Making decentralised systems viable: a guide to managing decentralised assets and risks

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Abstract

Decentralised systems have the potential to provide a viable option for long term sustainable management of household wastewater. Yet at present such systems hold an uncertain status and are frequently omitted from consideration. Their potential can only be realized with improved approaches to their management, and improved methods to decision-making in planning of wastewater systems. The aim of this paper is to demonstrate the value of a novel framework to guide planning of decentralised systems so that asset management and risk management are explicitly considered. The framework was developed through a detailed synthesis of literature and practice in the area of asset management of centralized water and wastewater systems, and risk management in the context of decentralised systems. Key aspects of the framework are attention to socio-economic risks as well as engineering, public health and ecological risks, the central place of communication with multiple stakeholders, and establishing a shared asset information system. A case study is used to demonstrate how the framework can guide a different approach and lead to different, more sustainable outcomes, by explicitly considering the needs and perspectives of homeowners, water authorities, relevant government agencies and society as a whole.

Keywords: asset management; decentralised wastewater systems; risk management; socio-economic risk; wastewater planning

Introduction

The need for new approaches to risk management

Practitioners in the decentralised wastewater sector recognise the need for new frameworks and tools to enable effective long-term management of and decision-making for decentralised infrastructure. Risk management is the most appropriate focus for such frameworks and tools (Willetts et al., 2005). Centralised wastewater systems have benefited from extensive development of asset management approaches to manage risk (Etnier et al., 2005). But the characteristics (ownership, management, regulatory performance responsibility, technical purpose [treatment or transport]) of assets and their risks differ markedly between centralised and decentralised wastewater systems, so centralised asset management tools are not immediately transferable to the decentralised context. There are two potential paths for managing risks to facilitate improved acceptance and performance of decentralised systems (Willetts and Mitchell, 2005): (i) make decentralised more like centralised e.g., through centralised management of decentralised systems, and (ii) develop new tools for improved management of decentralised systems. The work described in this paper addresses both these aims.

The paper introduces asset management and risk concepts, then outlines a new framework that operationalises these in the decentralised context. The value of the framework for producing qualitatively different, and better, outcomes is highlighted in a fictional case study focusing on responses to the failure of existing on-site systems.

Central elements of asset management

"*Asset management is a means of managing infrastructure to minimize the cost of owning and operating it while delivering the service levels that customers desire*." (AMSA, 2002). Within the diverse approaches to asset management, four aspects are both pivotal to asset management in centralized systems (Fane et al., 2005) and are critically different for decentralized systems. These aspects and their relationship to centralized systems are explained below:

(i) Clear performance standards: regulators play a crucial role in setting performance standards and in defining who is responsible for meeting performance standards. Performance-based regulations align with asset management strategies by providing latitude for choice between a range of technical and management solutions to meet a defined performance goal.
(ii) A functional asset information system: Contains information about the assets of concern, including an asset inventory (system type, age, location, capacity/scale/design flow, maintenance history), ongoing performance information, data on expected reliability of systems and components, and cost data for capital works and operations.
(iii) Explicit consideration of the organizational and regulatory structures: These structures define how and by whom the risks and costs of wastewater management will be borne. In the centralized sector, a corporate model is the norm, with ownership and operation usually vested in the same organisation. This promotes the cost-optimisation central to asset management approaches.
(iv) Accessible reliability and costing tools: Reliability and costing tools are needed to translate the data contained in the asset information system into predictions about system performance and failure risk, together with the likely cost of responding to failures versus proactive maintenance and management.

These aspects differ markedly in decentralized systems because the range of stakeholders is broader. That means that responsibilities are distributed, diffuse, and often lack clarity and accountability processes, and data availability and management is typically partial and/or inadequate (Willetts and Mitchell, 2005). The framework we developed to operationalise these aspects for decentralized wastewater systems deals with these differences by being explicit about stakeholders, information, and the need to account for broader risk types.

Decentralised systems have multiple risk types.

Risk, for wastewater infrastructure, is of multiple types: engineering, public health, ecological, and socioeconomic (ORNL, 2003). For decentralized systems, these risk types exhibit strong, almost causal, interactions, e.g., the engineering risk of (a set of) systems (the probability and consequence of system "failure" at a local or larger catchment scale) largely defines the public health and ecological risks posed, which in turn define many of the socio-economic risks. But the local geography influences the engineering risks (e.g., through a high groundwater table), and the socio-economic conditions also influence the engineering risk (e.g., through ability to pay).

