RISK ASSESSMENT, COSTS AND BENEFITS FOR COMMUNITY EFFLUENT REUSE AND DISPOSAL SCHEMES: CONTRASTING EXPERIENCES FROM VICTORIA AND NEW ZEALAND.

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ABSTRACT
Specific challenges to the provision of a sustainable wastewater service for existing towns with poorly performing on-site systems are being identified through both domestic wastewater management planning and the Victorian Government Country Town Water Supply and Sewerage Program. A key challenge is the development of economically and socially viable effluent reuse and disposal schemes for community wastewater systems that also meet regulatory requirements for the protection of human health and ecosystems.

This paper presents the outcomes of a risk assessment and cost benefit analysis for a proposed community wastewater system for a small town in central Gippsland, Victoria. Preliminary modelling suggests that very limited improvement in environmental / human health performance can be expected with the provision of large storage facilities (i.e. wet weather dam) and restriction of deep drainage. Recent experiences from New Zealand support the outcomes of this assessment. Current Victorian guidelines, however, discourage deep drainage in effluent irrigation and therefore the benefits that such schemes can deliver in the future. The outcomes illustrate the need for case by case risk analysis and triple bottom line assessment of wastewater servicing options

Keywords: cost benefit analysis, decentralised wastewater systems, effluent reuse, winter storage

INTRODUCTION
In a number of countries including New Zealand and Australia there are programs being implemented to identify and develop sustainable wastewater servicing solutions for small towns and peri-urban zones. A significant number of towns or local areas are identified as in need of improved wastewater servicing to address risks to human health and ecosystems. These areas face specific challenges to sustainable wastewater servicing including limited economies of scale, sensitive receiving environments, low rate bases for on-going funding, limited local capacity and infrastructure for servicing and limited available or suitable land for community wastewater treatment and reuse infrastructure.

In Victoria efforts for improved servicing are being driven by the Country Towns Water Supply and Sewerage Program (CTWSSP) managed by the Department of Sustainability and Environment. The program includes the identification of areas or towns with poorly performing on-site wastewater management systems and the development of Domestic Wastewater Management Plans (DWMP) by local councils for improved practices and reduced risk to human health and ecosystems. The CTWSSP also includes the development and implementation of innovative and sustainable decentralised wastewater systems for towns where servicing by on-site systems or conventional sewerage is either unsustainable or too expensive.

In New Zealand similar initiatives are underway including consideration of a National Environmental Standard requiring a “Warrant of Fitness” for on-site wastewater management systems (New Zealand Ministry for the Environment, 2008). In 2006 territorial local authorities (local councils) completed Water and Sanitary Services Assessments of all unsewered towns and areas (Ray, 2007). This information is being used to prioritise the provision of some form of community wastewater system be it conventional, decentralised or somewhere in between. Of greater relevance is the growth in the use of Community Scale Decentralised Wastewater Systems (CSDWS) as the preferred wastewater servicing option for new residential subdivisions across New Zealand. There are estimated to be over 100 decentralised wastewater systems servicing residential communities throughout New Zealand with some in operation for up to ten years.

A distinct difference exists in the way in which Victoria (and other Australian states) and New Zealand approach the land application or treatment of treated effluent from both conventional centralised and decentralised wastewater systems. This is despite the fact that the guiding principles behind the protection of water quality that drive the design of these systems are similar in many ways and both draw from the *ANZECC Water Quality Guidelines* (2000 and 2004). In most Australian states tight restrictions are placed on the amount of deep drainage permissible for any proposed effluent irrigation scheme. Deep drainage (the drainage of water out of the root zone of the irrigation field) must be limited to the minimum required for adequate flushing of salts from the soil profile. This ensures soil salt concentrations do not exceed thresholds for plant growth. In New Zealand this is a luxury that cannot be afforded due to high rainfall in many areas and as such land treatment schemes are often designed for deep drainage for most days of the year (NZLTC, 2000).

The requirement to restrict deep drainage results in the need for very large storage facilities (e.g. dams) with typical capacities of 150-250 days Average Dry Weather Flow (ADWF). When effluent irrigation is being considered for a large scale municipal sewerage scheme (e.g. >1000 lots) the cost of both land purchase and construction of this facility is typically 20-30% of total capital costs and is less of a limiting factor in the feasibility of the scheme. However, in the case of smaller country towns aiming to provide a sustainable wastewater service (e.g. a 200 lot CSDWS) the cost of this storage facility and additional irrigation land can be up to 60-70% of total capital costs and render the concept unfeasible.

