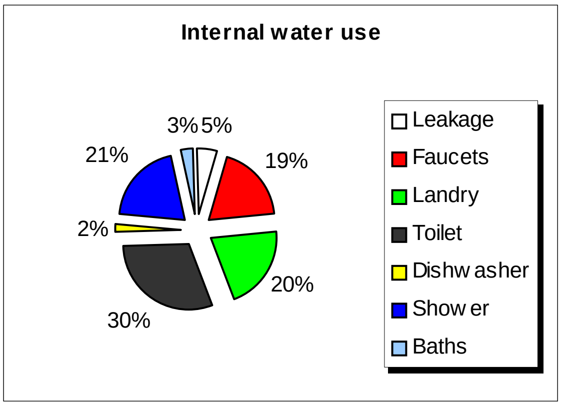


Figure 27: Water use for a single family unit (Christchurch City Council Water Conservation Report, 2002)

Three main categories of water conservation techniques include: *flow reduction, use of water conserving appliances and fixtures, and utility water rates and rate schedule incentives.*

Flow reduction is the least expensive technique to implement. Water can be conserved in the shower, toilet, laundry, and sink faucets with the use of inserts, fixtures, and water saving appliances (e.g. wastewater quantities can be reduced by 15-30% when using a toilet tank insert). New types of flush toilets should be required in new constructions, as well as showerhead flow restrictors are. Different technologies can reduce wastewater at source (Table 15).

Table 15: Technologies to reduce wastewater at source (Ferguson et al 2003).

Aim	Technology
Reduce the amount of water used in toilets – reduces amount of blackwater	➢ Low-volume flush toilets ➢ Vacuum toilets ➢ Urine-separating toilets ➢ Composting toilets ➢ Waterless toilets
Reduce the amount of water that becomes grey water	➢ Low-flow shower heads ➢ Low-volume washing machines ➢ Aerated tap faucets ➢ Controlled-flow tap valves ➢ Pressure-reducing valves
Recycle and re-use of water before it becomes wastewater	➢ Greywater recycling (e.g. washing machine water) ➢ Rainwater collection and stormwater recovery

Water-saving technologies comparison with conventional household equipment is presented in Table 16. Changing to water-saving components can result in significant reduction in water consumption and therefore wastewater output. In 1997 it was found that compared to top-loading machines, front-loading machines used less water, energy and detergent. Low water use washing machines can reduce laundry wastewater volumes by 30%. Usually front-loading washing machines uses less water than top-loading one.

Table 16: Comparison of water use between conventional and water-saving domestic appliances (On-Site NewZ, 1997)

Household water use	**Appliances/fixtures per capita daily flow (litres/person/day)**				
	Toilet	Washing machine	Shower	Washbasins, kitchen, bathroom, laundry	Total per capita flow (L/p/d)
Standard household fixtures					
11/5.5 litre dual-flush cistern, top-load washing machine	38	22	90	30	180
Full water-reduction fixtures					
6/3 litre dual-flush cistern, front-load washing machine, low-flow showers, aerator faucets	22	13	45	15	95
% saving	**42.1**	**40.9**	**50**	**50**	**47.2**

Water conservation can be achieved as a result of economic incentive associated with water and sewer rates and rate structure. For example, a conservation rate structure could have higher summer demand (e.g. for irrigation) provided at a higher rate.
Most studies show a reduction in peak demand than in annual demand, due to higher percentage of discretionary water use at peak periods with savings ranging from 15 to 50% (Jordan 1999, Foxon et al. 2000). Auckland City Council reports higher use of water for non-metered customers, Wellington Regional Council estimates 20% reduction in water use through metering, Rotorua reports 35% lower water use annually, and 50% lower use during summer for metered customers (PCE, 2000; MED 1999). A Parliamentary Commisioner for the Environment report identified charging and pricing for water services as a key issue (PCE, 2000). However, there is a political resistance to flow-based charges, mostly because of the lack of knowledge about that form of water charged, and fear about the commercialization of water services. Additional reason is the low income customers.

5.6.2 Pollution prevention

The polluting qualities of the wastewater are important when considering the measures that might be taken at source to reduce pressure on the wastewater management system, and the final impact when treated wastewater reaches the ecosystem. For example, garbage grinder can increase the biochemical oxygen demand (BOD) by over 35% (Ferguson et al., 2003). Products that are being flushed into wastewater system but should not be include paints, pharmaceutical mixes, antibiotics, hormones, oils and volatiles, pesticides, herbicides, detergents, cleaning agents, polishing agents and others which ingredients can be both a health risk to humans and impact detrimentally on wastewater treatment and eventually ecosystem. As re-use initiatives start in the supermarket (Patterson, 1999), the community should be supported with education and awareness programs to encourage good household practices resulting in healthier and more sustainable wastewater cycle, which will be more integrated with the local ecosystem. Moreover, decentralized management of wastewater flows, greywayer and blackwater separation could also be applied. Additionally, in New Zealand there is commercially available system for greywater treatment and recycling: the East Coast (ECO) Wastewater Recycling System, where recycled greywater is used for toilet flushing and garden watering.

In general terms, examples of improved water and wastewater engineering design and technology options that may be relevant are:

- *Rainwater collection and storage for non-potable uses*. Benefits include reduced demand on town water and reduced stormwater flows;
- *Water saving technologies at the source* (e.g. at home, office or industry). Up to 30 to 40 percent saving are possible in terms of the types of water technologies used (e.g. in Australia, voluntary water efficiency labeling on household technologies was introduced by the Australian Water Resources Council in 1994, using a drop-shaped label with three grading – A, AA, and AAA (the most water efficient) (Cullen et al., 2004) (Appendix A).

Different toilet systems (water-saving - usual dual flush, vacuum and composting) and designs (porcelain, stainless steel and plastic) are available nowadays. For each system there can be an option for urine-separation or traditional non-separating solution producing blackwater. For urine separation a special urine flushing mechanism is installed, which uses less water than the faeces flush.

Vacuum toilets are used in residential units. Cluster of homes may be served by a single vacuum unit. The volumes of wastewater from vacuum toilets are very low and typical daily flush volumes for 1 EDU (equivalent domestic unit, representing a home with the average number of adults for a community; 1EDU= 2.65 adults) are presented in Table 17. The blackwater production is dependent on the type of toilet used, and, urine separating toilets reduce volumes considerably (Table 17). That enables the recovery of the nutrients from the urine (which typically contains 85% of the nitrogen and 50% of phosphorous in the total domestic wastewater stream), and return them back to productive land (Ferguson et al., 2003).

Table 17: Typical daily volumes of blackwater per person for different types of toilet (Ferguson et al., 2003):

Type of toilet	**Total volume per EDU (L/day)**
Conventional (older style with 15 L per flush)	284
Dual-flush (11/5.5 L)	122
Dual-flush (6/3 L)	70
Dual-flush (3.3/1.5 L)	38
Vacuum (non-separating)	28
Vacuum (separating)	7.5
Hybrid	<6

Research carried out by the Swedish Institute for Infectious Disease Control showed that, *E.Coli* and other coliforms die quickly in stored urine, moreover, some microorganisms, such as faecal streptococci and parasite *Cryptosporidium* survive longer than *E.Coli*, and probably some viruses (Olssen et al., 1996). The hygienic risks connected with human urine are a lot less than faeces, and the amount of hormones are very small compared to other sources.

Vacuum toilets are possible to obtain for residential installation, and some are designed to separate urine and feaces. At the moment however, they are not yet available in New Zealand, and there are no proposals for urine recovery under development (Ferguson et al., 2003). In Scandinavia, the application of urine separation and recovery technology has led to conversion of urine into fertilizer at central processing facilities (Olssen et al., 1996). Urine storage tanks next to apartment blocks, enable routine collection of the raw product, and transfer it in bulk to the processing plant. The product is sold later for farm and horticultural use.

Some *waterless urinals* have been installed in a number of men's toilets through New Zealand, each made from fiberglass-reinforces plastic with a special gel-coat surface (Ferguson et al., 2003). The alcohol-based sealing fluid with trap ensures odour control and hygiene.

The interest in *composting toilets* is increasing nowadays. From environmental point of view, there are some advantages: water use is reduced, nutrients and organic matter can be recovered to re-enter the natural nutrient cycle. However, they are more expensive than conventional flushing toilets.

In some countries however, it is not easy to apply innovative approaches due to regulatory barriers. In New Zealand for example, the Ministry of Health concluded that such toilets are not appropriate for full-time household use on residential-sized lots. The most successful systems can be found in holiday recreational areas when controlled management can be provided. The Ministry also points out that once reticulated sewerage is provided, than *composting toilets* cannot be used under the Building Act (New Zealand Building Act, 2004). Special use alternatives can include *composting* and *incinerating toilets*, that could be used in certain situations, e.g. by homeowner choice *composting toilet* or on a difficult site in the case of *incinerating toilets*. These systems can treat only the black water component of a waste stream. In each case however a separate grey water septic system is needed. Both of these technologies require a reasonable amount of lifestyle adjustment and active management. That is why those toilets have been for seasonally-used vacation homes or cottages, as the level of involvement has to be higher than most homeowners expect. The advantages and disadvantages of various toilet designs are shown in Table 18.

Substantial water volume reductions and nutrient recovery can be achieved according to the type of toilet installed. The organic and nutrient loading of blackwater from equivalent domestic unit

(EDU) will not be affected by the type of toilet. The greywater component of domestic wastewater can also be reduced by the use of water-saving technologies. Separating the greywater from the blackwater will enable separate and more appropriate management of these two streams.

Table 18: Characteristics of different toilet designs (Ferguson et al. 2003).

Toilet	Liters/flush	Technical features	Benefits/constrains
Conventional flush	6-15	Single flush	Low cost; high water use; good range of systems available
Dual flush	0.5-6	Double flush	Low cost; medium water use; good range of systems available
Vacuum toilers (discharge to vacuum sewer)	0.5-1.5	Separate vacuum unit required	Low water use; expensive; would need to import systems to NZ; limited range (can only be used in conjunction with a vacuum sewerage collection system)
Urine-separating (discharge to urine holding tank)	0.2-4	Separate plumbing for urine and for faeces	Enable recovery of nutrients; not common in NZ, requires separate urine-handling system
Hybrid or micro-flush (toilet pedestal located on top of pre-treatment tank)	<0/3	Very small quantity of water used to flush	Very low water use; available only from Australia; separate greywater system required
Composting	0-0.1	No water used	Not flushed after use; cleaning instructions are manufacturer specific; requires on-site management of compost and separate greywater system
Dehydrating	0	No water used	No water used; requires on-site management of removed solids and separate greywater system
Incineration	0	No water used	No water used; requires on-site management of removed solids and separate greywater system

New homes units should consider installation of water saving technologies and management techniques, while for existing homes, the economic benefits of retro-fitting water-saving technologies. For example, aerator fittings for shower heads and tap faucets have the effect of increasing the bulk of the aerated water stream, giving a sense of volume but with a reduced real volume of water, which makes it effective in showering and hand washing. Proprietary flow control valves such as Jemflow and Aqualoc are inexpensive, and claim to reduce water consumption by up to 35%. These can be fitted into new homes or retro-fitted into existing once. When water pressure is higher than necessary, causing excessive flow rates, the fitting of pressure-reducing valves will reduce water consumption.

The current wastewater management practices need to change, an access to an array of technologies, ranging from ancient to experimental that can help to manage wastewater more effectively. Resources can be conserved, and energy use reduced by switching to simpler technologies. Pollution prevention and water conservation expands usable water supply. Moreover, the loop can be closed by recycling and wastewater re-use. This approach will help to

maintain the water cycle by returning agricultural nutrients to land rather than discharging them into freshwater sources and keep water in circulation rather than discharging it immediately after first use to sewers, streams, and ultimately, the ocean.
The idea is to recognize that we can reduce the waste of water, the energy consumed, and the pollution of water supplies; and that wasteful approaches need to be replaced or not repeated; while the alternative, sustainable technologies should be applied in communities around the globe.

5.7 System Performance

Many smaller communities will have on-site systems, and the decision for cluster option will depend on the existing performance, or opportunities for improvement. Table 19 provides summary of effluent qualities provided by various on-site and cluster treatment plants.

Table 19: Performance of different treatment technologies for on-site and cluster systems*

	On-site systems				**Clusters**			
	Raw domestic wastewater	**Septic tank**	**AWTS**	**Sand filter**	**SBR**	**Extended aeration**	**Constructed wetlands**	**Packed bed sand or textile filter**
BOD5 g/m3	200-300	120-150	15-40	5-15	3-9	<30	5-15	<5
Suspended Solids g/m3	260-400	40-120	20-60	5-20	2-19	<30	5-20	<5
Total nitrogen g/m3	30-80	40-60** (Gardner et al., 1997)	25-50		2-9	<7	5-30	
Total Kjeldahl nitrogen (TKN) g/m3	30-80	40-60	25-50	30-50			5-30	
Total phosphorus g/m3	10-20	10-15	7-12	5-10	1-10	<8	5-10	
Faecal coliform cfu/100ml	10^6-10^8	103-105	10-103	10-103		<104	300-1000	1000

Note: some of the systems presented here are able to treat raw effluent directly (septic tank, AWTS, SBR, extended aeration); others are secondary and/or tertiary systems requiring some sort of preceding treatment (sand filter, constructed wetlands, packed beds).
* many of these systems can be designed in different ways and built with different sizes to achieve different treatment objectives (e.g. large constructed wetlands will generally work better than a small one treating the same flow).

** Gardner T., Geary P., Gordon I, (1997), Ecological Sustainability and on-site effluent treatment systems, Australian Journal of Environmental Management, 4, pp.144-156

Regional council or other local authorities' rules set the discharge quality requirements for a range of treatment technologies relative to the oversight of environmental effects from discharges. In New Zealand, Councils have the responsibility for managing the potential cumulative effects of wastewater servicing on the natural land and water environment. Cluster treatment plant discharges (as well as centralized) need to be processed via council consents procedures, and issued with a discharge permit to which conditions will be attached (including the effluent quality to be met). Poor soil assessment during the design phase, incorrect design, inadequate attention to installation, or lack of operational and maintenance servicing can initiate failure, which is defined as the inability of the system to perform as intended by the design (Ferguson et al, 2003). Improper use by overloading the system with more people than it was designed for, or the discharge of substances such as fats or paints or chemicals down the inlet sewer line, will also contribute to failure.

5.8 Risk Management

It must be mentioned that communities have to work wit the idea of risk, which involves understanding that problems may arise, the nature of those problems, their potential impact, and the probability of when they might occur. For example, there will be risk associated with the decision-making processes itself; another with each kind of technical solution (e.g. system may reduce the risk of water pollution, but there is that people will not look after them and they will fail). Some examples of risk analysis are presented in Table 20.

Table 20: Example of risks to be analyzed (Ferguson et al. 2003)

Process risks			
Stages	**Risks**	**Possible effects**	**Management**
Gathering information	- People do not understand technical issues - Important information not gathered in time	- Unnecessary conflict over options - Delays - All options not considered - Options cannot be fully reviewed - Time delays	- To find a way to introduce technical information - To find experts who can communicate - To set timetables and not proceed to next stage until people are comfortable with info
System risks			
Issue area	**Risks**	**Possible effects**	**Management**
Treatment Process	- Unable to handle normal circumstances of sewage, - Abnormal – major sudden toxic load - Odour and noise - Plant breakdown	- Treatment system shut down (need for short-term alternatives) - Low risk in normal circumstances - High risk in future (area growing)	- To set standards for normal treatment performance, or, - Resource consents and discharge permit provisions, etc.

Finding a solution is influenced by people's ideas, community vision and objectives, issues and risks, possible options identified, and as a result the best option is chosen. That is why risk management must be present in the form of understanding the issues, identifying risk or hazards, considering consequences of each risk as well as managing the risk (Ferguson et al. 2003).

5.9 Regulations

Water resources face competing demands from uses to support human health, economic development, and environmental services. Water is the perfect example of a sustainable development challenge – encompassing environmental, social and economic dimensions. Reconciling these three aspects through appropriate water/wastewater management is a significant policy challenge for governments (OECD, 2003). While water/wastewater management practices need to be tailored to suit local circumstances – the competing demands for water, etc., appropriate management is necessary. Poor water management will be one of the major factors limiting sustainable development during the next few decades (Hunt, 2004).

There is a gap between understanding and action (OECD, 2003). Governments are responsible for creating an enabling environment in which incentives for investors and for innovators are ensured and in which the interests of the public are secured. Due to Hague Declaration (Ministerial Declaration of the Hague: Water Security in the Twenty-first Century), the common goal is to provide water security in the Twenty-first century, by ensuring that freshwater, coastal and related ecosystems are protected and improved; that sustainable development and political stability are promoted; that every person has access to enough safe water at an affordable cost to lead a healthy and productive life and that the vulnerable are protected from the risks of water-related hazards (OECD, 2003).

The potential for global water crisis is the result not of technological incapacity to sustain the global water cycle so much as of the weakness of political will to adopt sustainable technologies (Hunt, 2004). The only way to avoid water crisis is for people to learn about sustainable alternatives to massive and ecologically destructive technologies, and to insist that their governments embrace these alternatives. Another gap is where the world is and where it might be with regard to the extent and distribution of sustainable water supply and sanitation services (OECD, 2003). Communities complain about the lack of funds to repair leaking infrastructure, while governments processed with costly and economically irrational projects. Moreover, people in the industrial world use highly treated water quality to flush toilets, wash cars and water lawn and golf courses. If the water crisis is to be avoided, these conditions must change (Hunt, 2004).

As the funding gap for centralized systems increases (USDC, 1997), policymakers, at each level, are realizing that decentralized infrastructure is likely to be their primary choice in many areas for foreseeable future, both to remediate existing health and environmental problems and to foster economic development initiatives (e.g. US EPA 1997). As the range of potential solutions changes, there is interest in ensuring that decentralized infrastructure is installed and maintained in economically sound ways and that these systems last as long as possible.

In the long run, legislation governing protection of the environment will continue to become more stringent and be applied more comprehensively (Beck et al., 1996). Moreover, as the infrastructure of pollution control and prevention becomes increasingly complete ambient environmental quality will improve. In addition, it is in the nature of things that the technology for observing the environment will become more complete and more refined, providing access to the dimensions of contamination at ever smaller concentrations over larger spatial domains at yet finer scales of temporal variation (Beck et al., 1996). Public awareness of an improved environmental quality will grow. Pollution prevention and water conservation are important as economic and social activities will continue to generate at least the same potential for contamination of the environment and the need to maintain the operational reliability and performance of applied solution has to be a priority in the long term (Beck et al., 1996).

5.9.1 Relevant legislation - New Zealand

New Zealand does not have a particular piece of legislation that oversees the management of cluster wastewater management other than the Local Government Act 2002. Additional legislation in this case includes Natural Resource Management Act 1991, the Hazardous Substances and New Organisms Act 1996, the Health Act 1956, and Building Act (2004).

When the formal resource consent stage is entered, a formal assessment of environmental effects (AEE) of options is needed under the RMA requirements. The range of effects to be assessed includes natural environment impacts and impacts on people's social, cultural and built environment.

The principal legislative requirements that have to be complied with are:

- *The Local Government (Rating) Act 2002* – especially the provisions in the Section 16 and Schedule 3 relating to target rates

- Section 108 and 407 of the *Resource Management Act 1991*, and Sub-parts 1 and 2 of Part 7, and Sub-part 5 of Part 8 of the Local Government Act 2002 regarding water services and development contributions, respectively
- Section 148 in the *Local Government Act 2002* (being the power to make a new by-law for tradewastes)

The life cycle cost of wastewater treatment systems include: design, construction, operation, maintenance, repair and replacement. Communities must be very careful when comparing costs. Very few grants are available nowadays, as these have been replaced by low interest loans, bonding, service fees and people paying of their pocket as methods to finance most wastewater systems.

The costs of the system, whether it is public or private include (Ferguson et al., 2003):

- Capital cost – the cost of building a new system, or of upgrading or extending an existing one,
- Annual cost of operating and maintaining the system
- Cost of making provision for future replacement (depreciation).

The *capital cost* of providing the new system is not as important as the cost of that is going to have to be paid annually over subsequent years. Sometimes it is better to select a system that is more expensive to built but cheaper to operate and maintain. However, the cost of loan servicing and the amount that is going to be put aside for depreciation are other important matters that influence decision. In terms of public system, there are three main ways of funding this capital cost (Ferguson et al., 2003).

- If the system is small or there are many properties to share the cost, the property-owners involved might agree to contribute a single lump sum, or to pay a capital contribution by installment.
- If sub-dividers and developers are likely to benefit in future, as well as requiring them to reticulate their own subdivisions and developments, contributions may be sought from them.
- The most common way is for the local authority concerned to raise a loan – usually for a term of 25-30 years.

The *annual cost* is made up of direct maintenance and operating charges, loan interest and repayments, provisions for depreciation, and, in case of a council system, an amount for management and general overheads.

There are many way these costs can be shared, however, first it must be agreed how much should be paid by user and how much by the community at large. It varies from area to area, but normally the full cost (or almost all of it), is required to be met by those whose properties are connected, or able to be connected to the new system. Ideally, the method for collecting the annual charges should be one that encourages water conservation, but in reality charging according to the quantity of water discharged is not legally allowed. Methods used include rating according to the land; levy charges per pan or urinal connected (charge may be uniform or according to a scale that reduces un price the greater the number of pans); levy uniform annual charge per rating unit, or per separately retable portion of every rating unit.

The availability of the system also benefits properties that are capable of being, but are not presently, connected, in that the ability to connect increases the value of the land. The owners of non-connected properties usually are required to pay a reduced fee – usually 50-60% of the basic charge. Whether the public system proposed, if it is local authority wastewater system, public consultation and discussion has to be undertaken. Annual plan and future, long-term council community plan has to be prepared. Another matter to consider is how the proposed new system is to be accounted in the future.

A new and significant source of assistance for smaller communities is the Government's subsidy scheme for wastewater systems. It provides small and isolated communities with the ability to develop systems that might not otherwise be able to afford. This assistance is for the capital costs of a project. If the community is considering the scheme, it must be checked if the operation, maintenance and replacement costs are affordable.

In New Zealand, the *Sanitary Works Subsidy Scheme (SWSS)* is primarily aimed at improving sewage treatment and disposal for small, largely rural communities that are unable to fund the necessary upgrades to meet public health and RMA requirements)Ferguson et al., 2003). The main criteria are:

- The health risks posed by each community's existing treatment/disposal system and discharge (priority criterion)
- The environmental and cultural needs will be covered by the scheme to the extent required to obtain relevant resource consents under the RMA
- The size and definition of eligible community to be communities between 100 and 10,000 people
- The maximum subsidy for eligible capital works to be 50% for communities up to 2,000, reducing in a straight line to 10% for communities of 10,000.

- The socioeconomic conditions of the community in question to be considered in reviewing applications
- The size of subsidy to a community sanitary works to be at least matched by an equivalent contribution from the relevant territorial authority, and an undertaking to ensure adequate maintenance and operating arrangements
- The responsible territorial authority to agree that constraints may be introduced as part of the grant agreement to ensure that the benefits of the subsidy are passed on to ratepayers

Traditionally local councils have provided wastewater schemes through their works division or department. This can be via direct labour, or via council engagement of consultants to design the work, arrange tendering of the construction contract, and supervise the construction. The council processes the relevant planning and environmental consents; arranges funding via loans, or direct charges against budgeted capital works funds, and on completion of the work; and funds monitoring, inspection, and operation and maintenance serviced against its operational budget. Two methods of purchasing wastewater schemes have been employed in recent years by some councils, although, the Local Government Act 2002 may have made these alternatives less likely to be utilised. These are design-build-operate (DBO), and build-own-operate-transfer (BOOT) contracts.

The relevant standard is AS/NZS 6400:2003 Water efficient products – Rating and Labeling

- Recycling of treated wastewater for non-potable uses e.g. toilet flushing and garden/lawn watering
- Integration of stormwater and treated wastewater with aquatic ecosystems e.g. wetland and stream augumentation
- Nutrient and water recovery from wastewater for productive purposes e.g. agriculture, forestry, nurseries
- Decentralized wastewater services instead of a centralized, the benefits of these include:
- Because small-bore recirculation is used, this eliminates stormwater infiltration and the consequent very high peak flows to the treatment plan,
- Improved opportunity for water recycling
- Because such systems are more local there is more incentive and opportunity for the implementation of demand management technologies and practices at source,
- More resilient to natural and other hazards
- Large volumes of final effluent are not concentrated at one point,
- Permeable surfaces can reduce stormwater

6. Application of cluster wastewater systems

Already Holdgate (1994) stated that engineers have to work with ecosystem rather than with concrete. To support that, cluster treatment systems may be the best choice in many areas from and environmental as well as economic point of view. Due to advanced technology, a wide spectrum of innovative options are now available that can overcome site constraints while providing high degree of purification. In this chapter the future development scenarios and real life examples are presented to show how alternative cluster wastewater treatment systems can be used to make more complex designs practical and environmentally friendly options for small unsewered communities.