Engineering, public health and ecological risks are often explicitly considered in wastewater management and planning (Beal et al., 2003). Socio-economic risks however, are often given little explicit attention, so here we explain the most important dimensions.

A systematic approach to risk assessment defines receptors of risks and stressors that generate risk (ORNL, 2003). In this model socio-economic risk receptors include a wide range of stakeholders affected: individuals (such as property owners or occupants), vulnerable subgroups, adjacent populations, the water authority, the local council, the environmental agency and the public health agency. Stressors occur at the micro (household) and macro (community or catchment) scale and vary from tangible to intangible. Tangible stressors include costs (e.g., expenditure on design, installation or maintenance of a system, and regulatory compliance costs); changes in property values; the time households spend to maintain a system. Intangible stressors include, for example, issues around privacy and access to inspect systems, perceived inequities between recipients of centralized and decentralized wastewater services, restrictions in use of particular products (e.g., certain soap products), aesthetic impacts such as noise or smell, socio-economic impacts regarding ecological or public health effects and organisational risk factors (e.g., for a water authority). Dealing with socio-economic risk is demonstrably complex. It requires consideration of multiple perspectives, and attention to spatial and temporal boundaries of analysis and setting up a consistent basis for comparison between potential options. It also requires appropriate communication with stakeholders and would likely benefit from deliberative processes to inform decision-making. The need for a systematic, participatory planning process is clear. The framework presented here is intended to enable such a process as a means of explicitly considering and managing socio-economic risk, alongside engineering, public health, and environmental risks in wastewater planning. This focus on the various stakeholders or 'actors' aligns with the latest thinking on analysis for planning investments in sanitation worldwide (IWA, 2006).

Methods

The National Decentralised Water Resources Capacity Development Program under the auspices of the USEPA, commissioned a project on 'Reliability and Life Cycle Costing of Decentralised Wastewater Systems' which was carried out by the Institute for Sustainable Futures, UTS and Stone Environmental, USA. As a part of this project, the ideas and concepts integral to centralised asset management and concepts and tools used in the field of reliability, risk assessment and risk management were comprehensively investigated and synthesized into a novel conceptual framework that operationalises them in a systematic planning process (Etnier et al., 2005). This initial framework is developed further in this paper to better represent how regulatory, policy and institutional issues impinge on wastewater planning processes.

Results: A framework to manage assets and risks

The framework is intended as a thinking tool for both managers and regulators. The framework (see Figure 1) follows a 6 step cyclic planning process to guide decisions towards cost-effective management strategies. Figure 1 shows how the actions in the planning cycle are bounded by the local environmental, or bio-physical, context. It also shows that at the core of the planning process is the regulatory, policy and institutional context, key aspects of which include communication with stakeholders and an asset management information system. Explicit recognition of and engagement with the biophysical boundary and communication with the institutional landscape are necessary at every step.

The planning cycle starts with situational assessment, through goal setting, to developing possible responses and criteria for their assessment, then choosing and enacting a particular response, and most importantly, checking back to see how the response worked in practice, before moving around the planning cycle again.