In the case of *existing* towns and local areas currently serviced by poorly performing on-site systems, the difficulty in funding excessively high capital costs of large storage facilities and land requirements is limiting potential improvements in wastewater servicing. As a result, existing discharges to surface or groundwater continue as do the risks to human health and the ecosystem. Consequently (using Victoria as an example), achievement of the original aim of the *State Environment Protection Policy (Waters of Victoria) 2003* may be prevented by the government guidelines established to help achieve them.

This paper compares the costs and benefits of the option of limiting deep drainage to minimum depths required for adequate salt flushing and the option of reducing storage size and increasing deep drainage. The focus of this study is on *existing* small towns and unsewered areas currently serviced by poorly performing on-site systems where there is limited or no potential for continuing use of on-site wastewater systems.

CONTRASTING APPROACHES: VICTORIA AND NEW ZEALAND

Climate is the biggest driver for different approaches to the management of effluent application to land in Victoria and New Zealand. While there are dry regions of New Zealand between 65-75% of the country experiences < 50 days of soil moisture deficit in a median year (NIWA, 2004). Irrigation of treated effluent to meet plant water requirements is a luxury that can rarely be afforded. The second key driver is the Maori philosophy to protect the waters of New Zealand by putting waste on land to allow it to be filtered or cleaned before entering waterways. These two factors have combined to foster local development of the concept of land treatment (rather than land disposal) of wastewater.

A typical land treatment system in New Zealand will consistently apply wastewater to land well in excess of plant water requirements resulting in on-going deep drainage to groundwater. The approach acknowledges the significant capacity of the soil and plant environment to assimilate pollutants when sustainable loading rates are maintained. Storage facilities for smaller scale CSDWS in New Zealand typically range between 1-3 days storage at average flow. Application of wastewater is only ceased when soils reach near-saturation or during heavy rainfall events to prevent runoff. Effluent is applied either daily at very low rates or in a pulse dose configuration with 3-7 days rest interval between applications to a specific site. The guiding principle for sustainable land treatment is to minimise the potential for saturation by limiting the depth of application to 50% of the difference between field capacity and near saturation (NZLTC, 2000). Each proposal for an effluent land application scheme is assessed on a case by case basis to decide if it meets the objectives of regional rules and policies and the broader direction provided by the *Resource Management Act 1991*. The *New Zealand Guidelines for Utilisation of Sewage Effluent on Land* issued by the New Zealand Land Treatment Collective (2000) is the only nationally consistent guideline for the design, establishment and operation of land treatment schemes.

In Victoria the *State Environment Protection Policy (Waters of Victoria) 2003* and the *State Environment Protection Policy (Groundwaters of Victoria) 1997* prescribe clear water quality targets for a range of surface and groundwater environments in Victoria based on the appropriate beneficial use. Specific guidelines on the design and operation of wastewater irrigation schemes are provided through the EPA Publication 464.2: *Guidelines for Environmental Management – Use of Reclaimed Water* (EPA Victoria, 2003a) and EPA Publication 168: *Guidelines for Wastewater Irrigation* (EPA Victoria, 1991). They also set out specific design criteria for irrigation schemes that include matching irrigation closely to plant water requirements and limiting deep drainage to the minimum required for flushing of salts from the soil profile. It is this element of the guidelines that result in the need for significant storage facilities. As previously stated these large storage facilities may be warranted where maximum plant growth and water efficiency is desirable and delivers an economic benefit. However, in the case of existing small towns where on-site systems are not considered sustainable, this requirement typically prevents the delivery of improved human health and ecosystem protection or a high quality wastewater service.

The above policies and guidelines all allow for variation from these storage and deep drainage requirements where it can be demonstrated that the proposed system will meet or exceed the water quality objectives listed for the relevant *State Environment Protection Policy*. In New Zealand, the land disposal concept would be referred to as *land treatment*. Full winter storage facilities are not typically required for small town CSDWS in most states of the U.S.A either.