6.1 Examples

7 real-world supporting applications of cluster systems both in New Zealand and in the United States are presented here and these are as follows:

- *New Zealand (*Innoflow Technologies, 2006):
  - Ocean Links Subdivision – Mangawhai
  - The Sands on Onetangi – Waiheke Island
  - Goodland Country Estate – Dairy Flat, Auckland
  - Shoal Beach Subdivision – Aramoana, Hawke’s Bay
- *United States* (Joubert et al. 2004):
  - Island Residential Compound – using advanced onsite and cluster systems to support mixed use while protecting coastal waters
  - Portsmouth Abbey School – using cluster system to maintain multiple use of limited open space
  - Shannock Woods Cluster Subdivision – a cluster system supporting compact design to minimize land disturbance and protect groundwater

6.1.1 Ocean Links Subdivision - Mangawhai

The Ocean Links Subdivision is a 42 section residential subdivision North of Auckland at the township of Mangawhai, in the centre of most popular summer holiday retreats, neighbouring a golf course. Developer’s goal was to create a subdivision consistent with the surrounding location by creating a natural visual impression and ensuring no impact on the environment. A system with very little maintenance was required, capable of providing high level of treatment under highly fluctuating flows, as owners of new houses would only be present for part of the year and during that time the subdivision would be at the capacity of numbers. For primary treatment and recirculation, Modified Effluent Drainage System (MEDS) was used due to terrain requirements. Screened effluent was fed to a recirculating packed bed reactor (rPBR) treatment plant discharging to a planted area via dripline irrigation. Plantings were harvested there and sold to offset maintenance costs. Design constrains included very hilly terrain, minimal visual impact of treatment and disposal system, possibility that Council will develop regional sewer reticulation in the future and highly fluctuating flows from seasonal occupation. All these were addressed and plant was positioned at lowest point with variable grade small-bore sewer. Planting was implemented around treatment plat to provide cover and dripline irrigation to bush resulted in no visual impact. Performance parameters (Table 21) of applied systems in Mangawnai, and the summary of the system is described in the Table 22. The use of MEDS reticulation allows the whole subdivision to be directed to council sewer if required in the future. This was the first MEDS installed in New Zealand.

Table 21: Ocean Links Subdivision - treatment system performance (Innoflow Technologies NZ Ltd.)

Parameter	Required Value*	Expected performance
Odour	None	None
BOD5	20mg/l	<5mg/l consistently
Suspended Solids	20mg/l	<5mg/l consistently
Total Coliforms	1000mnp/100ml	1000mnp/100ml
Discharge Area Loading	Not specified	10l/m2/day at peak flows only
* set values in the resource consent for that project issued by the Northland Regional Council		

Table 22: Ocean Links Subdivision - system summary (Innoflow Technologies NZ Ltd.)

Component	Specification	Comment
Design flow	30m^3/day	42 section subdivision
Primary treatment	Onsite-interceptor tanks (min. size 4.5m^3)	Only two sections required STEPkits
Collection system	Small bore variable grade MEDS	Maximum main line pipe size = 63mm polyethylene
Recirculation tank size	33m^3	All underground
Recirculation pump	2 x Orenco Multi-stage turbine	At peak ~ 8hours run time per day at 0.375 kW/pump
Packed bed reactor area	150m^2	Strategic planning minimized the visual impact of the treatment plant
Treated effluent tank size	33m^3	All underground
Discharge pump	1 x Orenco Multi stage turbine	At peak ~ 8 hours run time per day at 0.75kW
Disposal field	3000m^2	3 sections of pressure compensating dripline irrigation to a planted area

6.1.2 The Sands on Onetangi – Waiheke Island

The Sands on Onetangi is a beachfront apartment complex on Waiheke Island's Onetangi Beach (Figure 28). It comprises of privately owned apartments typically occupied during weekends and holiday periods. Because of the close proximity to the beach, a compact system was required, and Advantex Recirculating Textile Packed Bed Reactor was chosen, as a most suited method for highly fluctuating wastewater production and close waterfront. The solution involved the use of septic tanks fitted with a Biotube Effluent Filter pumped to Recirculating Textile Packed Bed Reactor (rPBR) discharging through a UV sterilization unit to a sectorized low pressure effluent distribution field, installed in deep trenched below car parking area of the apartments (Figure 29).

Figure 28: The Sands of Onetangi (http://www.thesandswaiheke.co.nz/images/aerialview.jpg)

Figure 29: Beachfront apartment complex (Innoflow Technologies NZ Ltd.)

The lack of offensive odour from the AdvanTex treatment plants allows them to be situated close to dwellings. The components of the system and technical specifications are presented in Table 23, 24 and 25. Due to low visual effect, no noise and no odour produced, the system was installed relatively close to the apartments. The size and layout of the treatment plant were important as the only available place for the plant was near the rear apartments (Figure 29). Much of the monitoring and control is managed by remote telemetry unit (RTU), programmed to cater the needs of the site. This allows improved efficiency in maintenance, as information about how the system is running can be known before visiting the site.

Table 23: Sands on Onetangi - design constraints (Innoflow Technologies NZ Ltd)

Constraint	Solution	Comment
Limited area for treatment plant	Utilize small footprint of textile rPBR	Textile Pods adjusted to meet site requirements
Materials needed to be ferried from mainland	Advantex Textile Pods - problem for transport	rPBR process has low biosolids production – reduced costs for removing offsite
Highly seasonal usage	rPBR process designed for peak loading	rPBR has a 100% turndown ration – consistent performance under fluctuating loads
Limited area for dispersal field and septic tanks	Tanks and disposal field both installed below car parking area	Tank risers required extra support to allow trafficability, disposal field installed in deep trenches
Water supply limited	Portion of treated effluent reused for toilet flushing and limited irrigation	Required automatic probe, proportional chlorine injection to ensure recycled water is free of pathogens
Remote location, limited onsite technical support	PBR with programmable control system	Low operation and maintenance requirements assist simple system management

Table 24: Sands on Onetangi - treatment system performance (Innoflow Technologies NZ Ltd)

Parameter	Required value*	Expected performance
BOD5	20mg/l	<10mg/l consistently
Suspended Solids	20mg/l	<10mg/l consistently
Feacal Coliforms	50/100ml	<45/100ml
Chlorine in reuse water	>0.5ppm	>0.5ppm
* set values in the resource consent for that project issued by Auckland Regional Council		

Table 25: Sands on Onetangi - system summary (Innoflow Technologies NZ Ltd)

Component	Specification	Comment
Design flow	$30m^3$/day	Fluctuating flow ~ reached on weekends and holidays
Septic Tanks	3 x $36m^3$	Installed under car park with extra support on riser lids for trafficability
Recirculation tank size	$6m^3$	
Recirculation pump	2 x High Head Turbine	At peak ~ 7.5 ours run time per day at 0.375kW/pump
Packed bed reactor area	$42m^2$	Installed near the back of the section, in front of a large retaining wall
Treated effluent tank size	$47m^3$	
Discharge pump	Existing	Reconfigured
UV Disinfection System	Steriflo Series L2	High transmissivity and low flow rate mean that the CT value is very high
Recycle system tank	4.6m3 water storage, 1m3 Chlorine storage	Dual chamber tank
Disposal	Sectorised Deep Trenches, 5 sectors, 2 trenches per sector	Installed under car park to allow best use of space available

6.1.3 Goodland Country Estate – Dairy Flat, Auckland

Goodland Country Estate is a residential subdivision with 63 sections and a communal 71.85 hectare farm, located North of Auckland. There was a need to treat wastewater from 49 residential homes and a community hall to a high standard to ensure no adverse effect on environment. High wastewater production levels were assumed due to the nature of development, and a treatment plant capable of producing consistently high quality discharge even under high loading was needed. Area surrounding development was largely rural, including farmland, thus, visual impact of the plant needed to be minimal. Moreover, the area chosen for the plant was close to the main entrance of the estate. Placement and size of the plant and land application systems was of importance, as the land is of high value there. The developer chose to make use of the resources created by the land application area by forming planted bungs along the roadside and a large planted area inside the gates to house the application area. This improved general aesthetics and enhanced the rural feel of the development. The idea was to use individual onsite interceptor tanks, feeding to a large central recirculation tank, feeding to a Recirculation Textile Packed Bed Reactor treatment plant discharging to a planted area utilizing pressure compensating dripline irrigation. The area was planted with a selection of New Zealand native trees to provide an aesthetically appealing feature in the subdivision and enhance evapo-transpiration. The summary of the system is presented in Table 26.

Table 26: Goodland Country Estate - system summary (Innoflow Technologies NZ Ltd)

System Components	Specification	Comment
Design flow	60m^3/day	From 49 residential lots
Interceptor tanks	On site for each home, fitted with Biotube effluent filters	Tanks sized appropriately dependent on number of occupants
Delivery system	Prostep Effluent Sewer	Small diameter MDPE pipe laid in shallow trench
Recirculation tank size	58m^3	All underground
Recirculation pump	4 x Multi-stage turbine (4”)	At peak ~ 5.1hours run time per day at 0.75kW/pump
Packed bed reactor area	72m^2	No odour production from treatment plant
Treated effluent tank size	58m^3	All underground
Discharge pump	1 x Multi-stage turbine (4”)	At peak ~ 6.8hours run time per day at 0.75kW/pump
Disposal field	20000m^2	Pressure compensating dripline irrigation to planted area (3l/m2/day at peak flows)

6.1.4 Shoal Beach Subdivision – Aramoana, Hawke’s Bay

The Shoal Beach is a beach in the central Hawke’s Bay, near Te Angiangi Marine Reserve. The goal was to ensure that development did not compromise the coastal environment. The focus was mainly on environment and sustainability, so the design of wastewater treatment system had to follow that approach, resulting in very high standard of water quality, and ways to reuse it. The wastewater from each was stored in individual on-lot interceptor tanks fitted with Biotube

Effluent filters. The screened effluent was then delivered by gravity to rtPBR treatment plant discharging to a planted area utilizing dripline irrigation. Automatically controlled chlorine dosing disinfection system provided high quality recycled water back to each household for controlled reuse. Recycle system allowed reuse of disinfected effluent for toilet flushing and drip irrigation. Moreover, the use of sectorized area allowed redirection of water to dry land for summer irrigation. Specifications of the system are presented in Table 27.

The focus on sustainability meant that design had to reduce environmental impacts. With the use of interceptor tanks and effluent filters flowing to a ProSTEP recirculation system, all the houses were able to gravity feed to the treatment plant, even through the site was nearly completely flat. This resulted in reduced electricity requirements significantly.

Table 27: Shoal Beach Subdivision - system summary (Innoflow Technologies NZ Ltd)

System Components	Specification	Comment
Design flow	$60m^3$/day	48m3 discharge to ground, 12m3 recycled
Collection system	STEG onsite tanks feeding to effluent sewer	
Recirculation tank size	$58m^3$	All underground
Recirculation pump	4 x Multi-stage turbine (4”)	At peak ~ 4.58hours run time per day at 0.75kW/pump
Packed bed reactor area	$48m^2$	No odour production from treatment plant
Treated effluent tank size	$58m^3$	All underground
Discharge pump	1 x Multi-stage turbine (4”)	At peak ~ 4 hours run time per day at 0.75kW/pump
Disinfection system	Continuous chlorine measurement and automatic control with PID capable Bulcometer chlorine management system	Mixing and storage tank installed under control room shed. Controller connected to telemetry system
Land treatment area	$14{,}000m^2$	Pressure compensating dripline irrigation to planted area

6.1.5 Island Residential Compound – Block Island

The advanced onsite and cluster systems are used here to support mixed use while protecting coastal waters. The residential compound, located on Block Island, is an example of how the use of alternative and innovative decentralized systems can enable sustainable mixed-use development at the outer edge of a well-established village but located in a fragile coastal zone. This compound consists of six structures on the parcel that are occupied by different family members (Figure 30). The existing structures were positioned on a dune-like coastal feature between the Atlantic Ocean on one side, and a poorly flushed coastal estuary on the other, that is both nitrogen and pathogen sensitive. Additionally, a small freshwater pond occupies much of the lot. Soils are sandy and do not provide adequate treatment to protect shellfish in the estuary


a)

b)

Figure 30: Residential compound (a), site plan (b) (Joubert et al., 2004)

Municipal drinking water serves the structures, which consists of one-year round occupied home and five buildings that get active summer use (shop, seasonal rentals). This site is on the outside boundary of the town's central village sewer district however sewer extension was not feasible because of the town and regulatory restrictions. The concern was about the opening the area for intensive development, new constructions on lots with high water tables and high flood zones. Decentralized advanced wastewater treatment systems were considered the best solution to protect public health and water resources, while allowing more intensive use of the property. The conventional septic system would have required raised leachfields that needed extensive filling and regarding due to the high water tables and slopes, which would change the whole character of the site without removing nitrogen. However, nitrogen reducing systems were required for this area because of the proximity to the coastal pond and sandy soils with shallow water table, which narrowed down the technology choices. The property was under single ownership, which offered flexibility in using cluster system. Four alternative systems designed to handle flow from the six structures were selected as the simplest and most cost-effective solution. Two of the homes had individual system. The other four homes were grouped into pairs, with each set having one shared system. Each pair of houses was close together with nearby land suitable for a shared leachfield, and each house using a shared system has its own septic tank, with gravity flow to a common recirculation tank, which then pumped effluent to a larger, shared treatment unit, followed by a narrow drainfield similar to the individual systems (Figure 30). Wastewater from homes flows into the septic tank (A) where effluent is recirculated to the media filter (B). Final treated effluent is dispersed to a shallow narrow drainfield (C).

The combination of individual and paired units was considered more practical than one large community system due to lower costs of wastewater collection, treatment units and drainfields, simpler installation and maintenance, no need for maintenance providers. From environmental perspective, a large drainfield would have been located closer to the coastal pond, creating a single discharge point with less opportunity for dispersal through the site and uptake through natural processes. Additionally, multiple systems enable flexibility for changes in flow with seasonal use, with some units closed during the winter time while others remain in use year-round.

6.1.6 Portsmouth Abbey School, Portsmouth

Advanced cluster treatment systems can permit multiple use of leachfield areas, and also accommodate large flows on difficult sites. This example shows how cluster system can maintain multiple use of limited open space, using 12,000 gallons (1 gallon = 3.7854 L) per day at the private high school, enabled multi-use of an athletic playing field for both wastewater treatment and a school sport program. School is located on Aquidneck Island, with gentle hills and silty soils that are slowly permeable with seasonal shallow water tables, and occasional large outcropping. The site was served by public water but the town was unsewered. Faced with poor performance of conventional septic systems on difficult soils, school decided to replace one of the existing systems serving the site with an advanced one that would function more reliably, last longer, and be more cost-effective. The old system consisted of a conventional septic tank with shallow concrete leaching chambers located in an athletic field, and it received only sanitary wastes, eliminating need for additional pretreatment or high-flow storage. The goals for protecting water quality were to ensure system hydraulic function on a site with difficult soils, reduce wastewater strength, so shallow drainfield dispersal could be used (encouraging additional nutrient removal), and to reduce bacteria for maximum protection of public health in a high-use area.

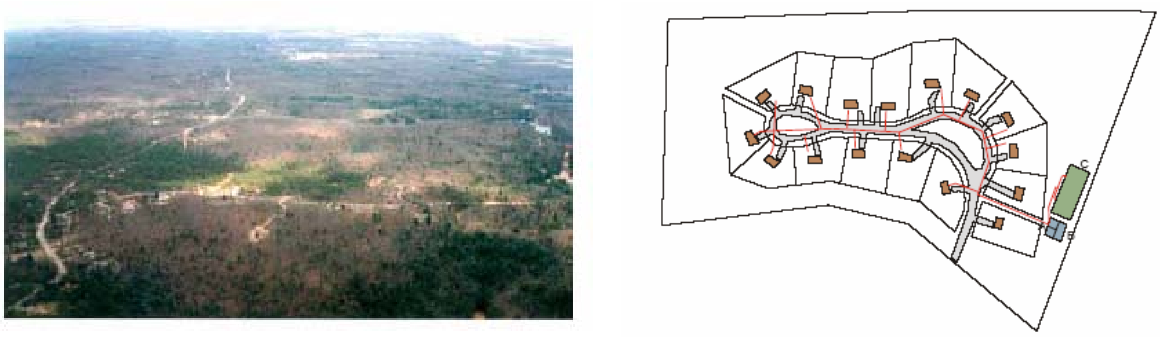
The site drained to well-flushed areas of Narragansett Bay and was outside shoreline buffers, shellfish beds, and sensitive habitat, minimizing the need to reduce nitrogen to extremely low levels. Recirculating media filter constructed in two separate cells was chosen to ensure routine maintenance without disrupting use. The two cells fit into topography at two grade levels following the natural slope, with minimal regarding. The media filters were followed by a shallow narrow drainfield for final dispersal (Figure 31). The shallow narrow drainfield was located in the athletic field. The inspection port covers were buried just below the ground surface with turf grass, and attach small metal plates that it can be located at the time of routing maintenance. The reason not to put them on the ground was that those would interfered with athletic activities and been a hazard to players. Although the playing field is not an ideal drainfield location, it is a workable solution that enables full use of the area as a practice field. As it receives highly treated wastewater, the life expectancy, is expected to be much greater than a conventional one.

Figure 31: School recirculating media filter and the athletic practice field with the shallow narrow drainfield (Joubert et al., 2004)

The system's cost was relatively low; maintenance requirements were simple, the school maintenance staff performed routine maintenance such as monitoring daily water use, checking the effluent filters monthly and cleaning them if necessary. In the event of the power failure, the flows can be diverted back to the leaching chambers.

6.1.7 Shannock Woods Cluster Subdivision

This is an example of a cluster system supporting compact design to minimize land disturbance and protect groundwater, and show how a 27,200 liters per day alternative treatment system can be used on a cluster development to minimize hillside clearing, soil erosion, and scenic impacts, achieving a high level of wastewater treatment to protect drinking water in a highly permeable aquifer recharge area. This 16-lot cluster subdivision, rests on 24 acres, contains 20,000-square-foot-lots (1.858m^2) in a one-acre zoning district (Figure 32b).



a) b)

Figure 32: Wooded Hills (a), Shannock Woods Cluster Subdivision plan (b) (Joubert et al., 2004)

Fifty percent of the site was preserved as open space, and each lot had a private well. Soils were excessively permeable sands and gravel, and water tables were deeper than 1.85m. Due to highly permeable soils, drinking water well contamination was a concern. Additionally, steep slopes posed a particular challenge to septic system design, and excessive erosion and scenic impacts are other major concerns due to hillside clearing (Figure 32a)

The cluster subdivision option was selected to avoid steep slopes and minimize site disturbance. Technology selected provided a high degree of treatment and minimized risks to private wells. Centralizing the treatment component and drainfield area reduced the minimum land needed for the individual lots and kept site disturbance to a minimum while enabling the same number of lots to be built. Building envelopes were designated for individual home sites to avoid erosion in the sloping terrain and reduce disturbance, moreover, the width of the entrance roadway was reduced to avoid loss of trees. Treatment objective in the groundwater recharge area was to protect nearby wells from pathogens and high nitrogen concentration. As a result, a recirculation media filter removing at least 50% of the nitrogen was selected. The treatment train consisted of septic tanks located on individual lots. Effluent flows from these tanks by gravity to two 18,900 liters recirculation tanks (Figure 32b(A)), wastewater is recirculated between the recirculation tanks and the recirculating media filter designed for 27,200 liters per day (Figure 32b(B)). Each recirculation tank doses two of the zones in the filter, and final treated effluent from the media filter is dispersed in a shallow drainfield (Figure 32b(C)) where additional pathogens and nitrogen removal can be expected through natural processes.

6.2. Innovative decentralized wastewater concepts within cluster approach

There is a broad variety of solutions to decentralized wastewater management. Innovative concepts have been introduced in several projects and have proven feasibility. Innovative source separation in cluster approaches does allow adequate treatment if different flows according to their characteristic. Fresh water consumption can be reduced to 80% while nutrients can be recovered to a large extent (Ottepohl et al., 2002). Moreover, source control can be advantageous for hygienic reasons, as low volumes are easier to sanitize. Experiences with urine-sorting systems or vacuum-biogas are available today. New ideas such as black and greywater cycle system are presently researched at the Technical University in Hamburg (Ottepohl et al., 2002). These modular integrated systems do have potential to be installed even in densely populated urban areas without the need for central water and wastewater infrastructure, as recent advances in membrane technology allow such development (Otterpohl et al., 2002). There are ten basic scenarios classifying the variety of combinations of modules in dependence of different geographic and socio-economic conditions around the world are presented by Otterpohl in his work (Otterpohl et al., 1999). Moreover, an extensive overview of realized concepts based on source control has been presented by Paris and Wilderer (Paris and Wilderer, 2001).

6.2.1 Examples

6.2.1.1 The vacuum-biogas concept

An innovative decentralized sanitation concept has been applied in a peri-urban area in Luebeck-Flintenbreite, Germany. At the moment 100 residents are connected to the plant with the capacity of the system up to 350 people that will be living in the settlement when it will be completed (Otterpohl et al., 1999). Grey and blackwater are collected and treated separately; greywater is drained by gravity and treated with a bio-sand filter (vertical constructed wetland), while black water is collected via vacuum toilets in a collection tank. The consumption of water per flush is 0.7L. The material is thermally sanitized and fermented after mixing with shredded biowaste (OtterWasser, 2002). The average water consumption is about 72L/(PE*d), whereof 65L/(PE*d) is greywater (Otterpohl et al., 2002). Moreover, about 90% of nitrogen load can be found in blackwater, thus, greywater is short of nitrogen. Vacuum toilets and drainage pipes are running without failure, while failures caused by users (e.g. cat litter or sanitary towels) are eliminated by users education. As grey water showed relatively high levels of phosphorous due to dishwasher detergents, organizing bulk purchase of good phosphate free brand has lead to decrease in phosphorous concentrations by 60%.
A similar project has been implemented Freiburg-Vauban, in a building with 40 inhabitants (Lange and Otterpohl, 2000). Grey and black water are drained and treated here similarly as in the Luebeck-Flintenbreite project. In Norway, however, the blackwater is treated aerobically thermophilic (Skjelhaugen, 1998). The utilization of vacuum technology for the collection of little diluted black water flow, as well as for blackwater treatment, is functional and available nowadays. However, proper operation, maintenance and staff education is necessary. At the moment, other pilot installations are being planned, and some are already under construction in the Netherlands and China (Otterpohl et al., 2002). The comparative feasibility study of the vacuum and biogas concept combined with urine separation has been presented by AQWA 2100

project group, showing that the additional costs of source control systems for urban systems are relatively small (Herbst and Hissl, 2002).

6.2.1.2 Yellow water with water flushing concept

Separate collection of urine as yellow water is available especially for buildings with public toilets, such as schools or shopping centers. Essential requirements for such toilet system include comfort for the users, little dilution of urine and faeces, as well as satisfactory drainage of both flows (Otterpohl et al, 2002). Urine-sorting toilets (no-mix toilets) are draining urine with or without water, and they allow a simple urine collection (with acid stabilization where necessary), and treatment (e.g. solar drying). Moreover, urine can be worked into brown soils as undiluted fertilizer, however, after dilution with 5-10 fold volume of water, it can be used directly to fertilize grassland. Urine should be stored for approximately half a year. A source separation concept with treatment of different flows renders the re-use of fertilizer where possible (Otterpohl et al, 2002). Separating toilets have been mainly developed in Sweden and are draining urine with more or less flushing water, causing urine dilution and enlarging the storage volumes. New developed separating toilets try to avoid this disadvantage. Sitting on the toilet causes an opening of the urine drain, while upraise causes closure, thus, urine can be drained without dilution of flushing water, moreover, nutrients are collected concentrated for utilization.

In Germany and Switzerland the problem of substances with endocrine activity, such as hormones and pharmaceutics, are being investigated nowadays (Oldenburg et al., 2002; Lambertsmuehle, 2002). Current experiences with urine separating systems show feasible separation and utilization of nutrients. In Linz, Austria, urine separating wastewater system is planned for a part of new settlement, called “Solar City” (88 flats and a school), followed by the idea to utilize nutrients for agricultural purposes. Additionally, in Berlin, Germany, the “Berliner Wassertriebe” intends the retrofitting of a maintenance building for sewage plant with the urine separating vacuum technology (BWB, 2002).

