

Small water system reliability in remote Indigenous communities in the Kimberley



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Indigenous communities
in the Kimberley**

Nerida Beard

Research Report 49

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FOREWORD

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CAT hopes that this work will stimulate a collaborative response to the inadequate water and sanitation conditions in many Kimberley homelands and encourage reflection and cooperative action with Indigenous settlements in similar situations across the country.

EXECUTIVE SUMMARY

Nationally, reliable access to adequate water supplies in discrete Indigenous communities in Australia remains inconsistent. Currently, more than half the population of discrete Indigenous settlements (44,563 people or ten per cent of the total Australian Aboriginal population) are affected by unreliable water supplies and 30 per cent by inadequate sanitation (ABS 2007b:29,31). Last year, this affected 92,960 Aboriginal and Torres Strait Islander people, three quarters (69,253 people) of whom live in very remote locations (ABS 2007b:17).

Internationally, provision of water supply and sanitation to human settlements are recognised as essential determinants of health and wellbeing (UNDP 2006; Bailie, Carson, and McDonald 2004; UNHCR 2003; Nganampa Health Council Inc. 1987). In Australia, multiple national infrastructure surveys since 1999 have enabled a cursory level of analysis of water and sanitation access in discrete Indigenous communities with populations of more than 50 (ABS 2001a; 2007a). All surveys have identified that equipment failure was the major cause of water supply restrictions and interruptions (ABS 1999; 2001c; 2007b). Regional analysis of the 1999 survey indicated that the largest frequencies of water system failure were in Kimberley communities and that small communities were disproportionately affected (ABS 1999).

This research investigates the reasons for the high frequencies of equipment breakdown in the Kimberley region, the effect on settlements with populations of less than 50 people and recommends ways to address the issues in the region.

The study focussed on 24 homeland communities in the Derby West-Kimberley Shire. The aim was to gain a detailed understanding of the management and operation of water supplies in these communities and how residents were affected by it. Sanitary surveys, infrastructure inventories, resident interviews, contractor maintenance visit reports and water quality tests were utilised in conjunction with historical water resource data to obtain an understanding of these water supplies. Information was collected on age and condition of infrastructure components, local hydrogeology, water quality, road access and seasonal conditions, and collated in an internal database. Regular dialogue with key community residents throughout the project enabled an understanding of local water issues and water 'histories' to be gained. Interviews were also conducted with key regional stakeholders in local government, education and program management.

Results obtained paint a picture of frequent water supply breakdowns due to ageing and ailing infrastructure, inadequate supply capacities and water quality protection measures and a lack of coordination of water services. A total of 52 major water restrictions were recorded between 2004 and 2005, affecting 75% of the study communities. 75% of the communities surveyed had no backup water supply to access in the event of a water system failure. Restrictions were caused by an array of infrastructure issues, in pipes, pumps, storage tanks and power sources. Water quality in 'hard' water areas was also a source of water system failures, through scale build-up on components. Mechanical failure of components was the cause of nearly half the restrictions. Most of these infrastructure failures were consistent with ageing infrastructure and a lack of an adequate planned maintenance, replacement and upgrade program.

A total of 15 communities reported ongoing water quality issues during the study period. Half of the communities (12) reported microbial water quality to be of concern, however only five communities had any kind of disinfection systems and on five occasions (10%) these were the source of water system breakdowns.

The risk to residents from water system breakdowns are greater where they have few remedial options or lack an alternative supply. This 'vulnerability', to water system breakdowns and therefore interruption to their water supply, increases with distances to service centres, access to communications, wet season accessibility, the presence of a back up supply and where there are unaddressed microbial risks. A vulnerability indicator is proposed that draws from these factors as key characteristics of reliable water supply infrastructure, and may provide a method for funding agencies to prioritise community infrastructure upgrades based on need.

Many remote residents were conscious of their vulnerabilities due to distance and wet season inaccessibility, and residents from 10 communities requested technical assistance or advice on a range of water issues to equip themselves better to deal with their water problems. To varying degrees in most communities, there was a semi-skilled person who informally assumed local responsibility for the water supply. These skills ranged from simply turning the bore on and off each day through to being able to strip a generator or make major repairs to pumps and pipes. These residents often indicated a desire to have more knowledge support for local water management.

A number of educational options in water supply or environmental health exist in the study region. However, the existence of jobs for people completing the courses, and problems associated with courses being delivered in town was considered to be an important factor in the retention of students. Pursuing these training options usually requires that water supply operators leave the community for the study periods, and this can have important ramifications on the homeland left behind.