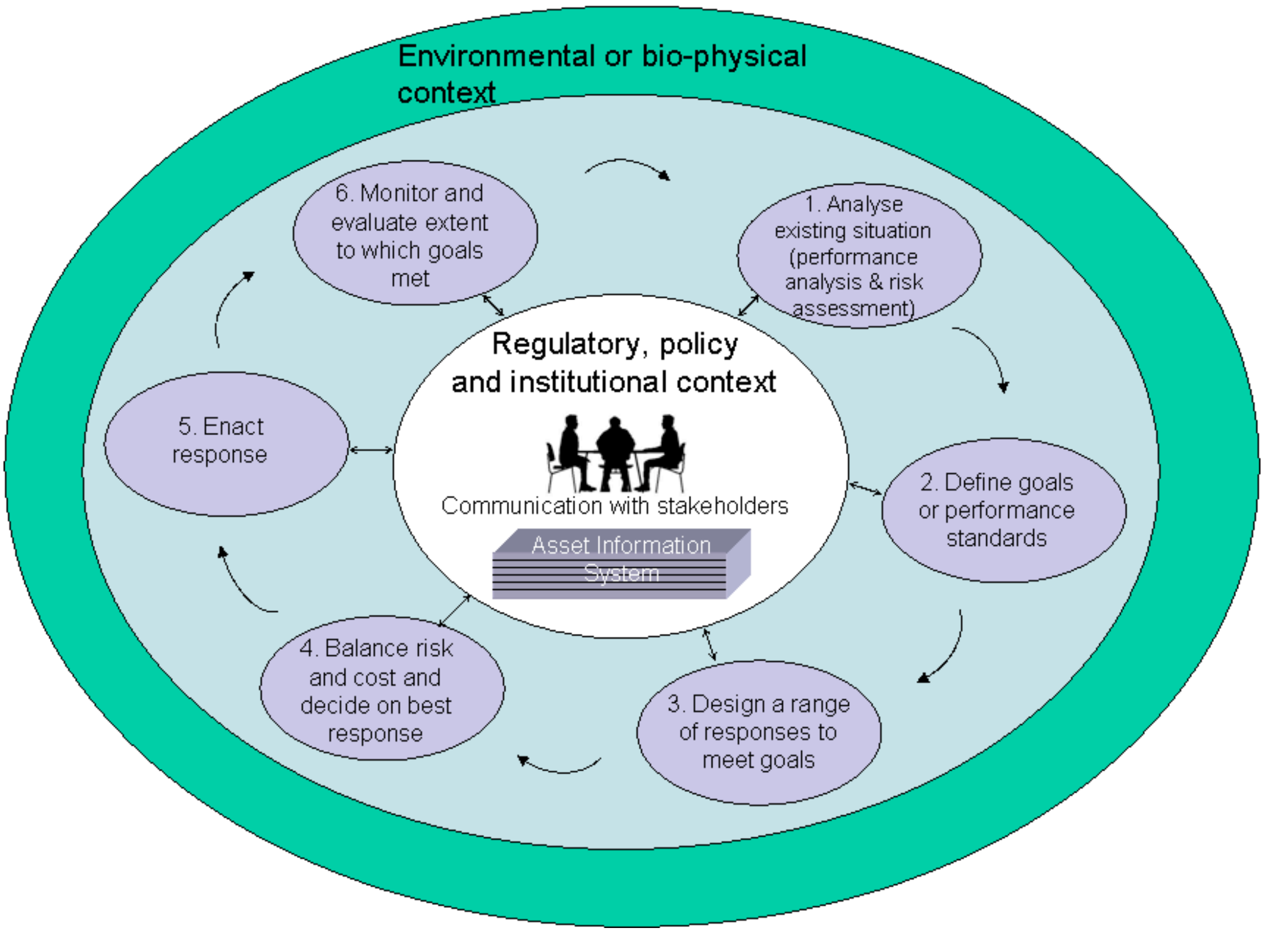

Figure 1: Framework to manage assets and risks in the context of decentralised wastewater systems.

Case study application of the framework in Johnsonville Australia

The following hypothetical case study draws on a range of real projects and situations that have taken place in Australia in recent years. It uses a combination of elements extracted from these experiences to illustrate how the framework might be used, and how it would help provide different outcomes compared to other approaches.

Setting the scene

The local oyster industry has been closed down by the State Health Department for three months and now summer visitors are being warned about the potential dangers of swimming in the river estuary.

Failing onsite systems have been branded as the cause. With tourist operators joining the oyster farmer's call for action, and an increasing community interest in sustainable development, the councilors of Port Johnson meet and decide the time for a more sustainable wastewater solution to be developed is now.

Port Johnson is a (fictitious) regional locality in Australia, that has a rural estate (Johnsonville) of some 2500 houses released 10 years ago that utilises septic systems for management of domestic wastewater. The rural estate consists of a hill with larger blocks (and houses) (upper Johnsonville) and smaller sub-divisions at the foot of this hill (lower Johnsonville). A major tidal creek enters the estuary at the foot of the hill. The local council environmental officer (EO) knows that poor management is usually the reason why septic systems fail, and the EO also knows there are other options besides sewering. At the national EO's conference earlier in the year, the EO heard about a new framework for planning and managing on-site systems. Historically, the water authority steps in and sewers 'problem' areas. Instead, Council agrees to trial the framework because it seems to have the potential to deliver more sustainable, lower cost outcomes with community support.