6.2.1.3 Decentralized systems for dehydrating with high solar radiation

There are many technologies for a source control wastewater management including different flow of human excretions (Windblad, 1998; Otterpohl et al., 1999). Some are more suitable for rural, while others for urban areas. Basic technologies for low-technological and low-cost treatment with or without biodegradable waste include (Otterpohl et al., 2002):

- Heating and drying (solar heating, double chamber system) – may be problematic for wet anal-hygiene (~50% of worlds' population, Muslim countries), requires urine separation
- Digesters for blackwater provided sufficient number of users is connected
- Double-chambered soil toilets, after usage over-strewn with soils, requires urine separation
- Composting (often problematic operation, research necessary)
- Low diluting toilets in combination with biogas systems
- Separate urine collection in combination with biogas systems for faeces

Different urine separating toilets have to be specifically adapted to local conditions (Winblad, 1998). In the case of water scarcity, treated greywater is often suited to replace missing freshwater. Moreover, combined with the faecal desiccation systems, it can make the entire system financially attractive. In addition to that, for this flow oriented concept, a project called *EcoSan* (Ecological Sanitation) was established (www.ecosan.de).

6.2.1.4 Reuse oriented processes for black and greywater

The separate collection and treatment of grey and blackwater is the basis of the "black water cycle process" method. Appropriate treatment and reclaiming the toilet flushing water for toilet usage renders a very high concentration of nutrients during daily operation, and this is an important contribution for a new viewpoint in domestic wastewater management. With this patented method (Brown, 2002), (Figure 33), only 1-2L /capita/day of an ideally clear, odourless and colourless liquid nutrient mineral solution will be produced (Otterpohl et al., 2002).

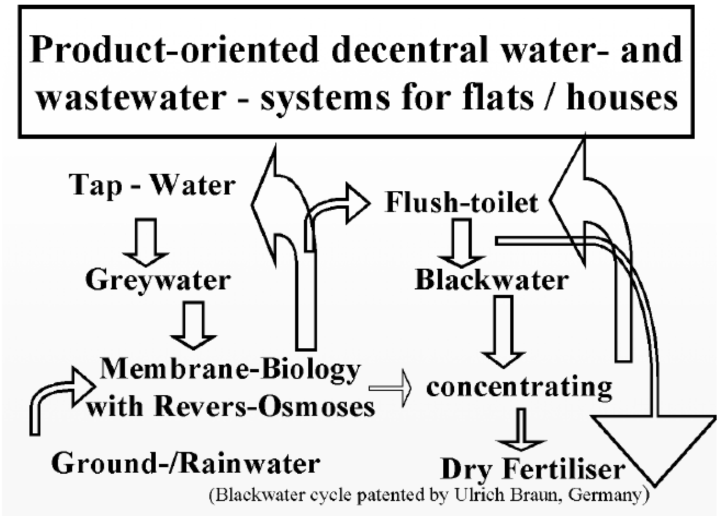


Figure 33: Flow diagram of black and brown water cycle processes (Ulrich Brown, Germany in Otterpohl et al., 2002).

What is more, the wastewater consumption of flushing toilets can be reduced down to zero; independent of the water consumption of specific toilet models by recirculation after treatment. This can be an interesting option for countries with limited water resources. Moreover, high concentrations of nutrient containing toilet-flushing water gives opportunity for new treatment options, and sophisticated technologies become feasible.

Recently, the technology of blackwater cycle became economically feasible with the development of membrane bioreactors. Additionally, this method is possible with urine separating toilets and reciculating “brown water cycle processing” modules (Otterpohl et al., 2002). Feasible connections are above 200 residents, and greywater recycling plants can be applied on housing levels. High quality water recycling as tap water is more accepted as it is the “own” water to be recycled. In addition to that, no fundamental problems are to be expected by the black or brown water cycle processes. Full oxidation of ammonia to nitrate (nitrification) is required; no hygienic or health risks are expected, as the water is treated thoroughly and reused only for toilet flushing. However, a disadvantage is that, by utilizing excess-water for direct fertilizing, nitrate is not as suitable as ammonia. Moreover, the de-colouring of the circulating liquid has been an occurring problem due to concentration of the gallbladder dyes (e.g. Urobillin). Fortunatelly, that problem has been solved by the research work done at Technical University of Hamburg-Hanburg (Otterpohl et al., 2002). Disinfection of black or brown water is a minor problem due to employed membrane bioreactors. The method of black and brown water cycle processes contains a high potential especially in areas where water, energy, or fertilizer are costly or scarce. Moreover, this approach helps gaining water autonomy in settlements. By high number of modules production, competitive water prices can be reached.

6.2.1.5 Adaptation of existing water infrastructures

By subsequent introduction of urine separating toilets with storage tanks, the wastewater systems can be changed into an almost full reuse of nutrients (Otterpohl et al., 2002). Urine separating toilets and additional pipes can be installed during renovation works. As the drainage pipes are already connected, it means toilets are saving water, however, if sufficient number of connections in a neighbourhood is reached, the high concentrated nutrient solution can be utilized for fertilizer production. In case of nets with little external water influx (e.g. no rainwater), and a sufficient slope, the collection of urine can be done by time-controlled emptying the storage tanks (Larsen and Gujer, 1996). If sufficient collection of urine is established, the treatment plant does not have enough nutrients, and requires no N-elimination (denitrification). The remaining nutrients will be incorporated by microorganisms and transported into the sludge. With this method, bigger clusters can reach good nutrient resource efficiently.

Another option is successive de-coupling of toilets and employment of appropriate and decentralized blackwater treatment systems (Larsen and Gujer, 1996). This would transform treatment plant into a grey water treatment plant, and depending on the surroundings, the plant could be converted to water works for reuse. The disadvantage is the necessity of the additional investment costs and maintenance costs. However, the cost of stormwater storage tanks can be reduced by disconnection of blackwater.

6.2.2 Socio-economic consequences and models of operation and impact assessment

Many of the innovative concepts demand only a minor change in the users' behavour, as a different toilet is usually the change, e.g. for males it will be necessary to sit while urinating. The demand for change will generate new comfortable solutions, however, at the moment, the sanitary market is poorly innovative technically (Otterpohl et al., 2002). Another important aspect is the information and training provided to users of an innovative water technology. In many cases, it has been shown, that users are very cooperative and interested. In Luebeck, Germany, users have been shown the dependence between high phosphorous concentrations in the grey water and dishwasher detergent (Larsen and Gujer, 1996). As a result, users started to use phosphorous free detergents. Such actions can change daily routines of residents. Decentralized treatment plants can become very economically priced. Investments in decentralized wastewater streams flow into production and maintenance of plants, creating more jobs. For example the concept in Luebeck created one job for a caretaker including technical management of energy and water technology with total costs of system plus labour not higher than for conventional wastewater services (Otterpohl et al., 2002). Professional management of operating innovative water systems is of utmost importance. Local private operating companies or cooperatives are ideal legal options. Regular maintenance by external company is also suitable in case of small units. Additionally, considering catastrophes like earthquakes or floods, conventional systems are highly sensitive (e.g. New Zealand). Impact assessment points out, that failures of decentralized systems are rarer, comparing to central (Larsen and Gujer, 1996). The risk of many decentralized concepts can be effectively minimized by professional maintenance and modern sensor-based controls with alarm messaging and remote inquiry.

7. Case Study: Upper Hakatere Huts, Ashburton, New Zealand

The study presented here analyses the current wastewater management and tries to find an optimal solution for wastewater handling in the Hakatere settlement, Canterbury, South Island, New Zealand. As number of property owners in that community has been experiencing problems with their wastewater disposal systems, a new way of dealing with wastewater has to be found (Ashburton District Council). Different solutions developed by Ashburton District Council, by independent consultant, and some other ideas are presented here, showing different possibilities to deal with wastewater issues in that area.

This study was carried out by conducting a field survey to number of house owners in Upper Hakatere Huts; moreover, consultation with Ashburton District Council as well as with independent consultant, Dr. Anthony R. Taylor from Irricon Consultants in Ashburton was undertaken.

The primary focus here is on the new solution to wastewater management through cluster approach. Additionally, options proposed by the Council and social response to new these solutions are also analyzed here. This study identifies options for wastewater, and assesses them in terms of the range of issues. The purpose is to help to make a decision on future wastewater services for that, as well as for areas with similar issues.

7.1 Background

7.1.1. General

Hakatere (Upper and Lower) is a small coastal settlement, primary holiday baches, on the north side/terrace of the Ashburton River Mouth, located about 20km from Ashburton (Figure 34). This coastal settlement consists of Lower and Upper Huts (Figure 35), situated on both sides of the River Road. The total number of dwellings is estimated to be 115; with 58 in the Upper Hakatere (59 including one vacant property), and 56 in the Lower Huts (Appendix B).

Figure 34: Part of South Island Map 1:4,000,000 (www.multimap.com)


a)


b)


c)


d)

Figure 35: Hakatere Settlement: a,b) Lower Hakatere Huts; c,d) Upper Hakatere Huts

Historically, the Hakatere community was a less-frequently visited holiday location (Figure 36), with population swelling around the summer time due to holidaymakers and visitors. Additionally, each property was responsible for providing and maintaining their grey-water and sewage disposal system (Ashburton District Council, 2005). Residents own the Huts but not the land, as land belongs to Hut Holder's Society.

Figure 36: Holiday Baches at Lower Hakatere, 1974 (Christchurch City Library)

As the settlement has developed, many of its residents live there on permanent basis. This shift has resulted in difficulties for property owners to manage the increased quantity of household wastewater. Substandard operating existing disposal systems are posing a significant health risk to the occupiers as well as to neighbours of the affected properties. Moreover, some cases, where disposal systems have failed entirely and where no treatment is provided, still exist. In the worst cases some people are using public toilets. The use of Hakatere huts presents a challenge for wastewater management, particularly when dealing with permanently occupied summer/holiday homes.

The freshwater supply for Lower Hakatere settlement is serviced from a private supply (Ashburton District Council). In the case of Upper Hakatere Huts, installation work of water supply was completed in May 2005 (Appendix B). Before that upgrade, the water was not suitable for drinking, and often barely for washing. How bad the water supply was could have been seen in the content of the backwash storage tanks, which hold water out at the filtration process. The new water supply system is servicing 58 properties in the Upper Hakatere and it was designed for expansion in the future, due to growth expectations. However there cannot be any development without proper wastewater management in that area, as the freshwater consumption is directly related to the volume and quality of wastewater produced, treated and disposed. Ensuring adequate wastewater management at present and for the future is a chief concern of local officials as well as residents of Hakatere settlement.

Hakatere is a small community with a large number of people in a small area. That is why it is necessary to make sure that wastewater is handled in the right way. In addition to the need to protect environment, as well as follow strict environmental regulations, another motivation factor towards properly managed wastewater in Hakatere, was concern about residents' health.

The rules of Environment Canterbury, as well the location of the settlement in the Hakatere Ashburton River Mouth, and the community layout, will make it difficult for individual property owners to deal with wastewater treatment and disposal issues in the future.

At the moment each individual property owner has a responsibility to treat and dispose their wastewater. As some issues connected with a number of individual disposal system have developed, in mid 2005 a number of property owners approached consultant – Dr. Anthony Taylor from *Irricon* – requesting information on disposal options. At that point there were eight property owners with serious disposal problems, four of these listed as critical (Irricon).

As a result, Council become aware of the number of issues relating to wastewater disposal at the Upper Hakatere (Ashburton District Council, 2006), and undertook development of wastewater management solution for that coastal settlement, suggesting a community based system as a long-term, cost effective option.

As decision making process is based on consultation with a community interested, options proposed by the Council, as well as by the consultant were considered carefully by the community.

7.1.2 Options proposed by Ashburton District Council

In order to deal with wastewater issues in Hakatere settlement, different options were suggested by Ashburton District Council and these were as follows:

- Do nothing and work with individual property owners on the case by case basis
- Pursue a community based scheme on a staged basis dealing with properties experiencing problems as they arise
- A community based scheme

Public consultation was undertaken to determine the level of community support for the provision of a community based wastewater collection, treatment and disposal system at the Upper Hakatere settlement by Ashburton District Council. In August 2005, a preliminary consultation in Hakatere settlement was undertaken to provide information on possible servicing of the Upper and Lower Huts with a community-based reticulated wastewater system and see community attitudes. General options identified included:

Option 1 - *Individual On-site Wastewater Management*

This may be an appropriate long-term solution for some of the larger lots in the Upper Hakatere settlement as long as their average daily discharge does not exceed 2000litres/day. However, most properties are of insufficient size in terms of available land area for onsite wastewater treatment and disposal to meet legislative requirements.

Option 2 - *Modular Community Wastewater Scheme (two options: for 20 lots and for 58 lots)*

This solution could deal with properties experiencing problems as they arise. This option would initially service the high priority properties. The reticulation collection system could transport household wastewater to a common treatment module and disposal area. Additional modules could service the rest of community as required.

Option 3 - *Complete Community Wastewater Scheme*

This option is fully implemented in its entirety from the outset. This option would service all properties in the settlement and would provide the highest level of service to the community.

Costs of proposed options are presented in Appendix C. As a result of different technologies, some systems become more cost effective when serving larger number of properties. If community based wastewater scheme was chosen, the support from Council's funding policy relating to new schemes, would contribute 20% of the capital construction cost. The balance of the capital costs has to be met by the property owners (loan funding or lump sum payment).

However, before any particular system is chosen, decision about how the community wants to proceed has to be made The result of consultation process indicated a small majority support (55% of submitters) for a community based wastewater scheme (modular or full). A full wastewater was suggested to be the most cost effective long-term solution for the community. The scheme provides reticulation from individual lots to centralized package treatment plant located adjacent to River Road. The package will treat wastewater to a high level using ultraviolet sterilization. Treated effluent will then be pumped via a rising main and irrigated on a block of Council owned land located approximately 2km from the settlement.

Further consultation (Appendix D) into providing a full community wastewater scheme to both Upper and Lower Hakatere communities was undertaken. 115 documents were sent to gauge residents support or otherwise for a full community scheme and ask about existing wastewater disposal (Table 28, 29). Out of all submissions, 27 did not indicate their type of disposal system, and some of the septic tanks were past their use-by-date (Ashburton District Council, 2005).

Table 28: Existing wastewater management practices in Upper and Lower Hakatere Huts.

Disposal system		No. of Subdivisions	% of Subdivisions
Septic tank	Owned	17	17.9
	Common	37	38.9
Long drop		5	5.3
Holding tank	Owned	2	2.1
	Common	3	3.2
Soak pit		7	7.4
Other		1	1.1
Do not know		4	4.2
Did not indicate		27	28.4

Table 29: Submission on wastewater proposal for Hakatere settlement)

Settlement	Documents sent	Total submissions	% Return		No. of submissions	% of total submission	% of affected properties
Upper Hakatere	59	47	**79.7**	Do NOT support	29	61.7	49.2
				Support	17	36.2	28.8
				Did not indicate	1	2.1	1.7
				Total	47	100.0	79.7
Lower Hakatere	56	48	**85.7**	Do NOT support	45	93.8	80.4
				Support	2	4.2	3.6
				Did not indicate	1	2.1	1.8
				Total	48	100.0	85.8
Hakatere Combined	115	95	**82.6**	Do NOT support	74	77.9	64.3
				Support	19	20.0	16.5
				Did not indicate	2	2.1	1.7
				Total	95	100.0	82.5

The response rate was 82.6%, which equals 94 submissions received. 38.9% are septic tanks serving more than one property, especially in the Lower Huts, where septic tanks are servicing up to 4 or 5 dwellings (Table 29). The support for community based system was only 4.2% for

Lower and 36% for Upper Huts In general, however, 20% support was considered insufficient to proceed with implementation of combined community scheme to service both Lower and Upper Hakatere.

The support in the Upper Hakatere (36.2%) was considered too low to proceed with scheme to service Upper Hakatere alone. Issues that were raised by submitters included too high capital and operating costs, lack of funding, as well as the responsibility of properties with disposal issues to take care for own problems.

As the need to upgrade wastewater management in the Hakatere settlement was growing, main important issues arising from not well functioning wastewater disposal had to be considered, and these included (Ashburton District Council, 2005):

Public health protection. In some cases the existing disposal systems have failed, which resulted in untreated effluent contaminating the ground near the point of disposal. The likelihood of people coming into contact with untreated effluent is significantly increased and poses a serious health risk.

Compliance with existing and impending legislation. Environment Canterbury has notified proposed Natural Resources Regional Plan (NRRP) for the region, and under this plan, the area, location and community layout at Hakatere may make it difficult for individual property owners to deal with wastewater treatment and disposal issues in the future. Moreover, the existing long-drops and tank systems may not be sustainable. Additionally, the Ministry of Health requires that all households have a means of removing wastewater. What is more, properties not experiencing problems at the moment, may in the future be compelled to met new legislation

Water quality. The water supply for Hakatere is drawn from a groundwater bore some distance from the community, and it is (Appendix B) unlikely to be directly affected. However, the existing disposal systems are contaminating the surface soil, which may lead to increase the risk to water quality, due to water pipes traversing the contaminated areas.

Availability of land for effluent disposal. Any wastewater improvements in Hakatere have to include the suitable for treatment and disposal land available. On-site wastewater treatment and disposal for individual properties less than 800m2 may not be feasible due to land area required for disposal and the set backs of the disposal bed from property boundaries. That is why it is more convenient for the Council to find suitable land for a community-based scheme than to have an assortment of smaller less-efficient disposal systems.

Affordability and ability to pay. The cost implications of funding may place a financial burden on some property owners, especially those on fixed incomes. The benefits to property owners taking parting a community scheme include 20% Council contribution and the ability to repay the capital cost through rates. In cases of significant financial hardship, two schemes may provide assistance to subject meeting the qualifying criteria. First is the Rates Remission & Postponement Policy (draft ADC Policy); and Rates Rebate Scheme (Department of Internal Affairs).

Reliability. Any replacement system needs to be reliable and capable of meeting the requirements of the community on a consistent basis, which can be implemented, managed, operated and maintained by the Council.

Sustainability. Significant health risk currently present points out that the existing situation is not sustainable in the short to medium term. A long term sustainable approach is necessary.

Future property values. There will be an impact on the general market value for properties in the Hakatere area, as the Council has a requirement to pass on to potential property buyers (when requested) all relevant information held about a given property. If the Hakatere community was served by a community based wastewater system, it is likely the property may be more attractive and subsequently may command a higher price in the market.

Further investigation was necessary, that is why Opus International Consultants Ltd. was involved by the Ashburton District Council to investigate possible solutions to wastewater management in the Upper Hakatere. The system proposed by Opus has been designed to service the Upper Hakatere community (59 lots) and comprised of *gravity reticulation laid throughout the settlement, collecting at the coastal end of River Road, followed by 'Package' wastewater treatment plant (WWTP), and disposal field.*

Connecting gravity sewer reticulation using DN150 PVC-U sewer mains and 1050mm diameter concrete manholes was proposed. The reticulation was to be placed within the road reserve, avoiding seal where possible. Fall was in a general west-east direction. A number of package systems were suggested from the following suppliers: Innoflow Technologies Ltd., Oasis Clearwater Systems Ltd., Smith and Loveless and Wedeco Ltd. Package refers to the self-contained nature of the systems that comprise primary sedimentation tank or chamber where most of solids settle down. The solids have to be periodically pumped out and disposed of off-site. Tank can be also used as a buffer/balance tank to ensure even application of effluent onto the textile media. Textile is usually a type of synthetic material formed into a honeycomb pattern enclosed in a second tank/chamber. As the effluent passes over the textile, a film of microorganisms grows on the surface and digests the biodegradable effluent. The treated effluent passes through the final filter before it is discharged to the disposal field. The layer of microorganisms on the textile media surface will continue to grow until it falls off as a layer of sludge at the bottom of the tank and is pumped out and disposed of.

Among four systems considered, the one recommended was Rotating Biological Contractor (PMT Bio-disk) – Wedeco Limited, with UV treatment to reduce E.Coli levels. The textile media in this system is a series of discs on a rotating shaft, which keeps the system aerated. The wastewater enters a three-chamber primary sedimentation tank where solids are removed, and clarified water flows over weirs to the secondary treatment stage. Disks are attached to a horizontal rotating shaft. Biological film grows on the discs and is aerated as the discs rise out of the water. Treated water from RBC flows to a separator where heavy sludge slides down to a sludge hopper. The sludge is removed periodically from the primary sedimentation tank for off-site disposal. Clarified water from the separator flows through an enclosed UV reactor for tertiary disinfection treatment. Treated effluent is conveyed to the disposal field site. Other systems considered by the Council included:

Packed bed reactor: Interceptor tanks (septic tanks) for pre-treatment at each dwelling and small diameter flexible sewer reticulation to the treatment plant. The effluent is dosed evenly over a textile media and trickles through with a certain amount of recycling before discharge. (Innoflow Technologies Ltd.)

Packed Bed Reactor: The effluent is spread evenly over a textile media and trickles through (keeping the system aerated). There is a certain amount of recirculation of the effluent before the treated effluent is discharged. (Oasis Clearwater Systems Ltd.)

Fixed Activated Sludge Treatment: The textile media is submerged and the effluent is circulated around the media with an air blower to aerate the effluent (Smith and Loveless Ltd.)

The treated effluent disposal method was to utilize subsurface drip irrigation in accordance with ASNZS 1457:1999 with evaporation/transpiration assist. This method was chosen in preference to spray application which may result in odour complaints.

Other options consider by the council included *Ocean outfall* – however, extensive investigation and mitigation measures required in order to obtain resource consent. Potentially very expensive; and *small cluster treatment and disposal* – may be difficult obtaining resource consent due to accumulative effects and community drinking water supply protection zone.

Three general layout options (Appendix E) were considered in the development of the proposed scheme for the Hakatere community. These dictated the actual location of key components of the scheme and will directly influence the final cost of an implemented scheme.

<u>Layout 1</u> (Appendix E1)
Pump station located at end of River Road to pump raw sewage 2km to the treatment plant and disposal at old gravel. Treatment plant and disposal field on ADC land on River Road (2km north of settlement)

<u>Layout 2</u> (Appendix E2)
Treatment plant at the coastal end of River Road pumping to disposal field in council forest upstream from community bore; and disposal field in the forestry block at the top of settlement

<u>Layout 3</u> (Appendix E3)
Treatment plant at the end of River Road, pumping treated effluent 2km to disposal field at old gravel pit, and Disposal field on ADC land on River Road (2km north of settlement)

Layout 3 was recommended as the most cost effective option (Appendix E3). Advantages and disadvantages able to be removed or mitigated to some manageable level were identifies and are listed in Table 30. Proposed servicing would include 115 potential dwellings. It included pipelines with 80-100 year life expectancy, connections to existing drain within each property, package treatment plant, and disposal field. The quality of the effluent at discharge would be BOD 30mg/l, suspended solids 20mg/l and E.coli 1000cfu/100ml. Moreover, monitoring of nitrate in the disposal field would be carried out to determine whether additional nitrification needs to be undertaken. In case further reduction of nitrogen was necessary in the effluent, this would increase the total cost by additional NZ$130,000 (EUR 75,000) for another PMT bio-disc unit. Opus International Consultants analyzed normal and peak flows in order to estimate the volume of wastewater generation (Table 31).
Additionally, there is a possibility for government funding through the Sanitary Works Subsidy Scheme (SWSS) that is managed by the Ministry of Health. In the case the proposal was eligible, the project could receive up to 50% subsidy on the capital cost of the project (excluding resource consent costs). The balance of the capital costs would have to be met from the property owners and the calculations in Table 32 are based on the 20% Council contribution.