Residents report that the regular basic maintenance program in operation since 2004 has improved water security in the study communities, and residents were pleased with a regular monthly visit from the service contractor. However, program funding and management guidelines restrict the ability of this program to provide essential upgrades and planned replacement of ageing infrastructure. This leads to a situation where ageing infrastructure is continually 'revived' beyond its reasonable working life, resulting finally and predictably in a critical water system failure. Repair of such failures often results in long delays for the water supply to be restored, as a separate agency with minimal community contact is responsible for emergency replacement of the failed infrastructure. Whether for lack of finances, lack of human resources or something else, it was apparent that upgrades are not being afforded to those with inadequate supply or the biggest risks to supply, but to those with broken supplies. This regime of 'failure management' places the health of residents at risk in the short and long term as residents must go without water, or resort to carting water from distant locations. This places restrictions on the use of water for health and hygiene purposes and may introduce water quality risks from carting and storage.

Complexity and change in governance arrangements and a lack of clear communication mechanisms and accountabilities for water supply servicing left stakeholders confused at many levels of the system. A lack of transparency on the prioritisation and timeliness of infrastructure replacements and upgrades contributes to this. This confusion was repeatedly found to create delays in many aspects of water service delivery in a majority of the surveyed Kimberley communities.

Although the basic cyclical maintenance program provided an improved level of water security to communities, a gap still exists in what is delivered by the water service structure as a whole and what was required by community residents to obtain a reliable water supply. It is in this gap that there needs to be a greater interface between resident water users' understanding of the water supply system and that of a technical outsider. The practicality of this is that community members are the ones that are most quickly able to respond to water system failures in remote areas. The following recommendations were made to improve this situation:

- Greater transparency, accountability and simplification in the governance of water supplies are required to enable residents to have reliable access to water supplies in the region.
- It is recommended that water supply governance be underpinned by a regular planned maintenance program and a transparent process for prioritising future upgrades based on health risk as an indicator of need.
- It is recommended that the overall program be delivered through a department with technical water expertise to improve understanding of water supply issues.
- Indigenous input is required into the development of an appropriate mechanism to support the knowledge and practice of the currently informal resident Indigenous water supply monitors.
- Improving communication between serviced communities and service delivery agencies will also assist in ensuring water service outcomes.

Recent experience on the application of the Risk Management Framework for water supplies (NHMRC 2005; CRC for Water Quality and Treatment 2004) and elements of the Sustainable Livelihoods Framework (Moran et. al, 2007; DFID 2001) illustrates that when combined, these two frameworks provide a successful method for practitioners to facilitate engagement on local water management in small, remote Indigenous communities (Grey-Gardner 2007). This approach could provide a platform from which to engage Indigenous communities and service providers to determine appropriate water supply governance arrangements and a useful interface for external service support. Developing the skills of residents in conjunction with defining and providing appropriate service delivery support will be the key to improving water supply reliability in the region.

Residents were not leaving, despite intermittent and unreliable water supply access in the surveyed communities. The net effect of withholding appropriate services through under-resourced and uncoordinated water services is increased risks to the health of residents in these Kimberley homelands.

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1. INTRODUCTION

Reliable access to adequate water supplies in discrete Indigenous communities remains inconsistent. The 2006 Community Housing and Infrastructure Needs Survey reported that more than 50 per cent of Aboriginal and Torres Strait Islander people living in discrete Indigenous settlements were affected by unreliable water supplies, that is 44 563 people (ABS 2007b:29). This equates to approximately 10% of the total Australian Indigenous population. Half of those, or 21 291 people, experienced water supply interruptions more than 5 times in the previous year (ABS 2007b:29). One third of the discrete Indigenous community population (30 140 people) were affected by inadequate sanitation (ABS 2007b:31).

In 1999, 2001 and 2006 CHINS collected detailed data on communities with populations of more than 50 people, and less detailed data on communities with less than 50 people, enabling analysis of water access and availability (ABS 2001a; 2007a). All surveys have identified that equipment failure was the major cause of water restrictions. In the 12 months prior to the 1999 survey, the primary determinant of water restrictions was attributed to equipment breakdown, causing 61 per cent of restrictions across all large communities nationally (ABS 1999). Regional analysis of that survey indicated that water supplies in the Kimberley region, home to nearly a quarter of Western Australia's Aboriginal population (DIA 2005) or nearly 16,000 Indigenous people, experience the greatest frequency of water system failure - more than any other region in Australia (ABS 1999).

Analysis of water restriction data by community population size indicates that water supplies experience more frequent breakdowns with decreasing population, suggesting that those supplying small communities of less than 50 people would be worst affected.

This project was scoped to investigate the reasons for the high frequencies of water restrictions and equipment breakdown in the Kimberley region, assess the effects on a subset of settlements with populations of less than 50 people and recommend ways to address the issues in the region.