1. Analyse existing situation

There is little information available on the existing systems and their impact, and so the EO does a high-level risk assessment across the four primary dimensions of risk. The EO conducts a survey of 10% of systems checking for surfacing effluent as well as perspectives and level of knowledge of and maintenance by homeowners. The EO also talks widely with other stakeholders. The EO gets help to set up a new database as the beginning of a simple asset information system. Brief results:
Engineering risk - roughly 40% of septic systems could be classified as failing.
Public health risk - a quarter of households divert grey-water to relieve failing septic systems. Untreated grey-water are generally reused for surface irrigation. Despite the warnings, many locals and visitors are still swimming in the estuary and there are some reports of illegal oyster harvesting.
Environmental risk – a nitrate level of over 18mg/L is measured at several points in the waterway.
Socio-economic risks - Residents in upper Johnsonville are against having the area sewered as they believe this would open up the area for development, and people in lower Johnsonville already can't afford charges and are afraid it'll get worse. The oyster farmers face bankruptcy if the ban on sale of their product continues. As the mainstay of the local economy, any impact on the tourist industry affects the whole economy of the region.

Already the process is looking complicated so the EO sets up a steering committee including members of council, the local water authority, some innovative engineering consultants, the environment agency, public health agency, representative of the local business chamber and a selection of five homeowners.

2. Define goals or performance standards

The steering committee meets and deliberates on a set of goals. There is much discussion and argument, and eventually they agree on a set of three performance goals related to each of the risks of concern. The steering committee decides that the engineering performance goal is implicit in the other performance goal. The agreed goals are:
Performance goal 1: Level of nitrate in the waterway below WHO guideline of 10mg/L and *E.coli* occurrence must drop below Health Agency requirement for the oyster farms to reopen.

Performance goal 2: All wastewaters, including greywater, with a potential for human contact must be treated.
Performance goal 3: Costs should be minimised in line with sustainability principles i.e. the least cost to society should be sought.

3. Design a range of responses to meet goals

Sewering was going to cost around $45,000 per lot, and both residents and councilors are concerned with that figure. The EO engages innovative engineering consultants to consult with homeowners and devise a set of alternative responses The final set of options accepted by the steering committee for further investigation are:
Response 1: Council enforced homeowner control. Council inspects all systems and issues orders for improvement for suspect systems (failing or situated too close to the creek). Homeowners must either replace with AWTS or revamp these systems. Septic revamp involves replacement of the absorption trench with a subsurface irrigation system and the addition of a septic filter. All remaining septics have filters added. Homeowners trained in monitoring and maintenance.
Response 2: Local water authority takes on the on-site systems, to manage and maintain. Water authority inspects all the systems and replaces the suspect ones with aerated water treatment systems (AWTS). All remaining septics have septic filters added.
Response 3: Local water authority takes on the on-site systems, to manage and maintain. Water authority replaces all with AWTS with telemetric monitoring.
Response 4: Local water authority takes on systems and using the existing septic tanks installs three STEP (septic tank effluent pump) small-bore cluster wastewater systems and package wastewater treatment plants for the 1500 houses on the smaller blocks. Elsewhere the septic systems are retained with filters added and fully revamped if failing.
Response 5: Local water authority takes on systems and installs a total of five cluster systems.

4. Balance risk and cost to decide on best response

Balancing the four risk types and cost is a complex exercise in trade-offs and necessarily involves a transparent participatory process of relevant stakeholders and citizens to inform decision-making (Clark, 2004). In this case, the EO first asks for a cost analysis of the five responses conducted from multiple perspectives (society, and the three main stakeholders) utilising the life cycle cost (net present value at a real discount rate of 7% over 50 years) (see results in Table 1). The life cycle cost estimates include both the capital and operational costs for installation and maintenance of systems, as well as replacement and regulatory compliance. Only actual expenditures are included, for instance the time cost of homeowner's in system maintenance in Response 1 is excluded. Costs are based on estimates verified by five separate water authorities and from a published wastewater management study (Geolink, 2002)

Response	Total life cycle cost (NPV)	Water authority	Council	Homeowner
Response 1	$ 20,610,000	$ 0	$5,350,000	$15,270,000
Response 2	$ 28,880,000	$ 26,520,000	$ 450,000	$ 1,920,000
Response 3	$ 39,780,000	$ 35,650,000	$ 450,000	$ 3,700,000
Response 4	$ 28,950,000	$ 27,390,000	$ 450,000	$ 1,110,000
Response 5	$ 36,580,000	$ 35,030,000	$ 450,000	$ 1,110,000