Table 30: Summary of options

Option	Advantages	Disadvantages
Option 1 (NZ$700,000) (EUR 350,000)	No smell from treatment plant Disposal field meets required setback distance from community supply well	Expensive pump station and rising main to pump raw sewage to treatment plant Potential smell for residents across River Road at treatment site Most expensive maintenance costs with large pump station Limiting horizon in soil profile benath disposal field May require reworking existing soil profile or lower application rate to improve long term acceptance of effluent
Option 2 (NZ$560,000) (EUR 280,000)	Save on pumping and rising main costs - small pump station and shorter rising main to disposal field	May have smell from treatment plant Difficult and expensive to obtain resource consent with disposal within Community Supply Drinking Water Protection Zone Potential to contaminate drinking water Larger area required for disposal field as lower allowable application rate
Option 3 (NZ$530,000) (EUR 265,000) **Recommended option**	Cheapest option Save on pumping and rising main costs- smaller pump station and cheaper rising main as pumping clean effluent Disposal field meets required setback distance from community supply well Cheaper maintenance costs	May have smell from treatment plant Limiting horizon in soil profile beneath disposal field May require reworking existing soil profile or lower application rate to improve long term acceptance of effluent A land swap with the farmers leasing the dump site may find a more suitable site closer to the treatment plant and with improved soil characteristics

Table 31: Flow calculations

Normal flows	Peak flows
➢ 59 lots, approximately ¾ full time ➢ Assume 2 people/lot (118 people) ➢ Assume 220 l/person/day* ➢ ~ 26m3/day	➢ Normal residents x 1.5 peaking factor** during summer months (177 people) ➢ Add 30 campers and 10 day trippers (total 217 people) ➢ Assume 220l/person/day* ➢ ~ 48m3/day
* flows assessed by comparison to the historical water use, taking into account seasonal fluctuations and 25% increase in summer for irrigation. ASNZS uses 200l/person/day, hence 220l/person/day is conservative ** instantaneous peak flows are smoothed out in pre-settlement taks, the peaking factor is for daily flow	

Table 32: Cost estimate per property owner:

	Payment Option One Annual Charge per rateable property or hut* (NZ$)	Payment Option Two Lump Sum Contribution per rateable property or hut* (NZ$)
One-off Costs		
Lump Sum Payment	-	$6,535
Annual Costs (Per Property)		
Estimated Rates (Operating Costs)**	$208	$208
Annual Charge for Loan Repayment***	$538	-
TOTAL	$791 (EUR 345) incl GST/year	$208 (EUR 104) incl GST/year
Notes: * all costs are per rateable property or in the case of Lower Hakatere per Hut ** operating costs based on manufacturer’s recommended maintenance requirements *** interest calculated on 25 year loan period at 7.5% interest rate		

Any remedial work or scheme development will have to meet the requirements proposed by NRRP, both for individual or community based solution. Resource consent is required for the discharge of sewage effluent to land as the discharge volumes are greater than allowed for permitted status. Setback distances from boundaries as identified in the Environment Canterbury proposed NRRP may reduce the land available for disposal. This may be a problem for option 1 and 3, of application rates lower than 6mm/day are required. Moreover, nitrogen levels in groundwater are a serious concern and may also be a priority for a consent application to discharge sewerage effluent to land upstream of a community water supply bore. The normal wastewater flows are expected to be half the peak flows, and the option for additional nitrification proposed by Wedeco was an additional bio-disk unit. Hence, the nitrification effluent quality should be met during normal flows with a single bio-disk unit.

At the point, there was a lack of information available to the residents, as they realized it by reading about their situation in media. There is a lot of opposition to this proposal, as there are different needs and views about how to deal with this matter, it is difficult to find a good for all solution. At the moment consultation is still undertaken and the deadline for submission is not fixed, however when the NRRP will be approved, property owners will have to do what Council decides to, if no other solution will be found.

7.1.3 Public response and concerns

Options for wastewater management in Upper Hakatere Huts were proposed by Ashburton District Council however, none of them suited the needs of people living there. As some issues connected with a number of individual disposal system have developed, in mid April 2005 a number of property owners approached a consultant, Dr. Anthony Taylor from Irricon Consultants, Ashburton, requesting information on management options. At that point there were eight property owners with serious disposal problems, four of these listed as critical (irricon). Dr Taylor was engaged to carry out a study in order to provide best practicable options for wastewater treatment and disposal for Hakatere settlement. At present, each property is responsible for its own wastewater treatment and disposal systems. However, due to issues developing with a number of individual disposal systems, the need to upgrade wastewater management became crucial.

Low response to proposed community scheme has still led the Council to further investigate the option, which actually, was not a community preference because of financial implications. Cost estimates given to residents indicated that putting in private septic tanks would be more expensive than connecting to the proposed community scheme. The greater cost of putting own septic systems is probably one of the reasons a number of homeowners that indicated an interest in community scheme.

People become a bit suspicious, because investigated option was not satisfactory to community. If the proposed community wastewater scheme were to go ahead, with significant further rate increases for those who chose to pay off the cost of their connections, some residents on fixed incomes would have to sell up and leave Hakatere.

In addition to that, lack of information and communication between homeowners and Council has led even to higher to opposition. Nothing was explained. Another thing was that some lots have already existing well functioning on site systems; people have already put money in their systems, and to give up give up what they have in order to have community based scheme would make it difficult for them. That is why, homeowners started to look on the possible option to wastewater management in the Upper Hakatere on their own. People there want better solution than new scheme, and they want their will to be considered. Especially if there would be a chance to use some units of the existing systems (septic tanks and pumps).

7.2 Survey - Evaluating Community Response Towards Wastewater Management in the Upper Hakatere Settlement

The different needs of the Council and homeowners has pointed out that community based scheme is not the best option for Upper Hakatere, as the solution has to represent preferences of the people living there. It means that there is still a possibility and time to find appropriate solution to deal with wastewater in Upper Hakatere, solution that meets the needs of residents. In order to find out what are these needs the idea to prepare a questionnaire developed. Undertaking the Survey in this area allowed finding out people’s opinion in that field and helped estimating people’s preferences towards future wastewater management in that settlement, moreover, it provided information necessary to find an appropriate, innovative and cost effective solution.

The Survey called: *Evaluating Community Response Towards Wastewater Management in the Upper Hakatere* Survey was undertaken to:

- Develop a more comprehensive and accurate understanding of end-user-response to various wastewater management and technology options, in order to evaluate whether and how there might be an opportunity of introduction of new technologies or approaches.
- Assist/support Case Study/cooperation with Irricon consultancy and to gain a better understanding of user's attitudes and preferences toward wastewater system and management options.
- Identify customer attitudes regarding water quality and the adequacy of their existing wastewater management (infrastructure/systems), alternative wastewater solutions
- Identify contextual factors affecting customer attitudes and preferences related to wastewater issues
- Identify tradeoffs customers make between wastewater management options and their willingness to pay for wastewater management system
- Identify how different types of customers would make decisions about wastewater solutions differently

7.2.1 Methodology

To address these goals of that survey, a questionnaire was developed (Appendix F) under supervision of Dr. Anthony Taylor from Irricon Consultants, and, Magdy Mohssen, Lincoln University.

The Survey was conducted in the period from the end of March till the end of April 2007. Questionnaire consisted of five sections including: *General Information, Wastewater Management at Present, Attitudes Towards Proposed Wastewater Management, Willingness to pay, as well as Attitudes towards New Approaches and Technologies for Wastewater Management.*

Questionnaire forms were delivered (beginning of March 2007) to each mail box in the Upper Hakatere (59 lots) while meetings were appointed three weeks later. All homeowners were chosen to take part in that survey as the issue of wastewater management in the Upper Hakatere involves each homeowner.

Completed forms were collected in the period of one month (five visits on the site at different times), and information gathered was summarized in the MSExcel® document, and responses were analyzed. Basing on the results, recommendations made in the thesis could be applied for that settlement as well as could be of advantage for other small communities facing similar wastewater issues

As main source of information was gained from filled questionnaires, and from talking to people while collecting forms, however, additional sources of information were used as well, and these included:

- *Consultation*

  In order to better understand situation with wastewater issues in the area, a consultation with Dr. Anthony Taylor from Irricon Consultants (60 Cass Street, Ashburton, New Zealand) was undertaken. Additionally, cooperation with community representative living in Upper Hakatere Huts, Mr. Peter Opthoog, took place.

- *Documents*

  Documents concerning wastewater management provided for Upper Hakatere residents by Ashburton District Council were analyzed, and these included newsletters with proposed options, reports, survey results, consultation outcomes, etc. Moreover, two reports from Ashburton District Council with investigation of different wastewater management options and costs estimation, undertaken by Opus, Christchurch, were analyzed. Additionally, detailed maps of the Upper Hakatere provided by Dr. Taylor were used to investigate and propose potential solutions to wastewater handling in that area.

Delivering and collecting forms allowed talking to residents and get the impression about the community itself, as well as attitudes towards wastewater issues.

7.2.2 Results

The Survey was conducted in Upper Hakatere Settlement, aimed to cover all households there (59 lots), however, actually 30 of these were approached, and these responded to the survey (50.80% response rate) (Figure 37). Among 30 responses, 16 residents (27.12%) completed questionnaires, while 14 (23.72%) preferred the interview approach to define their attitudes and issues towards wastewater management in the Upper Hakatere Huts. Additionally these people stated the reason of not filling the forms provided. Summary of results is presented in Appendix G.

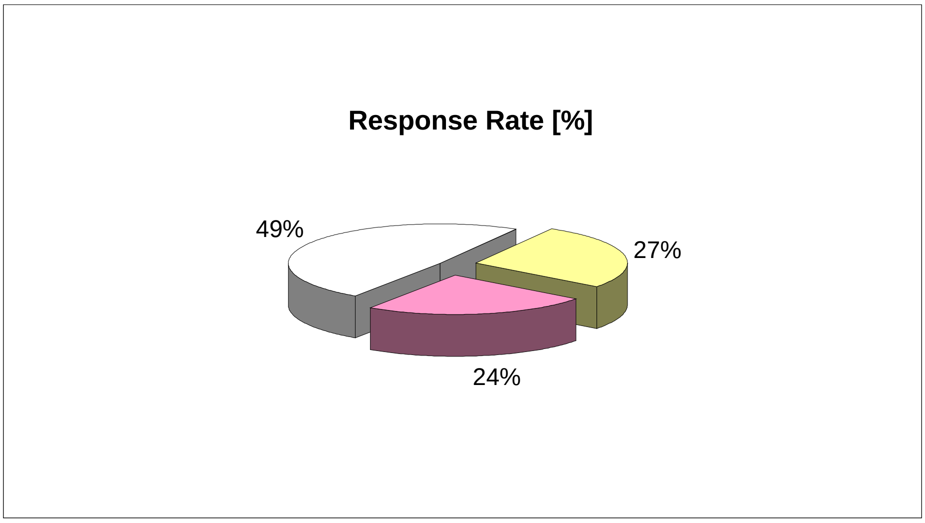


Figure 37: Response rate

An interest was noticed in the survey, however, the sample community has already experienced some troubles with consultation and cooperation with Council, some people were disappointed, some annoyed, thus, some respondents were more interested in the interview approach, than filling out questionnaires. As the expression of their attitudes and issues towards wastewater management in the Upper Hakatere via conversation was more convenient for them (Figure 38 category *Returned but not completed*, 24%). People in that group were either supporting community scheme proposed by the council, or not interested in that topic anymore, as the previous experiences with that issue were not satisfactory and only created troubles.

That is why it was necessary not only to deliver questionnaires to be completed, but also talk to people to gain understanding of their situation and attitudes.

However, some people were not reached during survey period (49%) and these consist of people that were not present in the house (e.g. at work, on holidays, etc.) during that time, as well as the houses that were empty (for sale) or holiday houses (Figure 37 category called: *People not reached*). Some information about the situation of these was obtained from consultation process undertaken with Dr. Taylor.

General Information

Basing on the results, most people in the settlement that have filled the questionnaires were older than 61 and retired, with most of them on fixed incomes. About 81% of these lives there permanently with their families (Appendix G). The number of people among the year in most of the houses stays constant (1, max. 2 people), while in some it changes up till 6 people during holiday season (e.g. summer holidays, Christmas, etc.).

Wastewater Management at Present

Most people have own or common septic tanks (81%) that are designed as a permanent method for wastewater management; while some of the residents have holding tanks within their lots. Both systems' age varies between 3 and 40 years old, however 50% of respondent do not really know the age of the system. These people are very satisfied with their existing systems as well as they are aware of the treatment level their wastewater receives. Moreover, no problems with these systems were recorded within the last five years, and tanks are regularly being emptied by local companies. The estimation of the satisfaction with the system performance is presented in Figure 38.

As the level of satisfaction is high, respondents do not really want new solutions, as their systems are reliable, and they see no need for additional expenditures for new systems (75% of these people has permanent solutions installed). Especially, as there is no one solution, that could work for everybody. For these people the idea of new wastewater management is not feasible, as they already have reliable wastewater management systems, and they see no reason to pay double for something that is functioning properly. More than 88% knew where their septic tank is installed and where the disposal field was located. In addition to that, the same percentage of people did not experience any problems with the system within last 5 years.

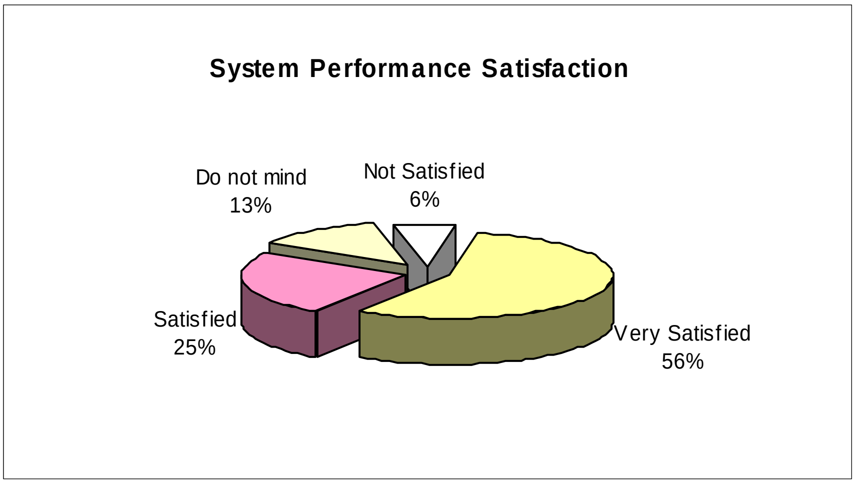


Figure 38: Estimating satisfaction of the existing system performance

There were actually not many issues connected with wastewater handling, and the once stated included environmental issues and consequences of potential leakages and council involvement. Additionally the influence of existing systems was pointed as having no (44%) or almost no (25%) influence on environment, while some influence was mentioned by about 21%. The remaining 11% did not know if there was the potential environmental impact of their systems.

Attitudes towards proposed wastewater management

Most of people in the community are already retired; some are on fixed incomes; and that makes it even more difficult to consider new options while the systems they have are working properly, and if there is a necessity to choose among options they will always be mostly dependable on the costs (the cheapest possible option), and not on the solution.

The results from the survey pointed out that the main issue while choosing among options is the cost of the system (62%), and not actually the solution (Figure 39 category: *Other*). Moreover, lack of information, education provided to make decisions, and no need for new solution, are contained in the remaining 38%. Most of the issues concerning wastewater handling included the lack of the solution that could work for everybody in the community, and council involvement. Moreover, environmental effects of not properly functioning systems (e.g. leakage) were pointed out as well. People in that settlement are aware of the fact that not properly working systems could influence surrounding environment (soil, water, etc.).

There were a lot of residents that were feeling not well informed (47%) about options proposed by the Council, while the others were relatively (13%) or stated that they did not know (13%) to make an informed decision. And these people would like to be provided with more information. Moreover, they thought that it is not necessary to have new systems installed if they had no problems with their systems. Some of the comments included cost issues already with existing water supply, as the drinking water in that settlement is the highest in the whole Canterbury region.

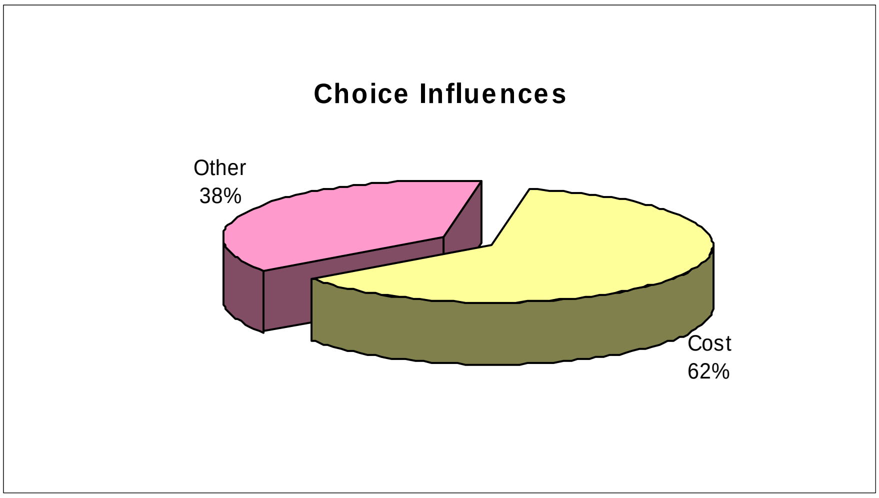


Figure 39: Choice influence

Willingness to pay

The willingness to pay for new system is low, as it is seen from the attitudes, replacement of the existing systems is not necessary if they are working properly. Nobody with good performing existing system wants to install something new. The costs were mentioned as a boundary condition to any change as well.

Attitudes towards new approaches and technologies to wastewater management

About 56% questioned people would like to improve their knowledge in the field of wastewater management taking into account the situation. Moreover, people are interested in environmentally friendly innovative approaches to wastewater management, however, they state that the biggest barrier towards changes is the financial issue. Additionally, they felt that the wastewater management in their settlement should be the community/property owner responsibility side (44%) and not the Council (25%).

People in Hakatere use water for normal purposes and sometimes for irrigation, however, the amount of fresh water use per day was estimated by respondents below 200L (100% respondents). Adding to that, people stated that the water rate was not less than 700$ per year (EUR 350), which makes it most expensive in the whole South Island.

7.2.3 Discussion

The data provided insight on the respondents' demographics; homeowners' knowledge about, and experience with, existing wastewater systems; attitudes and preferences for wastewater management, perceptions about local water quality and effects on water quality, moreover, openness on paying for maintenance and management of wastewater systems. Survey objectives were addressed; however, some informational gaps were identified, as well. Basing on the results, the aim was to find a solution to wastewater management meeting community needs.

The response rate that equaled 51% was probably caused by first of all, previous experiences with the Council in that field, did not enhance residents to take part in the survey. Secondly, some people were not present during the time the survey was undertaken (empty houses, holiday houses, houses for sale, people at work or on holidays). Questionnaires were distributed to the mailboxes first, while delivering them in person would have probably increased the response rate. That is why after visiting people and collecting forms, new forms were delivered in person to each household that has not completed the questionnaire. Moreover, the goal of the survey was explained where possible. This had shown that the explanation has highly increased the cooperation and interest in the survey.

A contributing factor to potential wastewater problems in community is definitely the change in land use from when the settlement were bach communities used primarily on weekend or holiday basis to permanent use of them. Some of the huts are becoming fully-fledged houses, running alliances like dishwashers and washing machines, etc. which leads to wastewater management problems of some primitive wastewater systems.

Another important thing that might have biased the results is that almost off of the respondents were people not facing wastewater issues. However, there is a number of residents that were facing problems with their wastewater, however they did not fill out the questionnaires. One of the reasons was the disappointing cooperation with the Council, additionally, the problem of wastewater management for these people was still not addressed.

Nothing had changed as they were still trying to address the problem of wastewater handling. Especially, as there was an urgent need to manage these problems, but, nothing actually, has been done so far. Instead of finding the solution for these, the Council's goal was to provide a community scheme to manage wastewater from all the houses. That solution would be good for residents facing problems, however, not for people with reliable, well functioning on-site systems. The main barrier for any change was financial matter, moreover, the residents were disappointed with the consultation problem as the concerns and needs of most of them were not taken into account. Not enough information was provided to them and the solution investigated was not acceptable by most of the residents. It is difficult to find a solution that works for all in the community, however that experience was not a satisfactory one, as firstly, people's needs and issues were not considered, the solution proposed was too expensive, and there was too less information and education provided to make informative decision. The cost here plays an important role, and is a main factor to say no to any change. Even with the support from the Council, most of people are not able to afford new system, and are not interested in them as they already have well performing systems installed.

Although results of the survey are useful in addressing its objectives, there is still an opportunity for future research in this field on a bigger scale in small rural communities facing wastewater decisions. There is an opportunity for such research as each community is different and has different attitudes and needs. Such research yields an understanding of the current state of wastewater handling and leads to better choices in wastewater solutions and technologies.

One of the aims of the survey undertaken was to recommend a treatment system and supplier, location for treatment plant, disposal filed, reticulation layout and raisin main alignment. The goal was to identify affordable, technically feasible and environmentally acceptable sewerage scheme for the Upper Hakatere settlement, for the long time.
Unfortunately, on-site systems to address wastewater issues for residents without proper systems were not longer optimal, as the lot sizes and area for effluent disposal was not big enough. That is why other options had to be considered.

7.3 Recommendations

7.3.1 Alternative wastewater management

In this part of this thesis a solution to wastewater management in the Upper Hakatere is suggested. The plans and construction costs were acquired from consultants, which helped in planning an alternative sewer system for Upper Hakatere Huts.
While designing option for wastewater management, things such as how many properties are to be served by the system, resource consents required, the fact that disposal is over reserve land, any Environment Canterbury issues; who administers the system, once it is installed, etc., have to be considered.
As some huts have already had well working wastewater management systems, some parts of these existing units (e.g. tanks and pumps) could be used for cluster approach. On one hand, a small cluster could be designed and implemented with potential future all huts involvement. However, a full cluster system for Upper Hakatere is recommended from the beginning. As it would substantially decrease the costs as well as disturbances caused at the site by works. The minimum water flows (2 people) were calculated to be 240L/day, while the maximum (6 people), 740L/day.

After consultation with Dr. Anthony Taylor, two main approaches to wastewater management in the Upper Hakatere were identified:
Option 1: Small cluster system serving only lots with critical wastewater situation
Option 2: Cluster system serving the whole Upper Hakatere Settlement – recommended

7.3.1.1 Option 1: Small cluster system serving only lots with critical wastewater situation

Small cluster serving critical properties could serve six houses facing critical wastewater situation (Appendix H). Parts of the existing system units could be used, together with some new tanks and pumps. A common tank for these six could be situated in the middle of the properties considered. Wastewater would be treated to a high quality, and discharged through 12 drip irrigation lines (100mm below the ground level) into a nearby green area (50x12m).

One of the barriers is that the land to be used for irrigation (Recreation Reserve) belongs to the Ashburton District Council (2804m^2), which claims that it would not be fair to other homeowners to use this common area to serve only these 6 properties. However situation in some of the lots gets critical, that is why the decisions concerning wastewater management in Upper Hakatere Huts should be taken soon. That is why, a system for a number of residents facing critical situation at the Upper Hakatere Huts is proposed. The place that this system could disperse through irrigation drip laterals is on the reserve behind these properties (no. 40, 41, 42, 55, 56, and 57) (Appendix H). The Upper Hakatere settlement is surrounded by Council reserve land which may be suitable as a disposal point, and there is a large area of Council owned land in the lower terrace area.

This is a good approach however with future perspective this approach would not solve all Upper Hakatere wastewater problems, as with regulations getting stricter, it would be only a temporary solution, as other - not included in this approach - lots would probably slowly experience wastewater problems. Existing and still in good condition septic tanks at present, may not meet the requirements of the near future. It would solve only some of the current issues. Moreover, the approach to wastewater management Upper Hakatere has to be a sustainable, long term solution, serving each lot, meeting present and future (NRRP) regulatory requirements, people’s preferences and environmental quality standards. That is why cluster serving the whole Upper Hakatere settlement is recommended and described below.

7.3.1.2 Option 2: Cluster system serving the whole Upper Hakatere Settlement – recommended

The idea was to provide sustainable long term wastewater management for each lot in the Upper Hakatere, using some of the existing wastewater systems’ units, where possible, in order to decrease the costs and take advantage of existing well functioning components. Within cluster approach some options are recommended, and these include:

1) *Biolytix Wastewater Treatment System or Advan-Tex Treatment System*
2) *Advan-Tex treatment unit for additional nitrogen reduction*
3) *Constructed wetland on the berm of the river or on the banks; or trenches on the banks*
4) *Trickle irrigation*
5) *Water reuse*

The focus has been towards low energy, labor and maintenance systems. As some parts of existing systems installed could be used, the cost of new solution will exclude some components, making the investment less expensive and more sustainable. For example some properties have their on-site wastewater system consisting of e.g. single chamber septic tank (min volume 2,250 litres), with a bio-filter, pumping bay and pump, and drainage field (3x10m long soakage trench) installed in 2003.

Another example includes combined system (3 houses) including dual chamber septic tank (min. volume 4,500 litres), bio-filter, pumping bay, pump and soakage trenches (3x18m long). Design loading was 30mm/day while actual equals 16.7mm/day. These existing systems are new and they are functioning properly that is why instead of abounding them, using some units (e.g. pumps) could be of advantage to everybody.