These two approaches represent more extreme ends of the land application spectrum. A number of researchers are working to develop understanding of hydraulic and pollutant dynamics in land application systems for the on-site and decentralised scales (McCardell *et al*., 2007 and Gielen *et al*., 2008). However, there are still many aspects of the field performance of such systems that remain unanswered. Is the New Zealand approach of regular deep drainage from land treatment systems providing an adequate level of protection in a range of environments? Similarly, is the Victorian approach of minimal deep drainage and large storage facilities demonstrated to be warranted in order to provide adequate protection of soil and water quality?

CASE STUDY: METHODOLOGY

The case study used to undertake a comparison of costs and benefits of varying degrees of deep drainage and storage is based on the town of Tyers in central Victoria. Tyers contains 75 existing on-site systems with highly variable performance. Previous work has identified that a significant proportion of the on-site wastewater management systems in the town discharge some or all of their wastewater to the ground surface and street drains. A risk assessment undertaken as part of the CTWSSP indicated that on-site systems are not a long term sustainable option for the town and an alternative option is necessary to provide a safe and effective wastewater service. A range of options were assessed and compared ranging from the do nothing option to conventional sewerage for the whole town and a concept design for a CSDWS developed.

This concept included the reuse of treated effluent using subsurface irrigation on public open space throughout the town. It was identified through the concept design process that the capital and land purchase costs associated with storage and land application would constitute a substantial (60-70%) proportion of the total system costs if established under the minimal deep drainage / winter storage configuration. Each option involves varying storage requirements. These servicing options are described in Table 1 below.

Table 1: Summary of Wastewater Servicing Scenarios Assessed for Tyers, Victoria

Scenario	Description
Existing	Maintain on-site wastewater management systems in existing condition and operation.
Best Practicable Option (BPO) On-site Systems	Upgrade of all on-site systems to BPO for the site. Some sites do not have capacity for sustainable long-term on-site wastewater management.
Community Scale Decentralised Wastewater System (CSDWS) 1 day storage	Community wastewater management with an effluent sewer collection system, centralised treatment and subsurface irrigation of treated effluent on public open space. One day storage capacity at central site. Fixed rate irrigation at 2.9 mm/day.
CSDWS 10 days storage	As above with increasing storage capacity at central site. Irrigation triggered whenever the soil is below field capacity. The depth of application above field capacity set to prevent storage overflow in the 90^{th}% wet year and prevent effluent runoff.
CSDWS 30 days storage	
CSDWS 60 days storage	
CSDWS 90 days storage	
CSDWS 120 days storage	
CSDWS 150 days storage	
CSDWS 180 days storage	
CSDWS 210 days storage	
CSDWS 240 days storage	
CSDWS 260 days storage and double the irrigation area.	As above with 260 days storage capacity at central site. This scenario meets the requirements of EPA (2003a) and EPA (1991) with respect to deep drainage and overflow from the storage dam. Irrigation triggered at 50% of plant available water with irrigation to field capacity. An additional 3.5 hectares of irrigation land required.

Hydraulic and nutrient modelling was undertaken for each scenario to estimate average annual loads to groundwater, runoff and overflow from the storage facility. This was undertaken using *Model for Effluent Disposal Using Land Irrigation (MEDLI Version 1.3)* developed by the Co-operative Research Centre for Waste Management and Pollution Control and the Queensland Department of Natural Resources. Some elements were assessed using an in-house daily soil water and nutrient model that has been calibrated to within 1-5% of MEDLI outputs for all parameters. The transport of viruses to groundwater through deep drainage was estimated using a simplistic daily viral dieoff model based on Cromer *et al* (2001).

Total export of hydraulic, nutrient and viral loads (and conversely total assimilation or "reuse" of these elements of the waste stream) to either surface or groundwater were incorporated into a comparison of costs and benefits by looking at the ratio of capital investment versus the mass or proportion of the total hydraulic, nutrient or virus load assimilated or reused in the land application system. Essentially, the lower the number the more efficient the system is in managing and utilising these parameters. In addition to the comparison of costs and benefits a number of other comparisons were made to water quality targets from *ANZECC (2000)* and the Victorian *SEPP(s)* along with comparison to typical small scale agricultural activities.

CASE STUDY: RESULTS

This preliminary modelling indicates that a CSDWS with even one day storage capacity delivers orders of magnitude improvement in nutrient and virus export to surface and groundwater (Figure 1). This is not surprising given the significant proportion of wastewater currently discharging direct to surface or groundwater.