2. RESEARCH QUESTIONS

1. How are water supply systems in Kimberley homelands performing?
2. Does the apparent trend of increasing failure rate with decreasing community size extend to small Kimberley homelands of less than 50 people?
3. Are there systemic management, investment, environmental, historical or other factors that have contributed to this outcome?
4. What recommendations can be made on success factors for water supply service delivery in the Kimberley region?

3. STUDY SITES

The research was proposed for a subset of communities from across the whole Kimberley region with populations of less than 50 people. In response to sub-regional uptake of the proposal, the study focused on 24 communities in the Derby West-Kimberley Shire region.

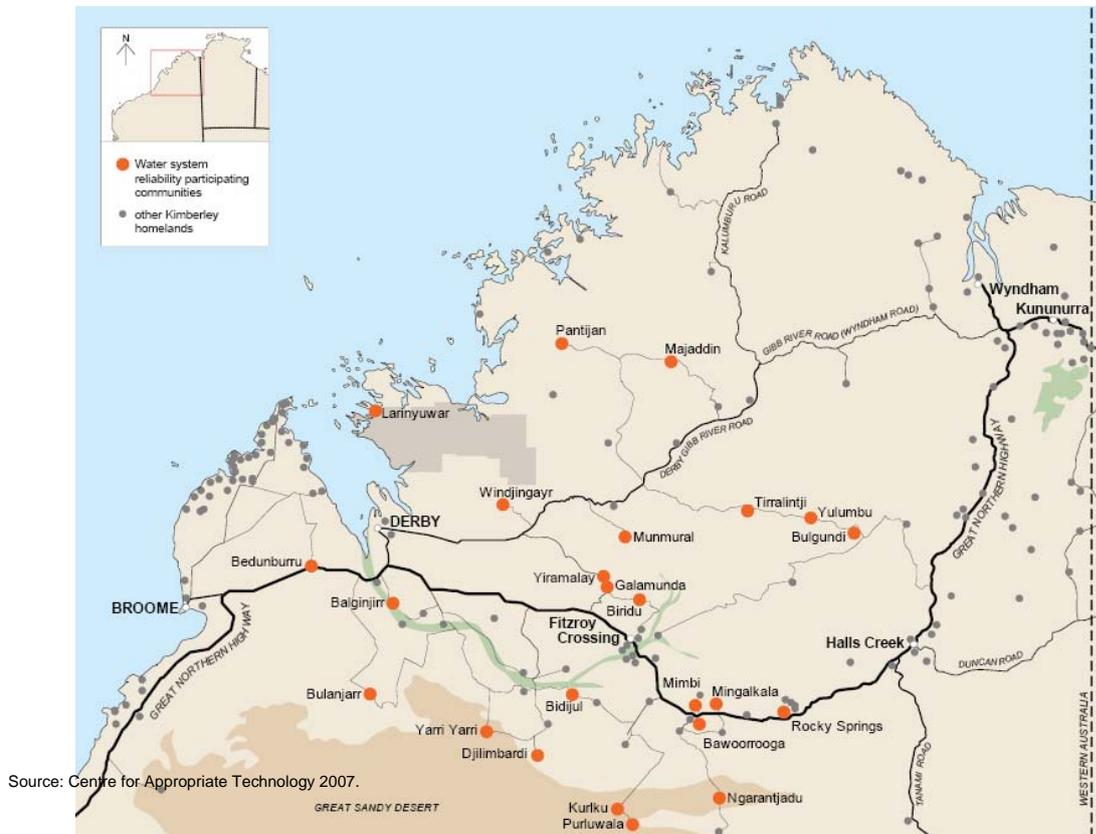


Figure 1: The 24 Derby West-Kimberley homeland settlements involved in the study (indicated in orange).

4. BACKGROUND

4.1 Indigenous health

In 2001, the Indigenous population was estimated to be 458 500, 2.4% of the Australian population (ABS 2006:1), of which approximately 20% live in discrete Indigenous communities nationwide (ABS 2007b:17). In Australia, Indigenous life expectancy at birth is 17-20 years lower than the national average, and children less than five years old are 5 times more likely to die than non-Indigenous children (NACCHO 2007:5). As well as crude rates of death and life expectancy, Indigenous people experience higher rates of ill health over the course of a lifetime than the rest of the Australian population (NACCHO 2007:6,17).

Poor health in the rural population disproportionately afflicts Indigenous people who live in greater numbers in remote areas (1 in 5 compared to 1 in 50) and experience a greater multitude of negative social and environmental determinants of health, than non-Indigenous residents – such as overcrowding, homelessness, high unemployment, poverty, lack of access to adequate essential services (water, energy, sanitation, health services), family violence and substance abuse (AIHW 2006:221; ABS 2006; Memmott and Moran 2001; Nganampa Health Council Inc. 1987). Other research (Bailie, Carson, and McDonald 2004; Henderson and Wade 1996; Hearn et al. 1993) has established the extent to which inadequate water supplies contributes to these levels of ill health and disadvantage.