The solution would be to collect wastewater from each lot by making small clusters (three houses), serviced by one pump (Figure 40); followed by small pipe systems (40mm pipe) to cluster treatment plant units (Appendix I).

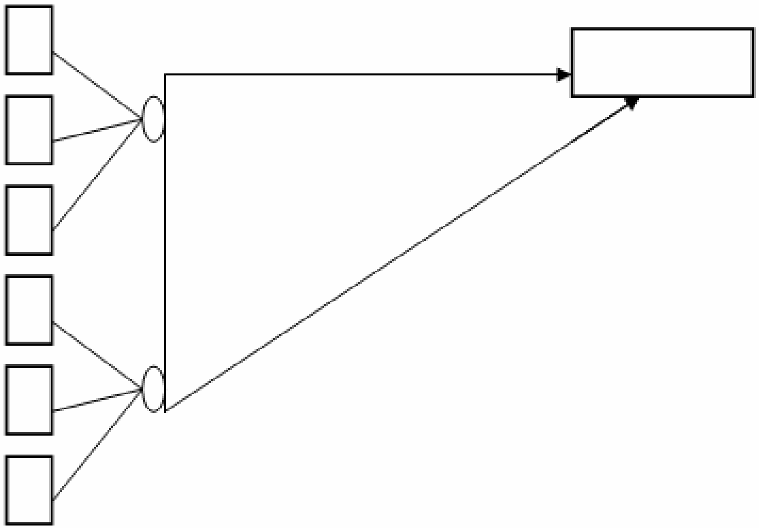


Figure 40: Scheme of the collection system for the Upper Hakatere

The idea is to use parts of existing treatment train units while implementing cluster wastewater approach in the Upper Hakatere. For example pumps could be put to the existing septic tanks (e.g. E/One pump).

Pumps

If a new pump has to be installed, grinder pump GP 2000i Series from E/One Sewer Systems as well as Biotube from ProSTEP Effluent Pumping Systems, Orenco Systems Inc., is recommended. Connecting three houses to one pump will help save on operating costs, the cost of waste collection, and reduce maintenance.

Grinding Pumps - GP 2000i Series - E/One Sewer Systems

E/One Sewer System uses a small-diameter (50mm to 125mm) main installed at a minimum depth below the ground following the natural topography of the land. It uses highly sophisticated technology, requires minimum maintenance, has low upfront costs and operating expenses, as well as it can be installed at any site. Moreover, this system consists of GP 2000i/2010i grinder pump (Figure 41) stores wastewater, grinds and pumps. The only visible part in this system is a low-profile cover, which provides easy access for servicing operations.

Figure 41: E/One Sewer System grinder pump a) GP 2000i; b) GP 2010iP (www.eone.com)

The GP 2010i grinder pump station consists of a pump and a holding tank. The pump, motor controls and level-sensing are integrated into a compact unit. Solids are ground into fine particles that pass easily through the pump, check valve and small-diameter pipe lines. The tank is made from tough, corrosion-resistant, fiberglass-reinforced polyester (FRP). The optimum tank capacity is 460 litres. The GP 2010i can accommodate flows of up to 3500 litres per day. The grinder pump is automatically activated and its annual electric energy consumption is typically that of a 40 watt light bulb (E/One information leaflet). E/One grinder pumps do not require preventive maintenance and boast an average mean time of 8 to 10 years between service calls. If service is required the pump core can be quickly pulled out and replaced, meaning minimal maintenance costs.

Biotube - ProSTEP effluent pumping systems - Orenco

Biotube is a filter used to prevent large solids from leaving the tank (Figure 42). This is possible due to bacteria that adhere to the filter and breaks down the effluent. As a result, TSS can be reduced by about 67% (Orenco, 2004b). The surface area (the area where the solids are caught) and flow area (the size of holes through the effluent falls) are optimized to be only a third of the size of surface area, and 2-4 times larger than other filters(Orenco 2004b). The larger is the flow area, the lower is the possibility for clogging. Orenco's Pump Vaults filter and transport effluent from septic tanks or separate dosing tanks in effluent pumping systems. They house High Head Effluent Pumps and can be used both in flows up to 132 liters/minute and in double-compartment septic tanks or separate dosing tanks with flows up to 227litres/minute.

Figure 42: Orenco’s Pump Vaults filter and Biotube (www.orenco.com)

Pump vaults are 12 in. in diameter and can accommodate one or two pumps. A variety of Orenco pumps can be supplied and sized according to each specific application. Each pump vault comes with a Biotube filter cartridge, vault housing, support pipes, and float bracket to hold float assembly. Pump valves are versatile and can be fitted into existing or new tanks. These pumps can provide approximately 2/3 of suspended solids (Orenco 2004b).

Biolytix or AdvanTex Wastewater Treatment System followed by advanced treatment unit for additional nitrogen reduction

The wastewater collected by the pumps mentioned, would be treated in either Biolytix or AdvanTex wastewater treatment system. Moreover, depending on the demanded effluent quality and potential re-entry, additional treatment unit could be installed. In order to reach high quality effluent meeting standards for re-entry, nitrogen reduction should be undertaken, which could be done through advanced treatment – AX 20.

Biolytix Wastewater Treatment System

Biolytix Systems separate organic matter (solids) from the wastewater and provide specialized organisms to treat it aerobically (Figure 43). It is surrounded by 22% oxygen. That system can treat up to ten times the BOD5 (organic) loading of rival technologies - can treat to high secondary standard. Biolytix filter can achieve high oxygen transfer, and the only electricity used is to pump out the reclaimed water. Moreover, if the drainage area is downhill, no electricity is needed. This filtration unit uses less space and power as equivalent treatment e.g. activated sludge or sequencing batch reactor. Biolytix is an organic soil ecosystem.

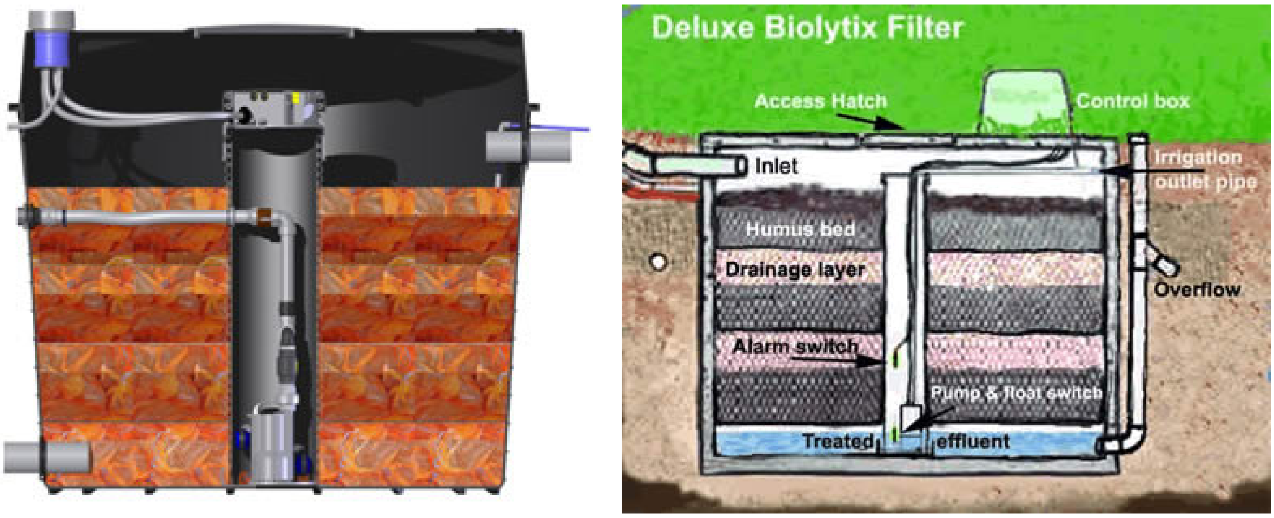


Figure 43: Biolytix filtration unit (www.biolytix.com)

All the waste is fed onto the filter bed (Figure 43). The top layer is made up of coarse mesh bags with plastic media in them, housing the wet soil. Moreover, it accommodates worms, beetles and other microscopic organisms, breaking up the organic material, converting the waste into humus and structuring it so that its drainage and air porosity are continually renewed and maintained indefinitely (www.biolytix.com). The organic matter particles accumulate on the surface of humus and coco-peat layer. In the middle layer, reprocess takes place and all is structured into a sponge-like filter matrix by the soil organisms. The fine structured compost is 90% water by weight, has a high cation and anion exchange capacity and adsorbs and holds back pollutants (e.g. chemical compounds and toxins). After the last layer, the effluent is well treated and a geofabric filter filters out all particles larger than 90 micron. This three dimensional filter is biologically cleaned, and does not need any maintenance. The water accumulates in the sump where more of the very fine sediment is settled out before the clear, reclaimed water can be pumped or drained to irrigation or reuse.

Advan-Tex Wastewater Treatment System

Advan-Tex AX100 Textile Systems are an advanced packed bed reactor treatment units, consisting of treatment pods. Instead of traditional bed of coarse sand or fine gravel, the technology incorporates recirculation, enhanced pre-treatment, steady-state hydraulic loading, frequent dosing, uniform distribution and substation of the granular media with a textile medium (Figure 44) (Orenco 2004a). AdvanTex treatment system is a natural treatment process operating under passive aerobic conditions. Micro-organisms that live on the textile media are naturally occurring soil micro-organisms. The use of the textile as a filter has resulted in reduced treatment size facility (e.g. the size of a sand filter treatment facility has a footprint of $35m^2$, while using textile it is compressed to fit areas of $1\text{-}3m^2$ (Orenco 2003a). Moreover, AdvanTex produces effluent with BOD5 and TSS below 10mg/L (Orenco 2004a), and it can treat up to 2,025 $L/m^2/d$ (Orenco 2003b).

Figure 44: Advan-Tex Treatment System (Innoflow Technologies Ltd.)

These treatment systems can be used successfully for single home (AdvanTex type AX10), as well as subdivisions or whole communities (type AX100 – AX 400). The AdvanTex AX100 services 10-15 lots is presented in Figure 45. Some examples of AdvanTex application is presented in Chapter 6.

Figure 45: AdvanTex AX100 (Innoflow Technologies Ltd).

Treatment media is a uniform, engineered textile, which is easy serviceable and allows loading rates as high as 2,000Lpd/m^2. The recirculation textile PBR is a bed of specialized textile nestled in a pre-made POD to which the effluent is uniformly dosed through a pressure distribution and spray system using a timer controlled dosing regime. These small doses at multiple spray sources across the reactor bed ensure even, thin film application of the effluent maximizing retention times within the reactor for renovation. That treatment produces effluent suitable for land treatment. Fig. presents the complex fiber structure and void space of textile fibers compared to that of typical 0.30mm and 1.5mm sand particles. Spray nozzles efficiently distribute effluent in the Advan-Tex textile filter (Figure 46).

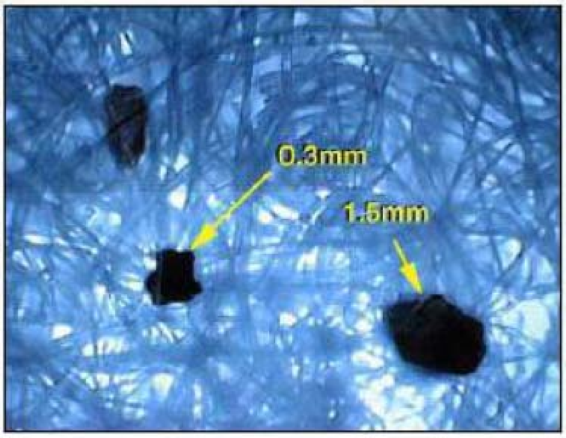


Figure 46: Textile fiber porous structure, relative to grains of sand and gravel (Innoflow Technologies Ltd.)

That uniform filter has greater porosity, surface area and water holding capacity; moreover, it does not compress, decompose, or vary in quality. These packed bed filters are capable of producing high quality effluent, which is superior to that discharged by the majority of municipal treatment facilities, and is optimal for many water-reuse applications, including irrigation and recycling for in-house uses. The number of modules depends on the number of houses being serviced by such systems (Figure 47: Figure 48). One module (AX100) usually serves 10-15 houses/people.

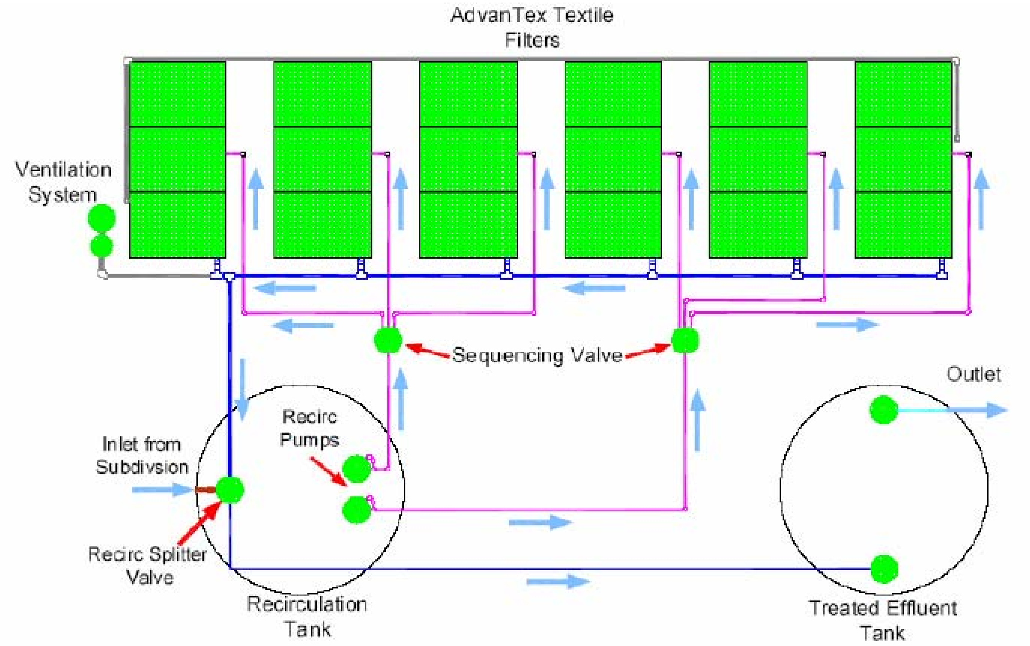


Figure 47: Flow train in the AdvanTex Textile Filter (Innoflow Technologies Ltd.)

Figure 48: Example of AdvanTex application

Advantages (Innoflow Technologies Ltd):

- Great porosity, attached growth surface area, and water holding capacity contribute to the textile media's enhancement treatment performance
- Treatment process inherently stable and robust
- Very low and easy to manage sludge production
- Well suited to STEP/STEG effluent sewer collection
- Passive treatment process - not depended on inputs of energy
- Low operation and maintenance requirements

- The system has quick start-up time (80% removal of cBOD within 24 hours of operation, and TSS of less than 15mg/l)
- The system is fail-safe (no possibility to release untreated sewage)
- Flow is managed (possibility to detect inflow caused by infiltration, leaky plumbing fixtures or higher than normal water consumption by the user)
- Technology is readily scalable (e.g. on-site, small or bigger cluster)
- The system can be implemented in modules (e.g. expansion without interruption of treatment processes
- Low energy demand
- High quality components assure extended lifetime
- Low noise levels (<15dB)
- Does not generate odours

The recommended PBR technology (Innoflow Technologies Ltd.) is well proven in New Zealand over 10 years and internationally over 25 years. The AdvanTex wastewater systems can provide in the Upper Hakatere consistently high quality effluent under variable wastewater strengths and fluctuation loads. That treatment plant assures a stable treatment process even under occasional shock loading without any adverse effects to the treatment plant or land application system. During periods of low flow (e.g. few occupants), effluent from recirculation tank is dosed onto the media bed within closed loop system (100% recirculation rate occurs when incoming flow is zero). This maintains the population of microorganisms on the textile media. Occasional large flows are flow modulated or buffered in the septic tanks above working volume using Biotube effluent filters. Flow rates above the discharge rate are buffered in the tank and released during off peak times.

As sludge management is a growing problem in New Zealand and world wide, one of the advantages of PBR is the ability to perform without generating any appreciable volumes of biomass or sludge. It is achieved by maintaining the aerobic microorganisms living on the textile filter media well into the endogenous respiration phase, which means that birth and death rates are in equilibrium regardless of incoming flow rates.

In addition to this, Innoflow has been involved in about 145 commercial community systems involving packed bed reactor technology as cluster treatment plant since 1994. Some of wastewater management systems implemented by Innoflow are presented in Chapter 6.

The treatment performance is a function of the biological and hydraulic loading rates applied to the textile medium per m^2. The filter can accommodate a peak flow rate (sustained for short periods) double the average flow, corresponding to about 2,000mm/day and still achieve treatment performance.

In the Upper Hakatere, 3 to 4 unites of AX100 could be installed (AX400) and because of the lack of odour and other heath hazards, it could be situated near the properties, in three potential options (Appendix I).

Advanced nitrogen removal using additional unit - AdvanTex AX20

On average, each person in a household generates waste containing ~ 4kg (range between 3-7kg) of nitrogen per year (Gold and Sims, 2001; Henze et al., Crites and Tchobanoglous, 1998), commonly resulting in daily N loads of 10-13g N/day (Crites and Tchobanoglous, 1998; NZLTC, 2000). Additionally some environments like Upper Hakatere are sensitive areas to nutrient loadings, that is why, the ability of the treatment process to remove nitrogen is of high importance. Typical nitrification (conversion of ammonia to nitrite and then to nitrate) processes in AdvanTex provide 98-99% reduction to <5mg of ammonia in the final effluent (Innoflow). The second step of the process is denitrification (conversion of nitrate to nitrogen gas), which is enhanced by returning part of the nitrified effluent stream to the carbon rich (high BOD), low oxygen environment in the anoxic blend tank prior to the recirculation tank.

To improve nitrogen reduction prior to wastewater discharge (for irrigation, constructed wetland application or trenches) AdvanTex AX20 (Figure 49) is recommended to follow treatment unit (AX100, AX400 or Biolytix). Dimensions of AX20 treatment unit are as follows:

- Height: 2.5ft (762mm)
- Width: 3ft (914mm)
- Length: 7.5ft (2286mm)

Figure 49: AdvanTex AX20 treatment unit with aligned textile sheets (Innoflow Technologies Ltd)

Proposed additional unit in the treatment train for Upper Hakatere, is an innovative technology for wastewater treatment. AdvanTex AX20 provides clean effluent that can be used for irrigation, or discharged to shallow, subtle trenches. One could be applied to treat effluent from even 4 AX100. There should be no problem even during peak times, as the water could be pump out. The system discharges small amounts of treated wastewater throughout the day. AX20 has a footprint of 930m^2, and includes a processing tank and a control panel with a programmable dosing timer. It discharges small amounts of treated wastewater, regularly. Effluent can be used for drip or subsurface irrigation, or discharged to shallow, inconspicuous trenches. Moreover, it can be discharged to fine-grained polishing filters for coliform removal and water reuse. In addition to that, filters can be monitored by electronic system (e.g. VeriComm), which measures the temperature, flow rates and pump cycles.

Constructed wetland (subsurface) on the berm of the river or on the banks (15m); or trench on the banks of the river

After the water is treated to the high quality, it has to be discharged. The idea is to use constructed wetland or trenches on the berm of the Ashburton River or on the banks (15m).

The soil (topsoil) in the Upper Hakatere is of 1-2 category due to NZ Standards mostly it is 1st class soil. The possible area available on the banks is the Local Purpose (Esplanade) Reserve to the vest in the Ashburton District Council (4689ha) (Appendix I). The water table on the berm is 2-3m below the surface (Appendix I), while the distance on the banks is 15m. As the flooding does not really occur, the berm of the river could be used for treated high quality effluent discharge to constructed wetland, where additional treatment occurs. Later, after that additional natural treatment, the water could be disposed to the Ashburton River (Appendix I).

Another option is to place trenches on the banks of the river, where the distance to water table is 15m, allowing natural treatment through the soil and groundwater recharge (Appendix I). These two options are described below.

Constructed wetland

Wetland system could provide additional treatment after Biolytix or AdvanTex system followed by additional nitrogen removal unit. Reed beds, rushes and cattails could serve as a matrix for attached biological growth (Crites and Tchobanoglous, 1998). One of the two types of the system could be chosen, surface or subsurface constructed wetland. The first utilizes a free water surface, where the microbes treat the wastewater. The second system uses subsurface flow to treat the effluent, as it slowly passes through the gravel base.

Subsurface wetland in the Upper Hakatere is recommended as it requires smaller area, moreover, it causes no odour or mosquito problems. In addition to that, it provides removal of nutrients, pathogens and carbon in the form of CO_2; produces high quality effluent when coupled with other treatment systems; no energy is required to operate (nature does the job); requires less area than a disposal field.

However, some disadvantages have to be mentioned here as well, such as users have to be responsible for maintenance (harvesting), dedicated land area is required, system may fail over time if the coupled system fails; limited usage may cause the wetland to dry-out. Design criteria are presented in Table 33. The area available is suitable for a constructed wetland however a consent would probably be required. The water discharged would be of high quality decreasing the adverse environmental impacts and health risks. Additionally, constructed wetland would provide additional natural treatment leading to highly treated effluent which could be discharged to the river.The water required to supply each subdivision is estimated to be 120.L/day/unit dwelling. The size of the discharge area depends on the discharge volumes and loading rates. For example, the Golden Valley (Chapter 6) has a disposal area of 5660m2, which means 142m^2/house; and this accommodates 7L/m2/day loading area.

Table 33: Typical design criteria and expected effluent quality (Tchobanoglous and Crites, 1998).

Design Parameter	Value
Detention time	3-4 (BOD) days 6-10 (N) days
BOD loading rate	<100lb/ac*d (112kg/ha*d)
TSS entry loading rate	0.039 kg/m^2*d
Water depth	0.3-0.6m
Medium depth	0.45-0.75m
Mosquito control	Not needed
Harvest schedule	Not needed
Expected effluent Quality	
BOD5	<20mg/L
TSS	<20mg/L
TN	<10mg/L
TP	<5mg/L

<u>Trenches – subsurface drip irrigation on the banks of the river</u>

Another solution is to use trenches for subsurface irrigation. A shallow gravelless drainfield trench is typically 12" (305mm wide) x 10" (150-250mm deep) or smaller. So the laterals are right in the midst of the top 16" of soil stratum, where roots and 99% of soil biota are concentrated. Shallow gravelless drainfields can usually handle flows of treated sand filter effluent in excess of 200Lpd/m^2. Nitrates and other contaminants are removed by microbial activity and plant uptake. Soil structure improves and permeability actually increases over time. Raised beds can be useful to enhance separation to groundwater. Drainfields can be landscaped, and water reuse is an option, via subsurface drip and spot irrigation (Figure 50).

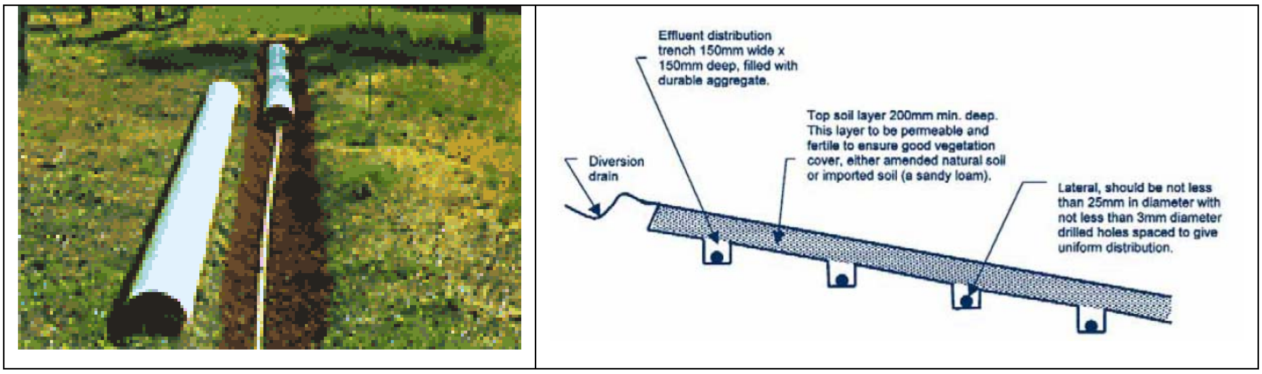


Figure 50: Typical subsurface irrigation cross-section A-A (Department of Environment and Health, Australia, 2005)

The research studies showed that 50 % of total nitrogen reduction when pretreated occurs in shallow trenches (Wert and Paeth, 1985). The minimum application rate is based on AS/NZ 1547:2000 for on-site systems and equals 15mm/week or 2mm/day. However soils with superior absorption can be receive 35mm/week. In such case, the BOD has to be <20ppm and 90% of TSS <30ppm (AS/NZ 1547:2000).