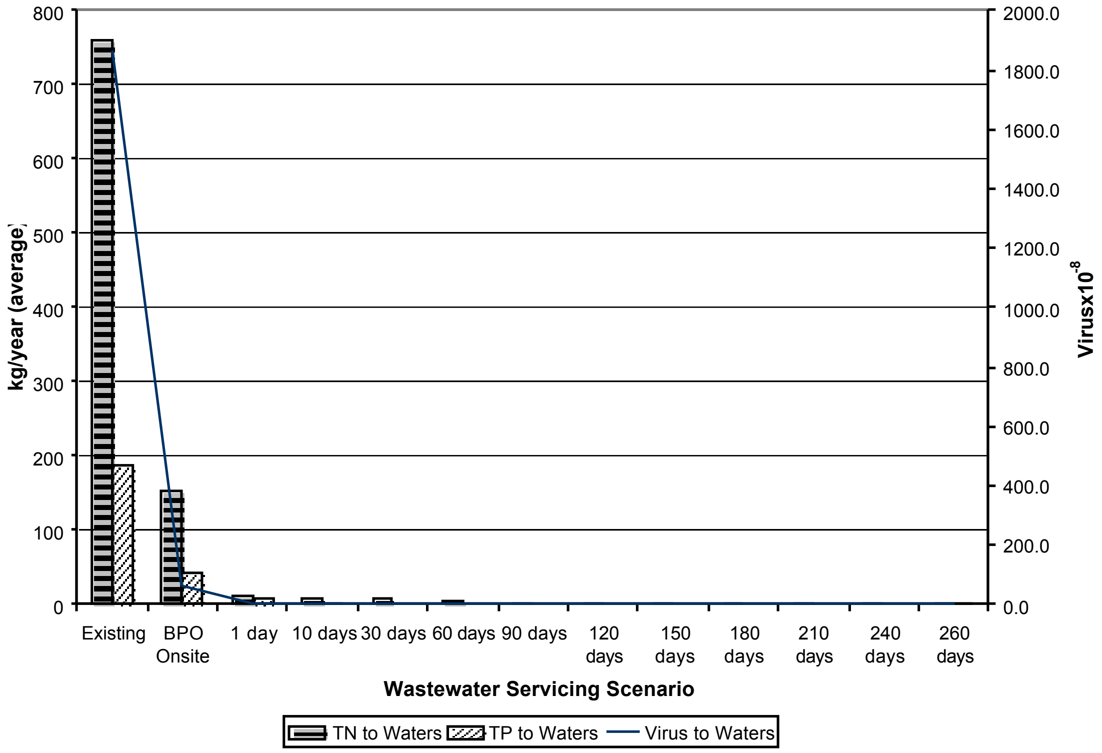
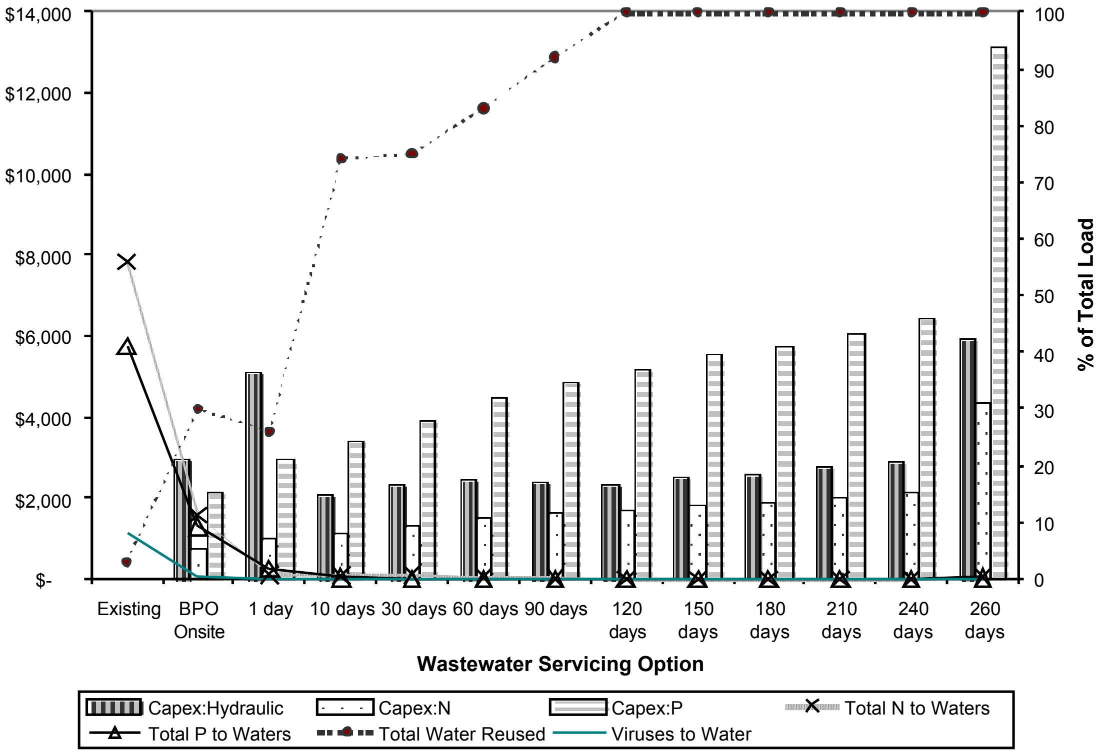