Table 1: Multiple perspective (cost to whole of society and each stakeholder) life cycle cost analysis

The EO organises a participatory process involving the entire steering committee, as well as a set of five randomly selected representative citizens from the locality (since they may be implicated through rising council or water authority rates etc.). A facilitator is hired to run the process and a form of multi-criteria assessment (MCA) (White et al., 2006) is used to deliberate on the costs and risks. This process involves participants considering the cost analysis for whole of society and each cost perspective, and then choosing and discussing priority risks and the resulting risk level within socio-economic, environmental and public health dimensions (summarised in Table 2).

After much debate, Response 4 is nominated as the preferred response. All agree that low public health risk, with its strong linkage to socio-economic risk to the oyster and tourist industry is critical. While Response 5 has the lowest ecological and public health risk, Response 4 showed a 20% lower life cycle cost. The decrease in risk of nitrogen pollution entering the estuary is not deemed to be worth $7.6 million dollars in life cycle terms.

5. Enact response

It takes 18 months for Response 4 to be implemented. The water authority and council come to an agreement to jointly fund the asset information system since they both require similar data.

Response	**Socio-economic risk (to society)**	**Socio-economic risk (to homeowners)**	**Socio-economic risk (to water authority)**	**Ecological risk**	**Public health risk**
1	High potential for conflict over compliance, high economic (oyster business) and recreational costs	High extremely high cost, resulting in inequity with other citizens	Low not implicated	High ecosystem health potentially compromised due to heavy reliance on homeowners for maintenance	High high public health risks due to heavy reliance on homeowners for maintenance
2	Medium concerns for oyster and tourism business	Medium medium cost	Medium institutional changes needed for centralised control of disperse assets	Medium potential for ecosystem damage depending on AWTS system reliability	Medium some health risk depending on AWTS system reliability
3	Medium concerns for oyster and tourism business, citizen concern about rising land and water rates	High high cost resulting in inequity with other citizens	High high cost, institutional changes needed	Low minimal risk since quality ensured through telemetric control	Low minimal risk since quality ensured through telemetric control
4	Low minimal public health risk	Medium low cost, large blocks have responsibility for septic systems	Medium institutional changes needed	Low all wastewater near waterway collected	Low all wastewater near waterway collected
5	Low low public health	Low low cost, no	High high cost,	Low all wastewater	Low all wastewater

and ecological risk	responsibilities	institutional changes needed	collected	collected

Table 2: Perceived risk levels for each potential response

6. Monitor and evaluate extent to which goals met

Given the debate that takes place about the choice of response, and the lack of information available about costs and reliability of different types of system, the monitoring system is taken very seriously and appropriate data is captured and input to the asset management system. Actual performance against all three performance goals is monitored:

Performance goal 1: The goal to maintain pollutant levels in the waterway below acceptable levels is assigned $30,000 in council's budget and is monitored through weekly testing for nitrogen and *E.coli* by council officers.

Performance goal 2: The goal of treating all wastewaters with potential for human contact is met through system design and inspection of remaining onsite systems for surfacing effluent, telemetry for cluster systems managed by water authority.

Performance goal 3: On-going costs to each party monitored and input to asset management system to inform future decisions in the region.

Next steps, moving to a second cycle of management actions

Information from the new asset management system is used to refine or redefine the performance standards after one year and provide input to another cycle of the planning process to fine-tune management of the systems and identify any further issues which required resolution. The inevitable changes in policies, costs, climate and regulations mean that the planning and management process is in constant evolution and the framework provides a means to proactively manage that situation.

Conclusion

The framework presented in this paper provides a systematic process to guide incorporation of risk and asset management into planning and management processes for decentralised systems. The framework moves people to the centre of the process rather than the technology, which is essential in achieving workable solutions that are accepted by the various stakeholders. This focus on people also means that cooperation and partnership are promoted (for example, in sharing of costs between water authority and council for development of mutually useful tools like the asset information system). The case study demonstrates how a broad range of options could be compared on equal grounds through a robust cost analysis from multiple perspectives and a deliberative participatory process engaging stakeholders and citizens to decide on the chosen trade-offs and cost-sharing arrangements.

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