The systems recommended (Innoflow) can achieve levels of 5pmm for TSS and BOD5 (Hawtorne, 2004). There are City Council guidelines for land application systems.

Irrigation – trickle irrigation

The top soil in the Upper Hakatere is of 1-2 category (NZ Standards) with most in 1st class soil type. The disposal area for trickling irrigation could be the landscape just next to the settlement (Recreation reserve to vest in the Ashburton District Council (two areas available: 2804m^2 and 3935m^3) (Appendix I). Additional land could be used if necessary with the area of 4480ha next to the river banks. Trickle irrigation (drip irrigation) is an effective method of watering landscape, as it applies water slowly and directly to the root-zone. Trickle irrigation involves frequent applications of small amounts of water directly to the root area of the plants. Water is applied under low pressure. Only a small area immediately around plant is wetted, leaving the remaining soil surface dry. Perforated pipe on the soil surface drips water at base of plants. Trickle irrigation (Figure 51) systems require a high quality of effluent to prevent clogging of the emitters through which water is slowly released into the soil.

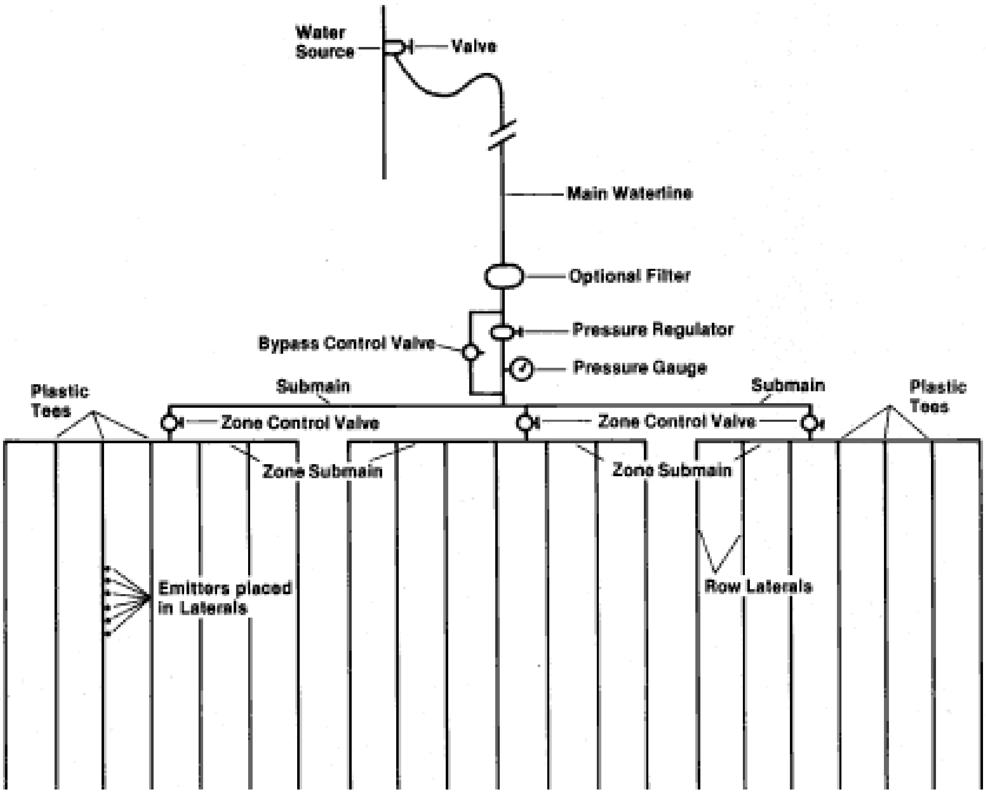


Figure 51: Typical trickle irrigation layout
(http://www.ag.ndsu.edu/pubs/plantsci/hortcrop/ae889w.htm)

The main advantages of trickle irrigation include:

- increased crop growth and yield achieved by optimizing the water, nutrients and air regimes in the root zone,
- high irrigation efficiency - no canopy interception, wind drift or conveyance losses and minimal drainage losses,
- minimal contact between workers and effluent,
- low energy requirements - the trickle system requires a water pressure of only 100-300kPa (1-3 bar),
- low labour requirements (the system can be automated)

In addition to trickle irrigation, plants with high evaporation could be planted (e.g. any small and low growing native plants with high evaporation potential) in the Upper Hakatere. These could be for example:

Reuse

The water required to supply each subdivision is estimated to be 240L/day/unit dwelling.

By using recycling system this figure would be less by 100l/day. Using recycling systems, a 30% reduction in the volume of water to be treated could be achieved (Baldwin, 2004). The disposable and recyclable water is 75% and 25% respectively, basing on Innoflow experience, where reclaimed water is provided to dwellings for non-potable use and the excess of treated water is disposed via subsurface irrigation.

The design of recirculating packed bed reactor systems (rPBR) (e.g. Innoflow Technologies Ltd.) combines design principles with quality components and state of art monitoring equipment. As a result, the effluent produced is suitable for many non-potable water reuse applications (e.g. irrigation, toilet flushing, fire fighting, etc.).

In 1998 a study comparing the influent and effluent BOD and TSS levels was performed on rPBR systems in the United States (Crites and Tchnobanoglous 1998). Some of the results are presented in Table 34.

Table 34: Performance of recirculating packed bed reactors (Crites and Tchobanoglous 1998)

Location of rPBR	BOD (mg/L)		TSS (mg/L)	
	Influent	Effluent	Influent	Effluent
Elkton, Oregon	141	6	32	6
Orcas Village, Washington	166	4	113	5
South Prairie	181	4	34	4

The results prove that packed bed reactors effluent quality <5ppm of BOD and <5ppm TSS is being produced consistently. Moreover, feacal coliform levels in of 10#3 mnp organisms per 100ml are typical for the rPBR, which allows for ground disposal. If even higher water quality is required, then ultraviolet (UV) disinfection or chlorination may be used (Hawthorne, 2004).

The system to be installed could be a block-wide wastewater system for wastewater reuse. Cluster wastewater treatment system as recommended above could be used and, treated at one location, water, could be distributed back to the dwellings for non-potable reuse (e.g. toilet flushing). The effluent has to be disinfected before it is reused.

All the recommended system components are available in New Zealand and there is no need to import them from overseas.

Additionally, it is recommended to educate residents and visitors about local resource values, septic system care, and the need for management; moreover, to limit additional bureaucracy and cost of mandatory inspections; to establish guidelines for homeowners; to provide financial assistance to build public support for management.

7.4 Summary

Management of wastewater in Hakatere settlement has traditionally been the sole responsibility of the individual property owners. Additionally, there is not a solution that could meet the needs of all the community. The process of choosing the solution to wastewater management is complicated, it needs time, information provided to residents, education if necessary, and appropriate consultation process that concentrates on community needs and issues. As many people as many opinions, additionally, financial aspects, being the most influential, should be addressed through grants or subsidy schemes in order to make it easier and more convenient to implement wastewater management systems.

Centralized management of decentralized systems provides the type of dependable wastewater treatment service that people typically associate with centralized wastewater collection systems and treatment plants. The most important lessons learnt are the effectiveness of making small steps toward decentralized management and the value of long-term perspective.

This study involved investigating residential growth and the demand it would generate for sewerage schemes, carrying out pre-feasibility design and analysis of strategic sewerage options, investigating the future capacity available to connect other houses with existing on-site systems in order to use parts of thee, without causing unnecessary costs, and initial consultation with residents, in the form of explanation of the survey goals while delivering questionnaires.

The study has confirmed that some of the present community areas are unsuitable for on-site septic tank disposal systems, particularly as the dwelling density is high with very small lot sizes. And cluster approach addressing properties without proper wastewater management could be implemented with potential future or immediate connection of all the properties in that settlement. Recommendations proposed here would address first properties with hazard potential, and by using parts of existing systems, manage all within the cluster approach.

Local factors such as soil types, ground and surface water characteristics including potential contaminant runoff and seepage to Ashburton River and coastal waters in the area, water supply protection, land use and potential development have been taken into account, and have resulted suitable for the proposed solutions.

Before a community begins to review wastewater treatment options, information that will help everyone to understand the situation has to be provided to the community. As the sewage treatment situation varies from community to community, so does the information. Later on communities can make a decision (Olson et al., 2002).

8. Discussion

Decentralized systems cannot address all the wastewater problems, as there will be cases where the decentralized concept is not the best solution. However, the benefits of this approach to wastewater management indicate that greater attention is needed especially in small communities as well as in developing suburbs.

Barriers to cluster approach implementation seem to be more institutional than technical. That is why, there has to be greater attention of policymakers, regulators, operating authorities, engineers, land developers and the general public on such wastewater management. At the times facing water resources challenges, more attention has to be placed on consideration not only conventional and accepted management strategies for wastewater handling.

At present, the idea is to treat and reuse wastewater (where beneficial and practical), as close where it is generated as practical. The on-site or centralized systems are not the only and often not the best ways to organize the overall wastewater system for small communities. Cluster approach, which falls in between these two options, may serve a group of homes, a whole subdivision or a commercial center, etc., which makes it more cost effective and more environmentally friendly. In addition to that, the potential for beneficial reuse of reclaimed water is of high importance nowadays, especially in places experiencing water shortages (e.g. Australia).

What is more, the image of being sustainable is becoming increasingly important nowadays. As a result, services such as potable water supply, stormwater, wastewater and waste servicing need to demonstrate they meet sustainability criteria (e.g. maintain high standard of human health and efficient use of natural resources, etc.). For some communities, water supply, wastewater and waste services fall short of some of these criteria. In the case of existing infrastructure the opportunities in terms of engineering design or technology are limited (e.g. Hamner Spring and Kaikoura), and the opportunities for such communities are likely to be in terms of infrastructure maintenance, upgrade or replacement, as well as specific areas of new green-fields development (Cullen et al. 2004).

Additionally, engineering can make a contribution to sustainability of water and wastewater systems by choosing appropriate approach, employing appropriate design and technology, as well as management of the infrastructure. Sustainable systems require total water cycle thinking, which means looking at synergies between water, stormwater and wastewater.

8.1. Recommendation

Numerous innovative technologies are available for wastewater collection, treatment, dispersal and reuse to be applied for cluster approach nowadays. High range of options for advanced wastewater management systems enables greater flexibility in wastewater planning and protecting water quality. However, there is still a need for technology improvements for example in the field of development of improved cost-effecting technologies, removal of nitrogen and phosphorous to low levels or treatment of emerging contaminants.

Moreover, it is important to understand that the decentralized concept embodies organized management of the overall system. Even the simplest systems require management.

As the basic idea of the decentralized concept is to treat, and beneficially reuse where possible, the wastewater as close to where it is generated as practical, the management has to be focused on maximizing reuse potential, thus reducing stress on regional water resources. For example, biofiltration plants could be used, with flow received by gravity, and small treatment centers could supply irrigation water, toilet flushing or other non-potable demands. If no local reuse opportunity is available to utilize the reclaimed water, the effluent could be pumped to a point of beneficial reuse (e.g. irrigation reuse could supply some private greenspace, agricultural land, or habitat enhancement). Opportunity reuse could be accommodated allowing the treatment system tank to overflow to a discharge if it filled up in case water has not been demanded at the reuse sites. This could address changing demands and opportunities. Moreover, remote monitoring system could be installed to allow minimal oversight. Additionally, ultra-violet disinfection could provide high treatment, and tank pumpage routed to composting centers. Moreover, production of high quality organic fertilizer would close the nutrient cycle and could create revenues.

The solutions take time to develop, and reuse-focused cluster systems can be the most cost effective and water resource conserving means of providing high quality wastewater for low density areas. Such approach offers more cost effective, socially responsible, and environmentally friendly solution.

Providing new infrastructure is challenging. However, with change in attitude, many innovative opportunities will come. By focusing on how decisions are made, costs are analyzed, and the engineering reliability of systems are improved, mistakes can be minimized, new technologies can be selected, and new infrastructure demands can be met while improving water quality, public health, as well as economic development of communities involved.

There are three possible paths considered as sympathetic community-environment relationship, in terms of material cycles, and these comprise:

- Doing more what is presently being done, more reliably and more efficiently in the filed;
- Changing the purpose of the current paradigm, to produce an optimal solid product, as opposed to an optimal liquid product;
- Migration from the present centralized ‘end-of-pipe’ paradigm, to a decentralized, highly segregated infrastructure in which the engines of material manipulation sit at the heads on many short pipes returning the products of the community metabolism to the environment– when properly functioning.

In general, there is not merely the technology of the wastewater infrastructure to be considered, but also the technology of water supply, of solid waste (refuse) collection, of energy supply, and of transport and communication (Beck et al., 1994). Then there are instruments of economic policy that may be wielded in order to foster a more sympathetic community-environment relationship (Haughton et al., 1994). Consideration of technology and economics has to be followed by stakeholders’ participation, as the logic of feelings plays an important background in steering technology and choices (Cornelis, 1995). It has to be aware of predominant role of social, institutional and philosophical considerations may have in fashioning the technological fabric of a wastewater infrastructure of the future.

At present, environmental laws and regulation shows the directions for improvements and suggests the ways for changes, research and innovation. For example, the Parliamentary Commissioner for the Environment (2001) in New Zealand identified opportunities for progress such as:

- Demand management and least cost planning: economic instruments and community awareness and education programmes;
- Integrated catchment management;
- Integrated design and management of water services – building efficiencies measures, recycling, and linkages with allied services; in particular the three waters, potable water supply, stormwater and wastewater

It is important to consider the integration of wastewater management with storm water management as well as with drinking water system management. Coordinated management of these vital community functions should create the most cost-effective and efficient approaches, moreover, empower creative solutions.
Another consideration that can enhance general support of cluster approach is an encouragement of community-based environmental protection. It promotes stakeholder involvement in designing, reviewing, improving, and defending local solutions.
Finally, there should be a general policy of determining when and under what circumstances local authority requires community to address failing wastewater systems. Such policy could increase the attention that communities give to their wastewater needs, and therefore increase the number of places where managed decentralized technologies may be applied.

In the long run, legislation governing protection of the environment will continue to become more stringent and be applied more comprehensively (Beck et al., 1996). Moreover, as the infrastructure of pollution control and prevention becomes increasingly complete ambient environmental quality will, on average improve. In addition, the technology for observing the environment will become more complete and more refined – providing access to the burgeoning dimensions of contamination at ever smaller concentrations over larger spatial domains at yet finer scales of temporal variation (Beck et al., 1996). Public awareness of an improved environmental quality will grow. Economic and social activities will continue to generate at least the same potential for contamination of the environment, that is why, the need to maintain the operational reliability and performance of applied solution has to be a priority in the long term (Beck et al., 1996).

What is more, the goal is to break down the barriers like absence of management programs, professional education programs and training opportunities focusing on decentralized systems, inconsistencies in enabling legislation or regulatory constraint. Additionally, critical information gaps have to be addressed in order to develop the capacity of community leaders, regulators, service providers, communities interested, to respond to increasing complexities and expanding needs for cluster wastewater management. One of the ways of achieving it could be by identifying research and development opportunities in cluster wastewater field and provide funding to support it (e.g. universities, organizations, public and private agencies and institutions).

Although ecological engineering is expensive in terms of land area necessary for achieving sufficient detention times for reactions to proceed to a sufficient extent, the results are promising (Holdgate, 1994). Long-term behaviour of an infrastructure on the properties of ecosystems is significantly less predictable than one based on the properties of concrete. However, failure may occur in any system because of inadequate understanding of its working. Reliability of service and the minimization of failure may in the end be an important factor in conceiving wastewater infrastructure that is different from conventional (Mitsch 1995), and new approaches may reach the habits of people (e.g. dry toilets). It is interesting to know to what extent daily lives can be altered by new solutions for wastewater management.

Communities have to focus attention on their wastewater problems (Jones, 2003), as water is one of the community issues, and on its own it is rarely a priority and rarely a topic to which community members are willing to commit their time and financial resources. Moreover, there is no simple solution to enhancing community awareness and willingness to act, however, this should increase. The effectiveness and long term sustainability of community wastewater solutions benefit from well-planed community processes. Active participation in comprehensive assessment of wastewater infrastructure is a first step that leads to better decision-making process and broader support. Numerous studies have shown that take the time to implement a strong community process usually reach a sustainable solution. Different communities will have different balance between the role of the expert and community members in carrying out functions such as assessments and the choice of specific wastewater technologies. Managing cluster wastewater solutions is as important as the technology chosen, but often more difficult to implement.

The value of effective management in ensuring that wastewater technologies meet required performance goals. More information that related failing wastewater treatment systems to environmental and economic damages is needed.

The focus maybe also on the description, performance, appearance, space requirements and operation and maintenance needs of proposed alternative technologies so that community members and regulators can better choose between them based upon their own needs. For example, the community may want increased water reuse and limited capital and operating costs, while the regulator may seek nutrient or pathogen reduction in local receiving waters.

A clear set of messages about the current status of wastewater management, the implications of failing systems and the capital and management costs for ensuring adequate treatment needs to be delivered. These messages should build a strong foundation for public support and political action to address small community wastewater problems. For example, during 1990s, a significant levels of impaired streams and the sources of pathogens and critical pollutants have been identifies in watershed-based reporting. In addition, a message regarding the relative economic and environmental value of decentralized solutions as compared to central (conventional) solution is also important to overcome current perception of decentralized technologies as less effective in treating wastewater and of centralized systems as desirable, cost-effective alternative solutions.

The number of communities that use effective community decision-making processes and decentralized technologies increase, experienced consultants, regulators and community members will help others overcome the challenges of initiating community process for making more cost-effective wastewater decisions.

There is a critical need for more trained regulators who are experienced in the trade-offs between decentralized and centralized solutions. There are several policy-related issues that affect the choice of wastewater solutions. One of those is growth management. The availability of wastewater infrastructure may direct and control future growth in communities. Therefore, more information regarding how cluster systems can be beneficial for adhering to planned growth is needed. Moreover, future land-use plans should reflect generated desirable growth patterns based on realistic community goals.

9. Conclusion

Alternative vision for water use and management in the future is hold in that century (Hunt 2004). That vision raises a question, whether or not rely only on conventional approaches to wastewater treatment. The intent of this work to outline the ‘third way’, that will allow people in the Hakatere settlement to achieve a comfortable standard of living while protecting the water sources and environment.

The word sustainable has entered common usage in recent years, and has become a matter of priority in research (Beck et al., 1996). This trend has fueled the concept for sustainable wastewater management for small communities, what is more it leads to the thought through how the entity of the community relates to the surrounding natural environment in which it exist. In addition to that, the image of being sustainable is becoming increasingly important. That is why, services such as potable water supply, stormwater, wastewater and waste servicing need to demonstrate they meet sustainability criteria.

The cluster approach shows how current wastewater management practices need to change in order to sustain the water cycle. The advantages of choosing decentralized wastewater approach, such as cluster systems, may include increasing water customers, protecting the district’s territory, preserving the source water quality and generating an additional revenue stream.

Moreover, conventional thinking does not work effectively for small communities, which means that different alternatives have to be considered, and cluster wastewater management can be a cost effective and environmentally friendly alternative that may lead to overall water demand reduction.

Local re-use of treated domestic wastewater is a potentially highly sustainable option, and one that is gaining popularity. This kind of intermediate scale treatment (between single lot and large-scale community systems) should be considered in planning wastewater options.

In addition to this, innovative technologies for cluster systems avoid the need for extensive collection infrastructure in low density areas. It has to be ensured that more should be done in this field, more effectively and reliably, with less consumption of energy. Modern wastewater technologies enable low energy, labor and maintenance systems to be installed what is more, it allows the system to operate effectively with minimum maintenance requirement.

Residents of every household influence the quantity and quality of the wastewater delivered to their system. Every time they use the water (flushing toilet, doing laundry, taking a shower etc.)

they operate the system. That is why, the homeowner can influence the performance of the system in a big scale, by controlling the water usage, disposing of wastes properly, using appropriate cleaners, avoiding overloading the system, making needed repairs in a timely manner and scheduling maintenance at regular intervals.

Education residents by providing information on best management practices is the least expensive and most effective step in managing individual or cluster wastewater treatment systems. Education is an important step, which leads to benefits, as it is extremely difficult to control how individuals use their system

Decentralized wastewater is currently a topic only embraced by innovators and slowly being considered by early adopters in the sequence of innovation adoption. The communication of ideas and experiences will facilitate its movement into the mainstream of wastewater management implementation.

Introducing source separation in wastewater management allows adequate treatment of different flows according to their characteristics. This is the key to technical solutions for the efficient reuse of water, energy and fertilizer. Low dilution and collection at source is necessary to achieve economic systems.

Innovative decentralized systems have been introduced and have proven feasibility. Fresh water reduction can be reduced up to 80% while nutrients can be recovered to a large extend. Source control is advantages for hygienic reasons, as low volumes are easier to sanitize.

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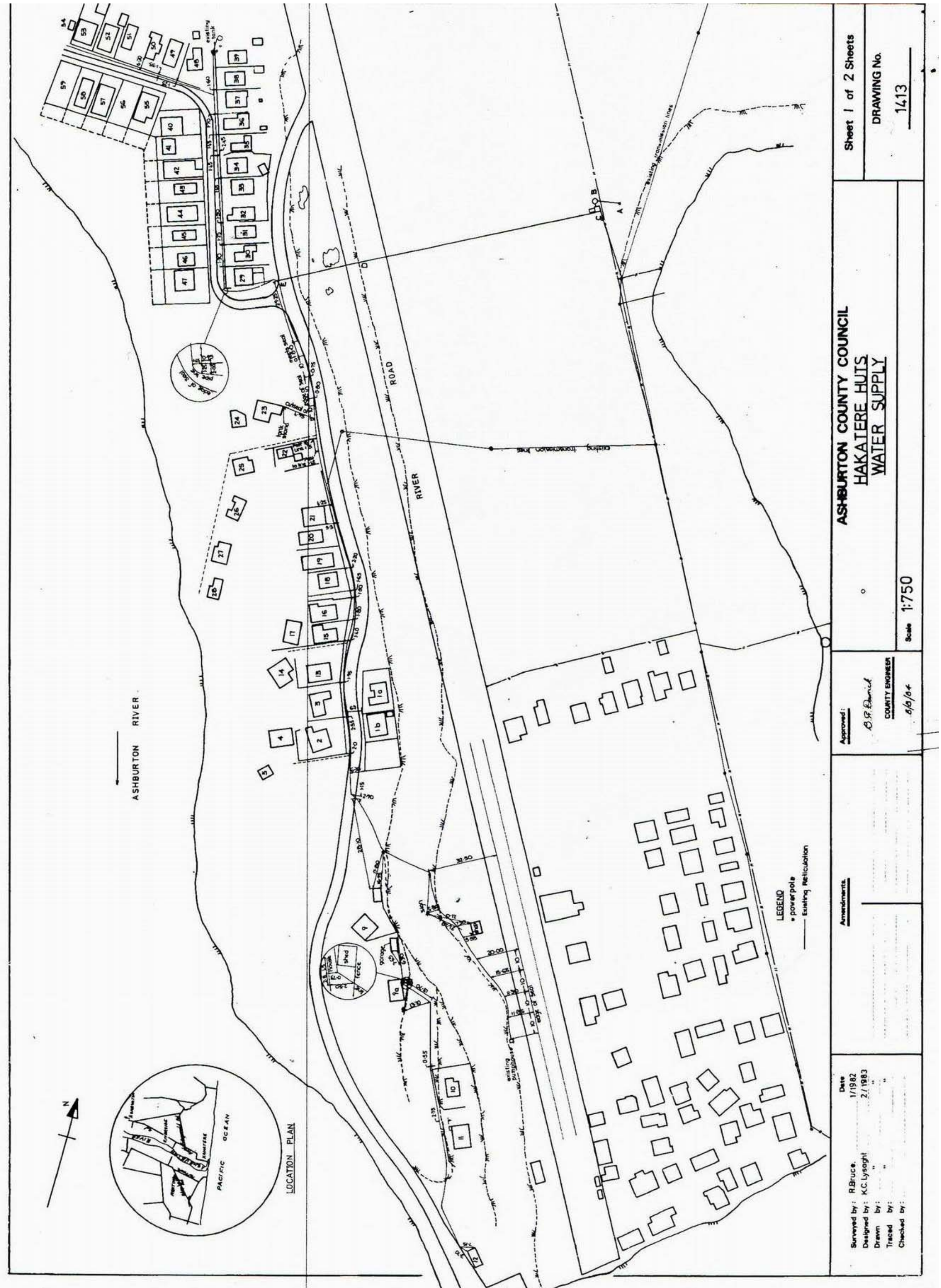
LIST OF APPENDICES

Appendix A: Comparison of water use by different domestic components

Appliance	Volume of water used
Washing machines:	Litres/load
➢ Front-loading washers	55-90
➢ Top-loading washers	120-190
Taps:	Litres/minute
➢ Aerated attachments	2-6
➢ Conventional	15-23
Shower heads:	Litres/minute
➢ Aerated heads	6-10
➢ Conventional	15-23

(Ferguson et al., 2003)

Appendix B: Hakatere Huts map with water supply



Appendix C: Cost comparison (NZ $) for different options suggested

Option	Capital cost (excl. GST)	Council Contribution 20% (excl. GST)	Capital Cost (minus Council contribution, excl. GST)	Capital Cost per Property (incl. GST)	Annual Operating Cost per Property (incl.GST)
Individual Onsite Wastewater Management	$10,000 - $12,000	Not applicable	$10,000 - $12,000	**$11,250 - $12,950**	**$60 - $120**
Modular Community Wastewater Scheme (for 20 lots)	$6,610 - $11,250	$1,322 - $2,250	$5,288 - $9,000	**$5,949 - $10,125**	**$650 - $1,014**
Modular Community Wstewater Scheme (58 lots)	$7,470 - $10,730	$1,494 - $2,146	$5,976 - $8,584	**$6,723 - $9,657**	**$693 - $993**
Complete Community Wastewater Scheme (58 lots)	$6,640	$1,328	$5,312	**$5,976**	**$480**
Notes: 1. All costs are per property 2. Costs include pipework from dwelling to proposed plant 3. Operating costs based on recommended annual maintenance of systems and interest on loan 4. Interest calculated on 25 year loan period and 7.5% interest rate					

(Ashburton District Council Newsletter)

Appendix D: Submission Form

Submission Form

Name: ______________________ Telephone: __________

Postal Address: ______________________ Email: __________

____

Note-: If your postal address differs from your Hakatere address; please indicate what area of Hakatere your property is situated (and property / hut number if applicable).