Figure 1: Discharge to Waters across Wastewater Servicing Scenarios

Figure 2 also confirms that the provision of a centrally managed CSDWS with even one day storage provides the lowest cost relative to benefits for nutrient and virus assimilation. Modelling did indicate however that 10 days storage provided the lowest cost benefit ratio for the proportion of the hydraulic load reused rather than discharged direct to groundwater. Cost benefit ratios increase by 300-400% between the one day storage option and the 260 day scenario that meets the current requirements of the Victorian government. This 300-400% increase in capital spending achieves less than 10 kg reduction in both nitrogen and phosphorus loads to groundwater in an average year.

When looking more specifically at the CSDWS options an assessment of deep drainage suggests that the provision of 10 days storage limits effluent deep drainage (i.e. deep drainage as a direct result of an irrigation event rather than rainfall) to approximately 10% of total water applied to the site in an average year (refer to Figure 3). Approximately 75% of effluent applied to the site is utilised by vegetation. Provision of one day storage does result in total deep drainage being dominated by irrigation events rather than rainfall. It is important to note however that deep drainage relates predominantly to rainfall events beyond the provision of 90 days storage and 260 days storage (along with a doubling in irrigation area requirements) is required to limit deep drainage to the minimum leaching fraction for salts flushing of 13%.



Capex = Capital Expenditure

Figure 2: Summary of Costs and Benefits of Wastewater Servicing Scenarios

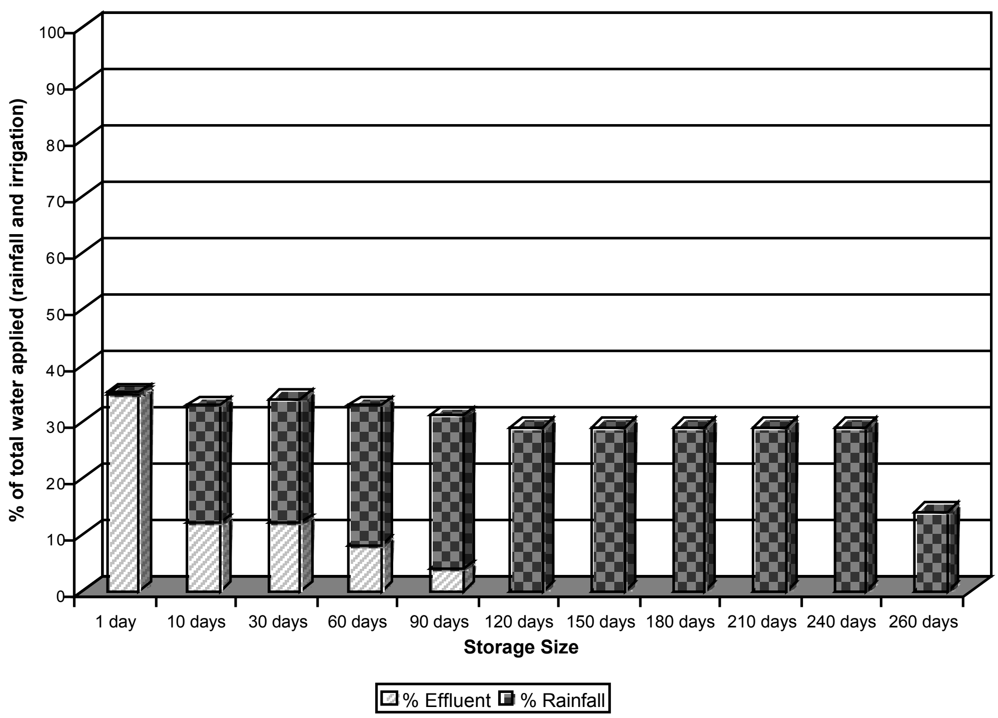


Figure 3: Breakdown of Deep Drainage across Storage Sizes

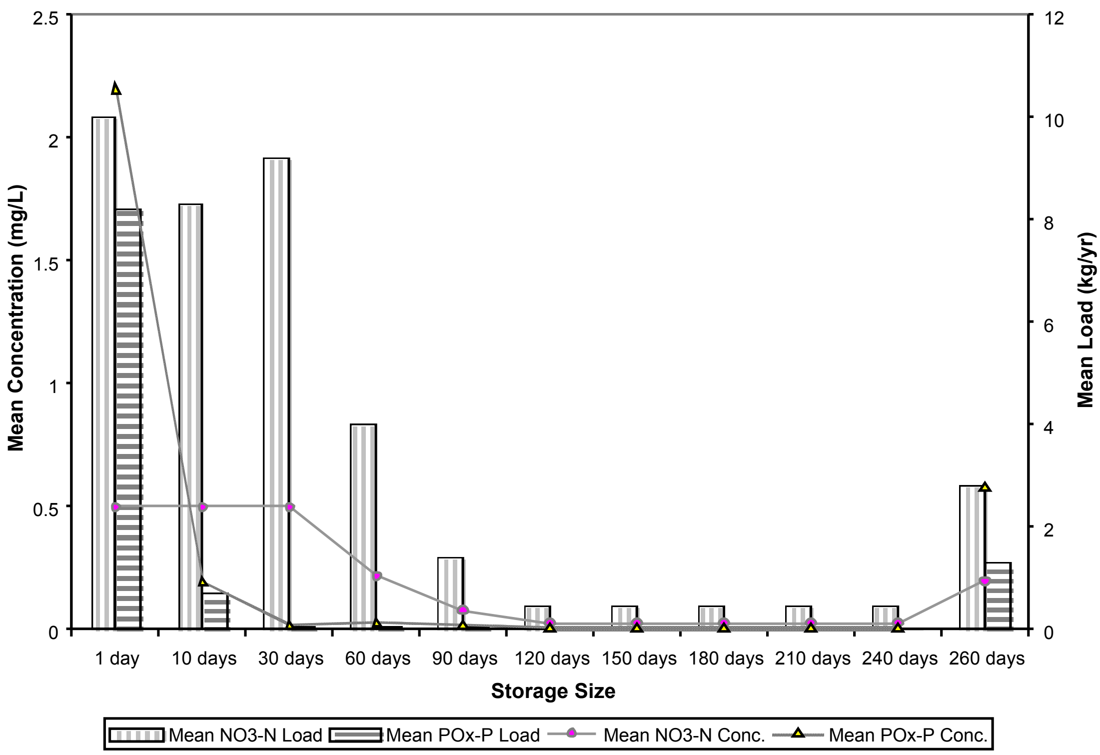


Figure 4: Nutrient Loads and Concentrations to Groundwater across Storage Size

It is also worth noting that supply reliability was above 90% for all storage size options meaning plants experienced moisture stress on less than 10% of days in average year. Considering the nature of the proposed land application sites (public open space) this constitutes a significant improvement in supply security. The provision of additional storage did not improve supply reliability for any of the options

Figure 4 provides a closer look at nutrient loads and concentrations to groundwater for the CSDWS options. Loads from the existing and BPO on-site upgrade options are orders of magnitude higher. It is important to note that even the highest nutrient loads shown in Figure 4 are very small in relation to likely total catchment loads. Even one day storage reduces areal loading rates to groundwater to 2-3 kg/hectare/year for both nitrogen and phosphorus. The provision of 10 days storage reduces phosphorus loads below 1 kilogram per year (200 grams/hectare/year). The provision of increased storage does deliver improvements in nutrient loads to groundwater (albeit very small, insignificant improvements) up to 120 days storage. Beyond this no significant improvement could be identified in the modelling. The slight increase in nutrient loads observed for the 260 day storage scenario relates to a switch in irrigation method from small regular applications (0.5-2mm/day) to more traditional irrigation depths following a significant reduction in plant available water (i.e. irrigation trigger at 50% of plant available water capacity). Loading up a soil so heavily creates the potential for significant deep drainage events where heavy rainfall follows irrigation.