☐ Lower Hakatere Property / Hut Number ________

☐ Upper Hakatere Property / Hut Number ________

Existing Wastewater Disposal System

1. My dwelling / hut presently discharges to: *(Please tick any that apply)*

☐ Own Septic Tank ☐ Common Septic Tank ☐ Long Drop

☐ Own Holding Tank ☐ Common Holding Tank ☐ Soak Pit

☐ Other *(Please specify)* ______________ ☐ Don't Know

Submission on Wastewater Servicing

2. In regard to the provision of a community based wastewater system to service the Hakatere settlement, please record my/our preference on this matter as follows:

☐ I/we **do not support** the provision of a wastewater scheme at the Hakatere Settlement

☐ I/we **support** the provision of a wastewater scheme at the Hakatere Settlement

3. If a wastewater scheme was provided by Council,

☐ I/we would be interested in connecting **immediately**

☐ I/we would be interested in connecting in the **next 1-2 years**

☐ I/we would be interested in connecting in the **next 3-5 years**

☐ I/we would not wish to connect at any time

If you have any further comments or suggestions, please write them in the space provided on the reverse of this form.

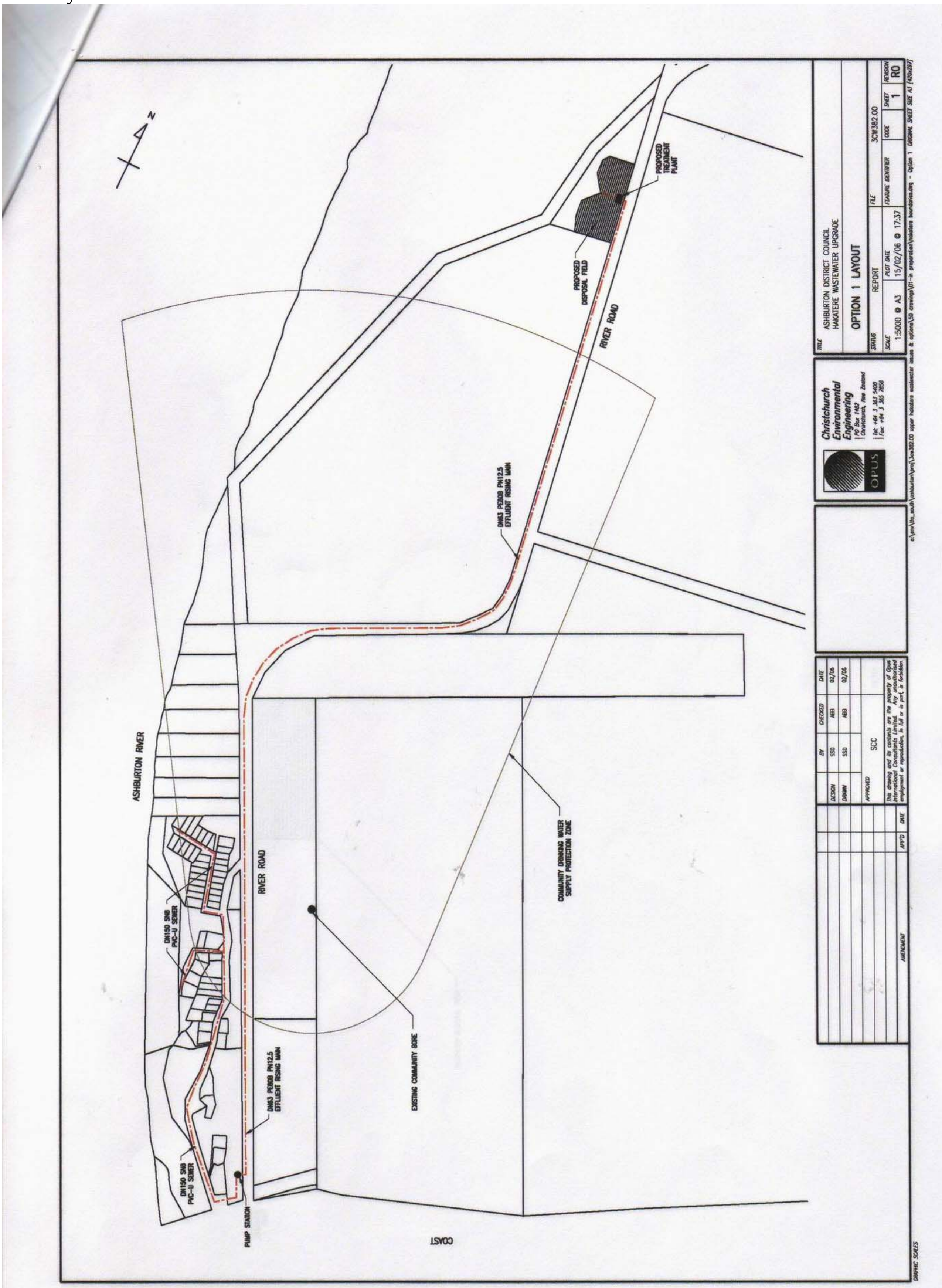
Signed: ______________________ Date: __________

Please complete and sign this form and return it in the envelope provided.

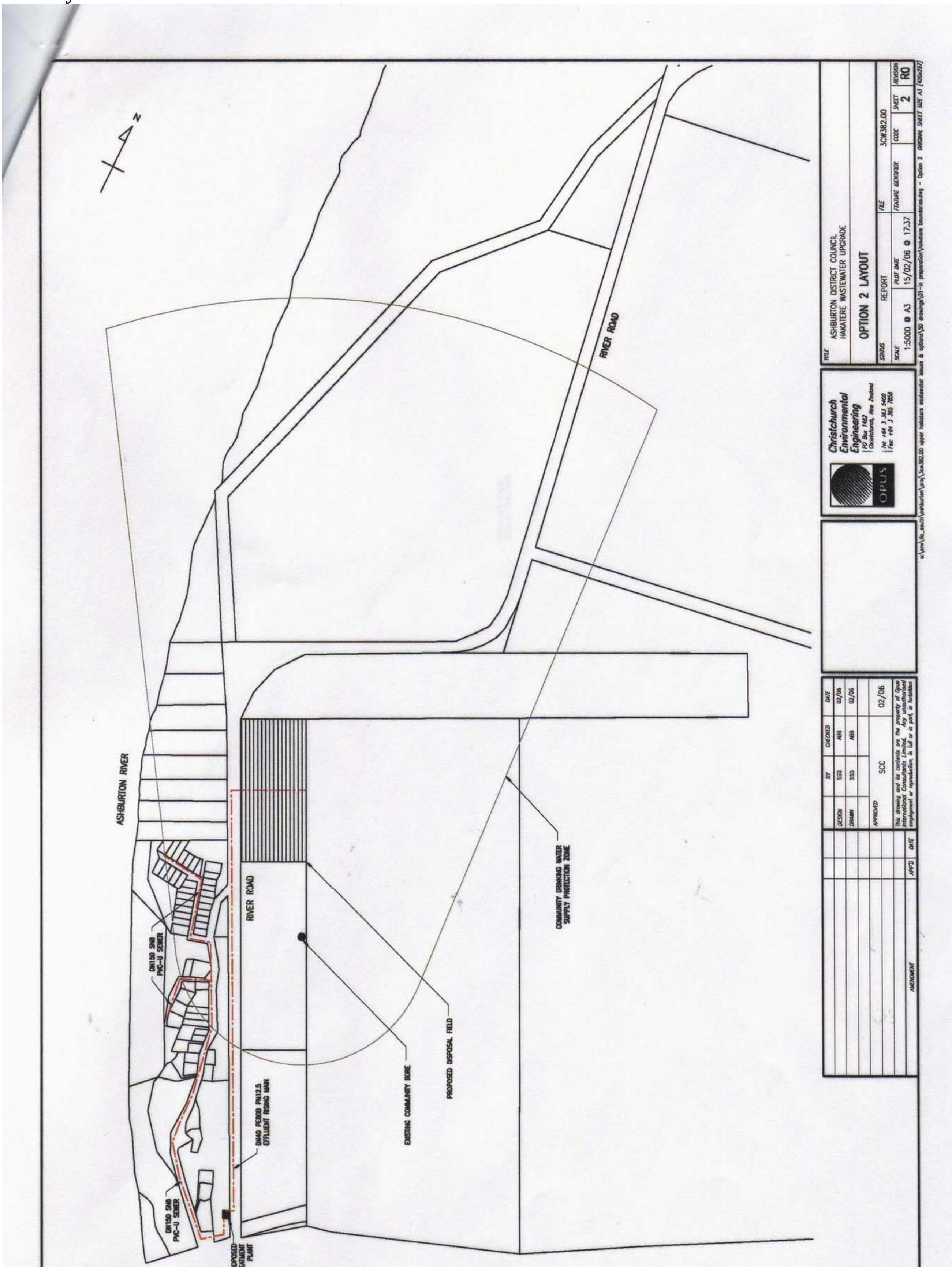
02/06/06 Ashburton District Council - Water Services Department Appendix C

Appendix E: Recirculation Layout Options

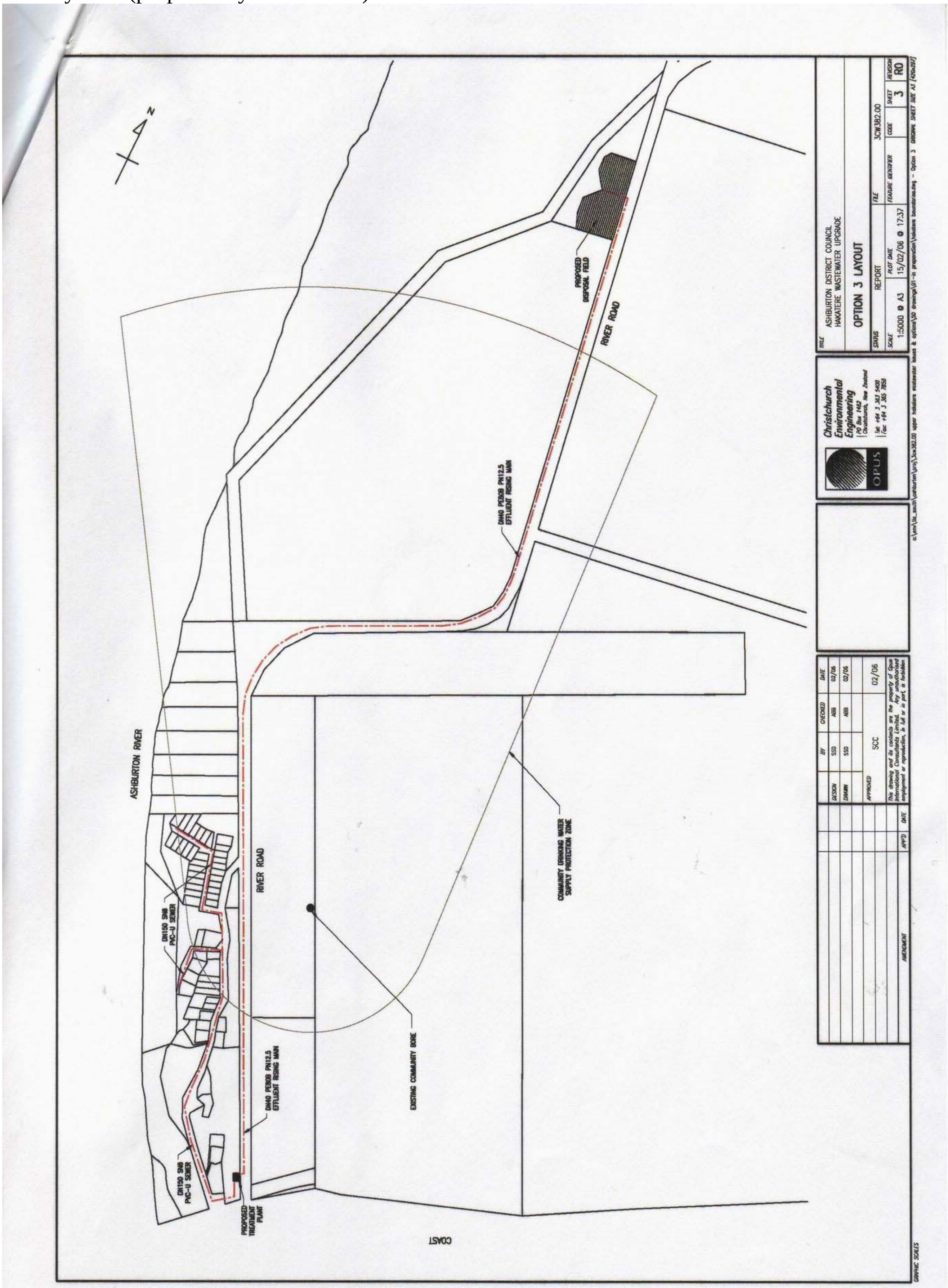
E1: Layout 1



E2: Layout 2


ASHBURTON RIVER
RIVER ROAD
RIVER ROAD
COAST
PROPOSED TREATMENT PLANT
DN150 SN8 PVC-U SEWER
DN150 SN8 PVC-U SEWER
EXISTING COMMUNITY BORE
PROPOSED DISPOSAL FIELD
COMMUNITY DRINKING WATER SUPPLY PROTECTION ZONE
Christchurch Environmental Engineering
OPUS
ASHBURTON DISTRICT COUNCIL
HAKATERE WASTEWATER UPGRADE
OPTION 2 LAYOUT
REPORT
3CW382.00

E3: Layout 3 (proposed by the Council)



Appendix F: Questionnaire

Questionnaire

Evaluating Community Response Towards Wastewater Management in the Upper Hakatere Settlement - 2007

Dear Homeowner,

My name is Agnieszka Kupc, and I am a postgraduate student at Lincoln University, Canterbury. At the moment I am writing my Master thesis in the field of Sustainable Wastewater Management in small communities. I am conducting a research questionnaire in the Upper Hakatere in order to:

- *Identify attitudes, opinions and preferences towards wastewater handling in your area,*
- *Better understand the issues the community is facing while making a decision on wastewater management,*
- *Evaluate whether and how there might be an opportunity for introduction of new technologies or approaches for dealing with wastewater.*

All residents of Upper Hakatere will receive a Questionnaire, and all information provided will be for the use in my Master thesis only and will NOT be presented to the Ashburton District Council in any form. No individual will be able to be identified in the thesis. Please, if you would be so kind and find 20 minutes to fill out the form.

This Thesis is supervised by Dr Magdy Mohssen from Lincoln University (phone no. 033253838). Moreover, Dr Anthony R. Taylor from Irricon Consultants in Ashburton (60 Cass Street, Ashburton) has been involved in the discussions concerning wastewater management for Upper Hakatere.

The research has been reviewed and approved by the Lincoln University Human Ethics Committee.

Thank you very much for your time and effort.

Kind regards,

Agnieszka Kupc Lincoln University

Mobile 021 053 22 70

<u>**Questionnaire**</u>

Evaluating Customer Response Towards Wastewater Management in the Upper Hakatere Settlement – 2007

Please fill the spaces provided. Any additional comments are welcome. Answer as many questions as you can. Thank you very much.

I. Wastewater Management at Present *(Please circle the correct answer where possible)*

A. What is your existing wastewater disposal system?	Own or common septic tank Own or common holding tank Long drop / Soak pit / Do not know Other………………………………
B. Is your system designed to act as a temporary solution until sewer is available, or to act as a permanent method for wastewater management?	Temporary Permanent Both Neither Do not know
C. How old is the system you are using?	…………. Do not know
D. How would you rate the quality of wastewater treatment system you have?	1 – excellent 2 – good 3 – fair 4 – poor 5 – do not know
E. Do you know where the septic tank and disposal field is located?	Yes / Do not know
F. How much have you paid for it?	$………….. Do not know
G. Have you had problems with your system within the last five years? If yes, what kind of problems? Did you fix them?	Yes / No If yes: Problems……………………………. Way of fixing……………………….
H. What sort of maintenance is undertaken? How often? Who is doing that?	………………………………………. ………………………………………. Do not know
I. How would you know if your system was not functioning properly?	
J. Are there issues concerning wastewater handling? If yes, what are they?	
K. Do you think the system you have has an influence on the surrounding environment (soil, water quality)?	1 – a lot 2 – some 3 – almost no 4 – no influence 5 – do not know

Comments:

II. Attitudes Towards Proposed Wastewater Management

A. What are your concerns towards options proposed by the Ashburton District Council?	
B. Do you know the benefits and disadvantages of proposed options?	Yes / No
C. Do you feel well informed?	Yes / No / Don’t know
D. Are you satisfied with consultation process undertaken and public involvement provided by the Council?	Yes / No If No: Why?
E. Do you think something else should be done?	
F. Do you think your knowledge about wastewater management is sufficient to make a decision, or would you like to be better informed?	
G. Among options proposed by the council which one do you support?	
H. What did you consider important when you had to choose among options for a proposed wastewater management system? (e.g. cost, solution, etc.)	
I. Do you know about ECans proposed Natural Resources Regional Plan NRRP and what is proposed in it for the wastewater for areas like the Upper Hakatere Huts?	

Comments:

III. Willingness to Pay

A. If your system was to stop working, how much do you think it would cost to replace it taking into account the NRRP?	
B. What is the yearly maintenance cost for the system you have?	
C. If you were able to connect to a sewer system, what do you think the sewer service would cost you and what will be the annual charge?	
D. Do you think the cost for sewer service would be less, about the same, or more, than your current system costs?	Less About the same More
E. If the costs were the same, would you rather be on your own or sewer system service? Why?	Own / Sewer service

F. Who should cover the costs of new wastewater system and why?	
G. Does the solution for wastewater management to be applied matters for you, if the costs are low or mostly covered by the Council?	Yes / No
H. How much would you be willing to pay to improve the wastewater management in your community?	
J. What is the most that your household would be willing to pay for wastewater service per year?	

IV. Attitudes Towards New Approaches and Technologies to Wastewater Management

A. How would you rate your knowledge concerning wastewater management options and issues?	Excellent Good Fair Poor
B. What is important to you while choosing a way to deal with your wastewater (e.g. costs, solution, water quality produced, sustainability, environmentally friendly approach, water reuse, benefits for you/environment, etc.)	
C. How would you like to manage your wastewater: a) if costs are <u>not considered</u>? aa) if the costs have to be considered? What are your criteria?	a) aa)
D. Would you like to improve your knowledge? What aspects of wastewater management are of special interest to you when choosing a wastewater management approach?	Yes / No
E. Would you be willing to pay a bit more if the solution would be more environmentally friendly than the cheapest option proposed?	Yes / No / Don't know
F. Who do you feel is the best able to manage future wastewater system?	
G. Are you interested in new approaches (e.g. wastewater reuse)	Yes / No
H. Do you think the volume of water you use per day is below or above average 200L/day usage? What are you using it for?	Below / Above / Don't know Normal domestic purposes / Garden irrigation / Car washing / Swimming pool / Other……………....
I. How do you pay for fresh water services and how much?	
What are your preferences/recommendations/comments/advices concerning future option for wastewater handling in your community?	

V. General Information *(Please circle the correct answer where possible)*

A. Are you:	A student / Employed / Unemployed / Retired / Other……………………
B. What is your age category? *Please circle the correct range or write down the year you were born.*	<30 31-40 41-50 51-60 >61
C. Gender:	Male Female
D. What is the highest grade of school you have completed?	
E. What is your net household annual income?	<$20,000 $20,000-35,000 $35,000-55,000 >$55,000
F. Are you living there permanently?	Yes / No
G. Are you living there on your own or with family?	On my own With a family
H. How many people live in your house?	
I. Do the number of people in the house changes during the year (e.g. during Summer time, Christmas, etc.). If yes, what is the min. and max. number of people living there?	Yes / No if yes: Min……. Max…….

That is all the questions I have for you. Any additional comments are welcome. If you have any questions for me, I can be contacted by e-mail at kupca2@lincoln.ac.nz. I will either e-mail you back or, if you prefer I can contact you by phone in order to make an appointment to speak with you in person.

Thanks to the kindness of Mr Peter Opthoog, you can leave completed forms at his mail box, 47 Hakatere Drive.

Thank you very much for your time

The questionnaire is anonymous, and you will not be identified as a respondent without your consent. If you complete the questionnaire, however, it will be understood that you have consented to participate in the project and consent to publication of the results of the project with the understanding that anonymity will be preserved (Lincoln University Polices and Procedures).

Appendix G: Summary of results

Response Rate

Questionnaires	Completed	16	27%
	Returned but not completed*	14	24%
	People not reached**	29	49%
	Total	**59**	**100%**
Comments	* Some people preferred to express their opinion face to face, instead of filling out questionnaires. Reasons for not completing questionnaires included: support for community scheme, being tired of consultation process already undertaken (bad experiences did not enhance people to cooperate in that matter), or not interested that topic again. ** People not present during the survey (empty, for sale or holidays houses, people at work or on holidays).		

Results presented here are from completed Questionnaires, while information from these who did not completed forms but provided information, is taken into consideration and included in Chapter 8 Case Study – Upper Hakatere Huts, Ashburton, New Zealand.

I. Wastewater Management at Present

Existing wastewater disposal system	Own septic tank	6	37.5%
	Own or common septic tank	6	37.5%
	Common septic tank	1	6.25%
	Own holding tank	1	6.25%
	Common holding tank	1	6.25%
	Not indicated	1	6.25%
	Total	**16**	**100%**
Comments			

System designed as temporary or permanent solution	Permanent	12	75%
	Temporary	0	0
	Both	3	18.75
	Not indicated	1	6.25%
	Total	**16**	**100%**
Comments			

Age of the existing system	Indicated	7	43.75%
	Not indicated/Do not know	9	56.25%
	Total	**16**	**100%**
Comments	The age of the existing systems varies between 3 and 40 years old.		

Satisfaction wit the system performance	Very satisfied	9	56.25%
	Satisfied	4	25%
	Do not mind	2	12.5%
	Not satisfied*	1	6.25%

	Total	**16**	**100%**
Comments	* Not sure if the system works properly		

Knowledge about system location	Yes	14	87.5%
	Do not know	2	12.5%
	Total	**16**	**100%**
Comments			

The cost of the system	Indicated*	6	37.5%
	Do not know	8	50%
	Not indicated	2	12.5%
	Total	**16**	**100%**
Comments	*The cost of the existing systems varies between 0 and 15.000 NZ$.		