Nitrate-N concentrations fall below the relevant local nutrient objective for ecosystem protection for all CSDWS scenarios (0.6 mg/L from EPA Victoria 2003b). Phosphorus falls below this target (0.045 mg/L) with the provision of 30 days storage or more. The CSDWS used in this assessment produces effluent with total nitrogen and phosphorus concentrations of 20 and 8 mg/L respectively. Reduction in total phosphorus to 6 mg/L through the provision of a dosing system (at a fraction of the cost of increased storage) would reduce deep drainage concentration below the ecosystem protection target. All discharge concentrations fall below the *ANZECC (2000 and 2004)* guideline values for drinking water, stock watering or irrigation supply. Virus concentrations were 1 virus/L or less for all CSDWS scenarios due to the provision of active disinfection.

Underlying this negligible improvement in environmental and public health protection is a substantial increase in capital costs for the storage facility and additional irrigation land required to meet current requirements for minimal deep drainage (Figure 5). In this case total capital costs could jump to as high as $80,000 per lot with limited evidence to suggest there will be a significant improvement in the discharge of pollutants to waterways or security of water supply.

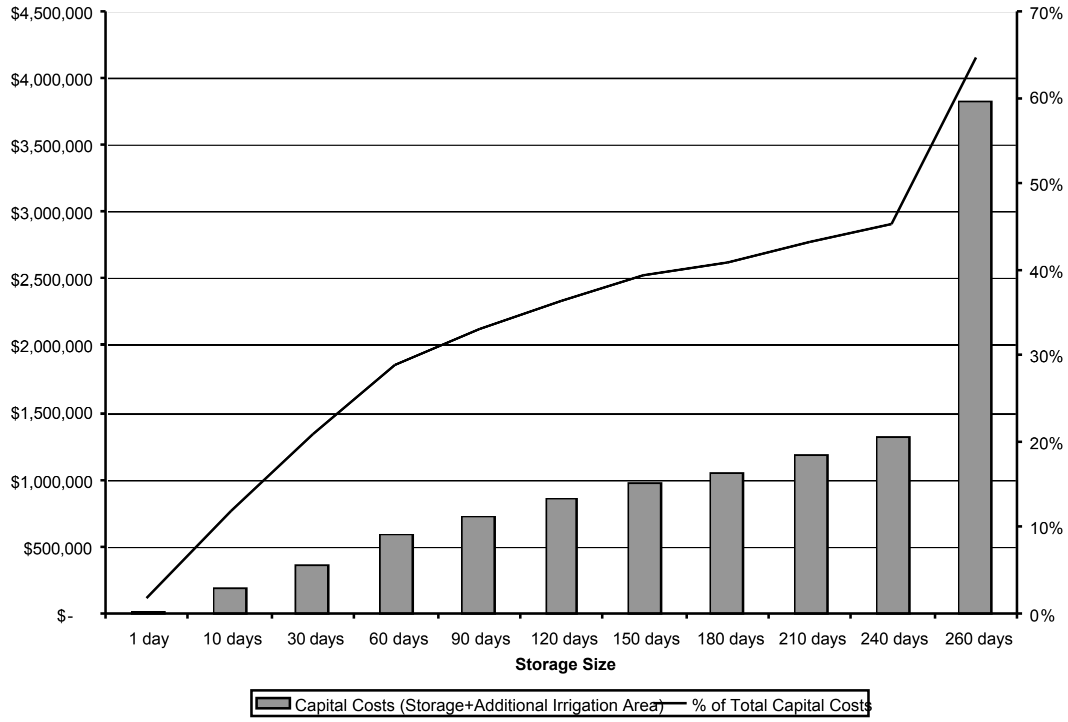


Figure 5: Capital Costs for Storage and Additional Irrigation Land

DISCUSSION

This specific example suggests that the cost of providing more than ten days storage cannot be justified for a proposed CSDWS of this size by the human health and ecosystem benefits. In extremely sensitive receiving environments up to 90-120 days storage may be justified, however, in this case, the potential discharge quality and extremely small mass loading to groundwater would meet the objectives of the two *State Environment Protection Policies* even with 1 days storage capacity.

It is important to view the modelling as preliminary as there is no field validation to confirm that the results are representative of actual performance. Having said this, MEDLI is comprehensive and represents the most capable model in Australia for assessing proposed effluent irrigation schemes. In addition, this assessment was applied specifically to existing unsewered villages where on-site wastewater management systems are not considered a sustainable long term option for wastewater servicing. The outcomes of this assessment are presented in relation to these existing towns where a requirement for large storage to minimise deep drainage is hindering the capacity of stakeholders to provide effective wastewater services. The importance of scale is demonstrated in this case study which represents a fairly small scale effluent irrigation scheme with small total loads compared with total catchment loads.

This preliminary assessment indicates three key arguments that support the allowance of reduced storage and increased deep drainage for CSDWS irrigation schemes for small towns.

Issue 1: A problem already exists

The case study presented here represents an existing town where (as shown in Figure 1 and 2) current pollutant loads to waters are orders of magnitude higher than a centrally managed CSDWS with even one day storage. Such a scheme would not create any new incidents of water pollution and would reduce the risks to human health and ecosystems currently posed by the wastewater. If the full 260 day storage facility was required this scheme is unlikely to receive sufficient funding and therefore on-site wastewater management systems would be required to continue servicing the town despite observed limitations. The net result here is maintenance and possible further deterioration of water quality in the town.

Issue 2: Impact of storage requirements on project feasibility

The town in this case study has approximately 3.5 hectares of public open space available for effluent irrigation. In order to minimise deep drainage to leaching requirements for salt flushing at least 7 hectares of total irrigation land would be required in addition to a large storage facility. This increase in land purchase has a critical impact on the feasibility of the project. The preliminary modelling undertaken suggests that this increase in land and storage does not provide a significant or necessary improvement in performance.

Issue 3: Cost effective investment in wastewater / water quality management
From a polluter pays perspective the level of investment required to provide the large winter storages necessary to limit deep drainage at this small town scale is substantially out of proportion with the problem. With areal nutrient loading rates in the range of 0.2-3 kg/hectare/year for 1-10 day storage facilities, nutrient loads to groundwater are minute in comparison to other sources. An equivalent level of investment for the provision of 7 hectares of irrigation area and 260 days storage for a 100 cow dairy farm is approximately 20-25 million dollars of up front capital infrastructure based on kilograms of nitrogen generated (8760 kg of TN between the dairy shed and paddock compared to 1358 kg/yr discharged from the example CSDWS). With the provision of active disinfection the potential for pathogen contamination of groundwater is negligible and no groundwater is consumed by humans within one kilometre of the proposed irrigation sites. The construction and central management of a CSDWS with 1-10 days storage is likely to provide essentially an equivalent (within 98%) level of human health and environmental protection for approximately 25% of the capital costs of the 7 hectare / 260 day storage option. That effectively means that an additional 3 similar sized towns could be provided with a sustainable CSDWS for the cost of one with an insignificant change in performance.

CONCLUSION

The results of comparison of costs and benefits do not definitively confirm that reduced storage size and increased deep drainage can be accepted uniformly at the small town scale. However, they do present a firm argument to suggest that more field research is needed to validate the outcomes of modelling such as that undertaken here. Such research needs to be targeted towards irrigation schemes typically sought for small town CSDWS. The results do raise questions about the current requirement in many Australian states for deep drainage to be restricted to salt flushing requirements. Experience from New Zealand supports the outcomes of this cost benefit analysis although more research at this scale is required there also.

While it is acknowledged that there are other site specific factors that may influence the capacity to allow more frequent deep drainage (e.g. groundwater mounding/perched watertables) these risks need to be quantified and compared to the existing risk to human health and the environment currently posed by poorly performing on-site wastewater management systems. There is an opportunity available to deliver a substantial improvement to wastewater servicing in rural towns and peri-urban zones through the allowance of reduced storage. It is recommended that initial CSDWS could be used as demonstration sites where further research is undertaken to better understand potential impacts.

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