Problems experienced	No	14	87.5%
	Yes*	1	6.25%
	Not indicated	1	6.25%
	Total	**16**	**100%**
Comments	* Improper connection – problem was solved.		

What sort of maintenance is undertaken	Indicated*	12	75%
	Do not know	3	18.75%
	Not indicated	1	6.25%
	Total	**16**	**100%**
Comments	* The maintenance includes doing nothing, checks by the owners, emptying by local company, cleaning (every year, every three years).		

Knowledge about indicators of system failures	Indicated*	12	75%
	Do not know	1	6.25%
	Not indicated	3	18.75%
	Total	**16**	**100%**
Comments	* Indicators included blocking toilet, smell, overflow, or back lag.		

Issues concerning wastewater handling	Indicated*	5	31.25%
	None	5	31.25%
	Not indicated	6	37.5%
	Total	**16**	**100%**
Comments	* Issues included costs, leakage, Council involvement, or effects on environment.		

If the system influences surrounding environment	No influence	7	43.75%
	Almost no	4	25%
	Some	3	18.75%
	Do not know	2	12.5%
	Total	**16**	**100%**
Comments			

II. Attitudes towards proposed wastewater management

Concerns towards options proposed by the Council	Cost	10	62.5%
	Other*	6	37.5%
	Total	**16**	**100%**
Comments	* Include: not enough information provided about potential options, having own systems, no need for new ones, new system - higher rates, no need to fix something that is working properly – no need for a new system, no option that works for all. People want council to sort out the wastewater management issues and cover the costs of new system, or support the homeowner to pay for their own tanks. The issue was the Council involvement itself (described as 'money-maker'), people were feeling pushed to do something Accountability of the Council – drinking water still not safe to drink, people did what council recommended and it did not work out properly, necessity unreliability of the council. People do not want to be forced into something they do not need		

If benefits and disadvantages of options proposed were known	Yes	6	37.5%
	Some	1	6.25%
	No*	7	43.75%
	Not indicated	2	12.5%
	Total	**16**	**100%**
Comments	* Not sufficient information provided		

If people fell well informed	Yes	4	25%
	No	7	43.75%
	Do not know	2	12.5%
	Relative	2	12.5%
	Not indicated	1	6.25%
	Total	**16**	**100%**
Comments			

Satisfaction with consultation process provided by the Council	Yes	5	31.25%
	No	7	43.75%
	Yes and No	1	6.25%
	Not indicated	3	18.75%
	Total	**16**	**100%**
Comments	People have no trust in the council after it was dealing with their fresh water supply, they do not understand why the council is trying to fix something that is working properly (individual systems), not enough information, some people found about it via newspaper, better answers to their questions. Some people could not believe (facing problems) that shortsightedness of the households not to take up the offer of the solution to Upper Hakatere		

Recommendations, what else should have been done	Indicated*	8	50%
	Not indicated	8	50%
	Total	**16**	**100%**
Comments	* To provide better and more information to people, no cost, accountability, to fix the drinking water supply and then to deal with wastewater.		

The level of knowledge to make informed decision	Sufficient	8	50%
	Not sufficient	8	50%
	Total	**16**	**100%**
Comments			

Option supported by people	Community scheme	1	6.25%
	Do not know	4	25%
	None*	4	25%
	Not indicated	7	42.75%
	Total	**16**	**100%**
Comments	* Happy with existing systems.		

Factors influencing choice of the system	Cost	10	62.5%
	Other*	3	18.75%
	Not indicated	3	18.75%
	Total	**16**	**100%**
Comments	* Solution, long term benefits, needs addressed, rates.		

Knowledge about Natural Resource Regional Plan (NRRP)	Yes	1	6.25%
	No	11	68.75%
	Not indicated	4	25%
	Total	**16**	**100%**
Comments	ECan does not know people living there, no more houses can be build there, lower socio-economic group, river is drying out		

III. Willingness to pay

How much would it cost to replace failing system?	Indicated*	7	43.75%
	Do not know	5	31.25%
	Not indicated	4	25%
	Total	**16**	**100%**
Comments	* The amount stated varies between 10,000-12,000 NZ$, however some people indicated that their existing system would not fail (no cost indicated in such case).		

Annual maintenance cost of the existing system	Cost indicated*	10	62.5%
	Nothing	4	25%
	Not indicated	2	12.5%
	Total	**16**	**100%**
Comments	* Cost varies between paying nothing or 20-200NZ$/year		

Potential sewer cost service and annual charge	Indicated*	8	50%
	Do not know	5	31.25%
	Not indicated	3	18.75%
	Total	**16**	**100%**
Comments	* The dominating opinion was that it would cost too much, more than people can afford, more than water service, somebody stated 6500$ and 1000$/year.		

Cost comparison between sewer and existing system	More	11	68.75%
	About the same	3	18.75%
	Not indicated	2	12.5%
	Total	**16**	**100%**
Comments			

People's preferences when the costs are the same	Own system*	8	50%
	Sewer service	6	37.5%
	Not indicated	2	12.5%
	Total	**16**	**100%**
Comments	* Easier to fix own systems, no confidence for council.		

Who should cover the cost of new system	Community	1	6.25%
	Council	9	56.25%
	No new system required	2	12.5%
	Not indicated	4	25%
	Total	**16**	**100%**
Comments			

Does the solution matters if the cost are covered by the council	No*	5	31.25%
	Yes	3	18.75%
	Do not know	2	12.5%
	Not indicated	6	37.5%
	Total	**16**	**100%**
Comments	* Refunds for existing well functioning systems are expected in case of implementation of something new.		

Willingness to pay to improve wastewater management in the community	Yes*	5	31.25%
	No	7	43.75%
	Other*	2	12.5%
	Not indicated	2	12.5%
	Total	**16**	**100%**
Comments	* $7/week, $100, 500, <1000, 2-3,000. ** Rates for drinking water are already high, the willingness to pay would depend on the actual costs.		

Maximum amount the household would be willing to pay per year for wastewater service	Nothing	6	37.5%
	Indicated*	2	12.5%
	Not indicated	8	50%
	Total	**16**	**100%**
Comments	* Two amounts indicated: 100 and 200$.		

IV. Attitudes towards new approaches and technologies to wastewater management

Factors important when choosing wastewater management approach	Cost	9	56.25%
	Other*	5	31.25%
	Not indicated	2	12.5%
	Total	**16**	**100%**
Comments	* Water quality produced, environmentally friendly approach, sustainability, benefits to owners and environment or solution.		

How people would like to manage their wastewater	Indicated*	4	25%
	Not indicated	12	75%
	Total	**16**	**100%**
Comments	* Nothing has to be done, rebuilding the house with totally environmentally friendly and sustainable approach, or to manage wastewater in a way that is the best for the future and the environment, or to hold to their septic tanks and systems they have at the moment.		

The need to improve the knowledge in the field	Yes*	9	56.25%
	No	4	25%
	Not indicated	3	18.75%
	Total	**16**	**100%**
Comments	* Knowledge about environmentally sounds approaches and costs.		

The willingness to pay more for innovative, more environmentally sound approach instead of the potential cheapest option.	Yes	6	37.5%
	No*	7	43.75%
	Do not know	2	12.5%
	Not indicated	1	6.25%
	Total	**16**	**100%**
Comments	* Existing systems are already environmentally friendly and well functioning.		

Who should best manage the system in the future	Property owner	5	31.25%
	Community	2	12.5%
	Council	4	25%
	Not indicated	5	31.25%
	Total	**16**	**100%**
Comments			

It people were keen on innovative approaches	Yes*	13	81.25%
	No	1	6.25%
	Not indicated	2	12.5%
	Total	**16**	**100%**
Comments	* Costs as influencing factor when making-decisions; the need to save water.		

Estimated water use per day was below or above average (200L/day)	Below	13	81.25%
	Do not know	3	18.75%
	Not indicated	1	6.25%
	Total	**16**	**100%**
Comments	Water is used for normal domestic purposes, and for small around house garden irrigation.		

The cost for fresh water service per year	Rates*	8	50%
	Nothing**	2	12.5%
	Do not know	1	6.25%
	Not indicated	5	31.25%
	Total	**16**	**100%**
Comments	* Rates vary between 680-850$/year ** Nothing – people have their own water tanks Additional cost to cover is drinking water bottle per week – water from the tap is not drinkable – bad taste The rates for drinking water are already too high concerning houses' values and lot sizes in the area, and wastewater service would probably cost even more than that.		

V. General Information

People completing questionnaires	Employed	4	25%
	Retired	5	31%
	Other (e.g. invalid)	4	25%
	Not indicated	3	19%
	Total	**16**	**100%**
Comments			

Age category	<30	2	12.5%
	31-40	2	12.5%
	41-50	2	12.5%
	51-60	2	12.5%
	>61	5	31.25%
	Not stated	3	18.75%
	Total	**16**	**100%**
Comments			

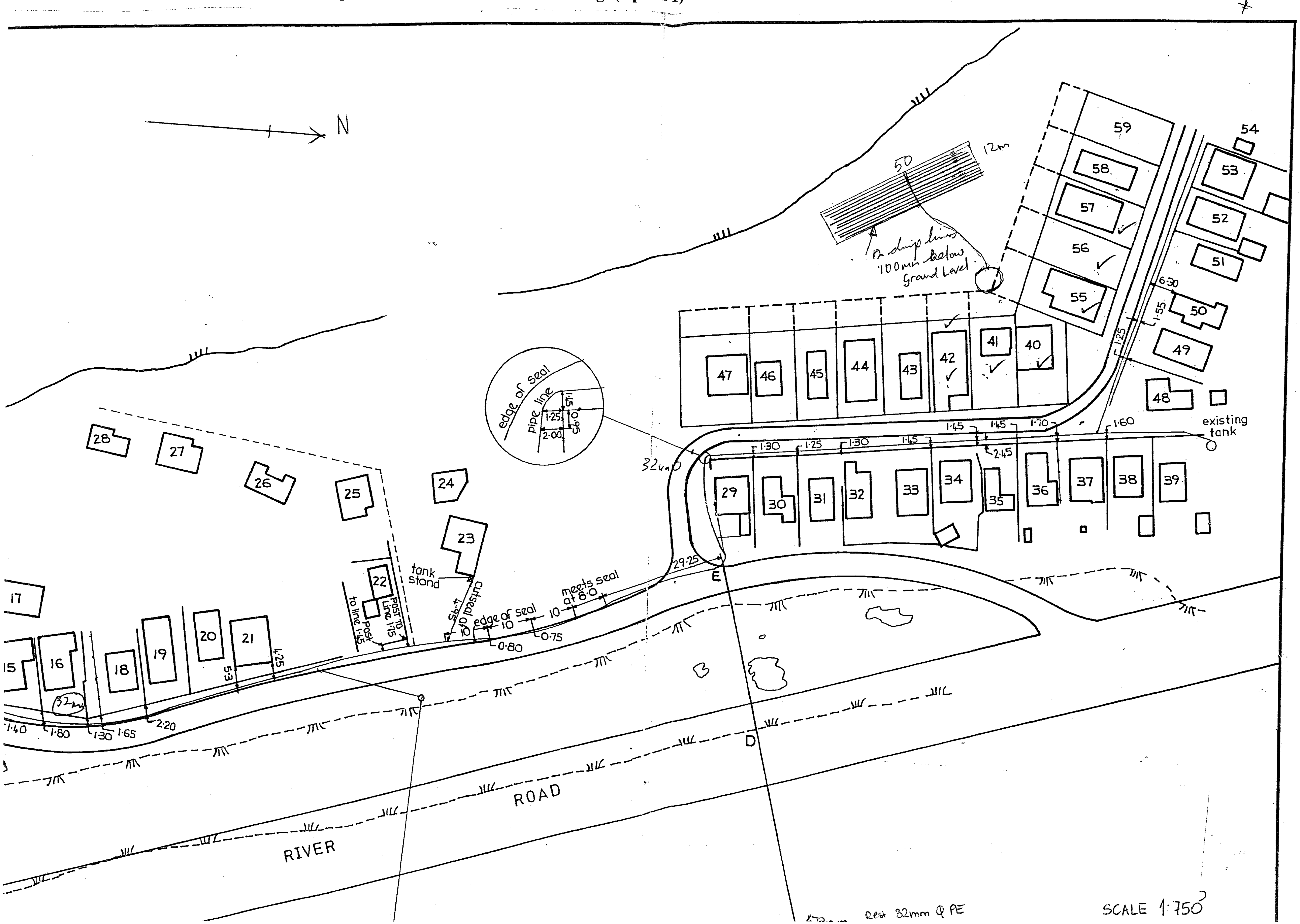
Gender	Female	7	43.75%
	Male	6	37.5%
	Not indicated	3	18.75%
	Total	**16**	**100%**
Comments			

Median annual household income in NZ$	<20,000	3	18.75%
	20,000-35,000	2	12.5%
	>55,000	1	6.25%
	Not indicated	10	62.5%
	Total	**16**	**100%**
Comments	Most people are on fixed incomes.		

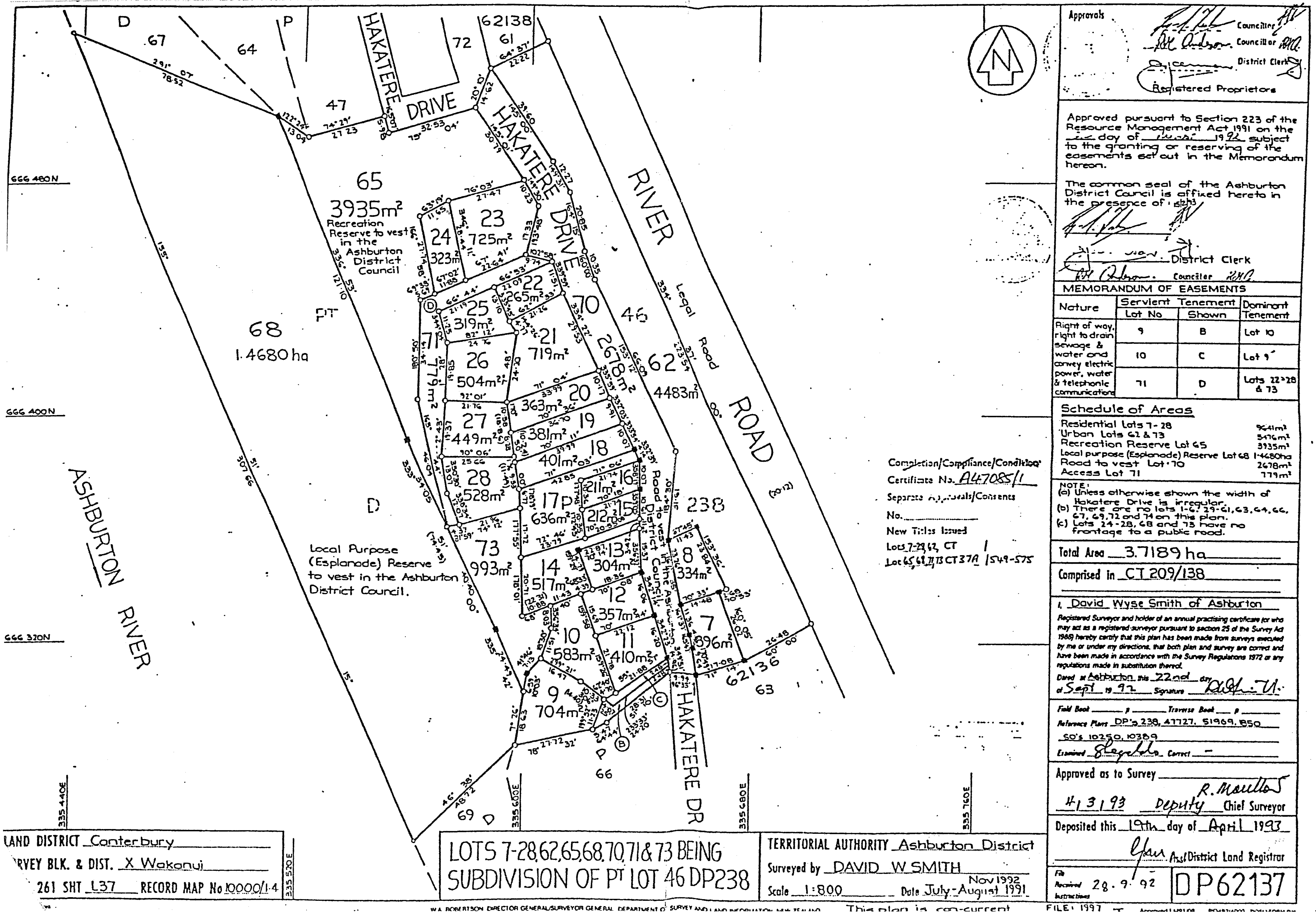
Permanent stay in Upper Hakatere	Yes	13	81.25%
	No	1	6.25%
	Not indicated	2	12.5%
	Total	**16**	**100%**
Comments			

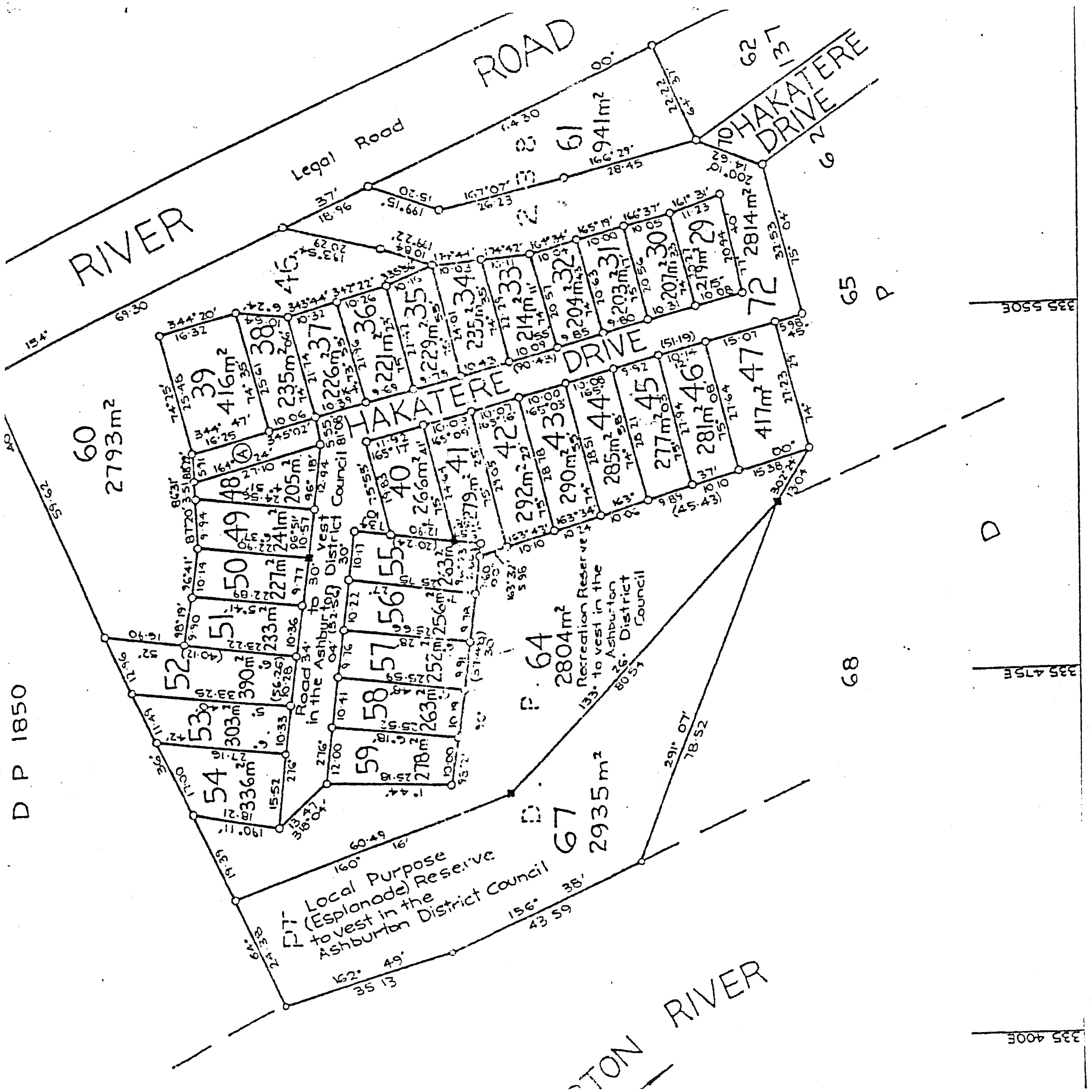
Living with family or on their own	Family	9	56.25%
	Own	4	25%
	Not indicated	3	18.75%
	Total	**16**	**100%**
Comments	The number of people living in the house varies between 1 and 4, with maximum 6 people in the house during holidays.		

Appendix H: Potential connections and options for wastewater treatment sittings (Option 1)



Appendix I: Potential connections and options for wastewater treatment sittings (Option 2 – recommended)




RIVER ROAD
Legal Road
HAKATERE DRIVE
60 2793m²
39 416m²
38 235m²
37 226m²
36 221m²
35 229m²
34 235m²
33 214m²
32 204m²
31 203m²
30 207m²
29 219m²
72 2814m²
61 941m²
48 205m²
49 241m²
50 227m²
51 233m²
52 390m²
53 303m²
54 336m²
55 263m²
56 256m²
57 252m²
58 263m²
59 278m²
40 266m²
41 279m²
42 292m²
43 290m²
44 285m²
45 277m²
46 281m²
47 417m²
P. 64 2804m²
Recreation Reserve to vest in the Ashburton District Council
Road to vest in the Ashburton District Council
D. 67 2935m²
Local Purpose (Esplanade) Reserve to vest in the Ashburton District Council
D P 1850
65 P
D
68
RTON RIVER

CURRICULUM VITAE

Agnieszka Kupc

Email: agnieszka_kupc@hotmail.com
Born: 29th June 1981, Trzcianka, Poland
Nationality: Polish

EDUCATION

February 2005 – January 2008	**University of Natural Resources and Applied Life Sciences (BOKU), Vienna, AUSTRIA** Master Course in Natural Resources Management and Ecological Engineering, Spec. Ecological Engineering Master Thesis in the field of: *Cluster Approach to Sustainable Wastewater Management for Small Communities.*
February 2006 – May 2007	**Lincoln University, Canterbury, NEW ZEALAND** Master Course in Natural Resources Management and Ecological Engineering – in cooperation with University in Austria
June 2004	**Bachelor of Science in Environmental Protection and Management,** Spec. Water Management (grade: very good) Thesis in the field of Water purification and recycling in modern car wash (Gdansk/Lisbon)
June – September 2003	**Instituto Superior Tecnico (IST), Lisbon, PORTUGAL** Research work within ERASMUS Student Exchange Program, Faculty of Chemistry, research within the EU Project - field of water desalination for energy production purposes
October 2000 – June 2004	**Gdansk University of Technology, Gdansk, POLAND** Environmental Protection and Management Course Faculty of Chemistry, Spec. Water Management (4 years, full-time studies in English language)
June 2000	Graduated from Secondary School of General Education, Rumia, POLAND, Faculty: Mathematics and Physics Baccalaureate Examination 1st June 2000

ADDITIONAL TRAINING

October 2006	**On-siteNZ and Building Officials Institute of New Zealand INC** (BOINZ), Christchurch, NEW ZEALAND On-site Wastewater Management Training Course

June/July 2005	**Czech University of Agriculture, Prague, CZECH REPUBLIC** EU Workshop on Disaster Prevention and Reduction with Emphasis on Floods and Droughts
Nov. 2004 – February 2005	**Gdansk University of Technology, Gdansk, POLAND** “ABC of setting up and handling business” evening course; **Pomeranian Centre for Environmental Research and Technology** (POMCERT), Gdansk, POLAND Manager of Environment Course

WORK EXPERIENCE

December 2006 – May 2007	**Irricon Consultants, Ashburton, NEW ZEALAND** Cooperation with Dr. Anthony R. Taylor, while working on case study (wastewater management for small communities) for Master Thesis
October – December 2004	**Institute of Meteorology and Water Management (IMGW)** Department of Oceanography and Baltic Sea Monitoring, Maritime Branch, Gdynia, POLAND Laureate of National project organized by Ministry of Environment (EcoCarrier) – Graduate Training in Laboratory of Water Chemistry, Water Quality Monitoring Projects and Cruises
February – May 2004	**CMR Ltd. (Car Wash Branch), Gdansk, POLAND** Student training, work on contract, market research, collecting information for Thesis

LANGUEGES

Polish - native
English – fluent
German – fair/good - still improving