4.2 Aboriginal and Torres Strait Islander water supplies

A lack of adequate water supply and sanitation in discrete Indigenous communities has been well documented (HREOC 2001; ABS 2001a; ABS 1999; Hostetler, Wischusen, and Jacobson 1998; Henderson and Wade 1996; FRDC 1994; Hearn et al. 1993), and remains a problem today (ABS 2007b).

In 2006, approximately half the population of discrete Indigenous settlements nationally (44,563 people or ten per cent of the total Australian Aboriginal population) reported interruptions to their water supply, and nearly one third experienced sewerage overflows and leakages (ABS 2007b:29,31). This affected 92,960 Aboriginal and Torres Strait Islander people, three quarters (69,253 people) of whom live in very remote locations (ABS 2007b:17).

Half of those affected by unreliable water supplies (21,291 people) experienced water supply interruptions more than five times in the previous year (ABS 2007b:29). Reflecting changes to the ABS survey in 2007, this data suggests an underestimate of the problem reported in 1999 and 2001, indicating at best that the reliability of water supply services have not significantly improved in the past 8 years, despite changes to government funding structures and service delivery programs.

The primary issues that recur through the literature on water and sanitation in discrete Indigenous communities are:

- incompatibility of remote community realities (e.g. economics, governance, available skills) with technology choice (FRDC 1994:168)
- appropriate levels of service, and definitions of what constitutes reasonable access to basic services at reasonable cost (FRDC 1994:23)
- incompatibility of the application of mainstream cost recovery measures (DoW 2006:44)
- 'gaps' in responsibility for delivery of basic services (FRDC 1994:171)
- complexity around meeting water quality guidelines, and their interpretation as standards
- lack of access to technical advice and technical personnel in Indigenous communities (FRDC 1994:171)
- mismatch of conventional urban technologies to sustainability in remote contexts (Walker 2001; FRDC 1994:172)
- capital replacement programs that do not cost or factor in ongoing maintenance (Altman, Gillespie, and Palmer 1998; FRDC 1994:173)
- lack of access to and reliability of services (ABS 2007b; Bailie, Carson, and McDonald 2004; EHNCC 2004; DIA 2005)
- lack of community control and ownership of water services (FRDC 1994:169)

Discrete Indigenous settlements nationally are characterised by small populations, nearly all (1170 of 1187 settlements) with populations of less than 1000 people (ABS 2007b:17). Within Australia, small water supplies are considered to be those that service less than 1000 people (NHMRC 2004). Internationally, water supplies considered very small are defined more through their lack of organised management structures and unskilled operations (WHO 1997). The defining characteristic is that small water supplies are prone to greater problems than their larger counterparts. Settlements serviced by small water supplies experience a range of issues in maintaining adequate quantity and reliability of water supply, most notably diseconomies of scale in service provision (Walker 2001). The level of institutional intervention in small water supplies in Australia varies according to the state of residence, settlement size, distance from regional service centres, governance and funding arrangements. In remote supplies, service provision is patchy, large funding gaps are evident, division

of responsibilities is unclear, and departmental underspending on housing and essential services portfolios relative to real need continues, as economic performance appears more highly valued by governments than service performance to beneficiaries (Walker 2001).

4.3 Service delivery and self-determination

The movement towards self-governance has been captured in political ideologies to imply 'self-sufficiency', primarily economic, but also pertaining to service delivery, in remote Aboriginal communities. Many of the difficulties of water supply provision to remote Indigenous communities are shared with the provision of housing and other essential services (FRDC 1994:23).

Community local governments and Outstation Resource Agencies have been required to provide a myriad range of essential municipal services (Walker 2001), and often have been unable to do so adequately. Reasons for underperformance vary with regions and staff; however it has been argued that in remote locations, labour force and economic limitations ensure that the skills and resources required to deliver reliable municipal-style services are at best in short supply. It is not known to what degree negative reports of self-interest and mismanagement of funds in Indigenous community governance accurately represent majority realities; however such issues have long been observed in communities across the world where resources are severely limiting and conditions marginal (Altman, Gillespie, and Palmer 1998).

The governance and health situation in remote communities has led to an outcry by conservative commentators that the whole 'cultural experiment' of self-determination has failed (Hughes and Warin 2005), and it's time for Indigenous people to move to towns and give up on a 'home' on traditional country (Vanstone 2006). Crough argues that the delivery of basic services on their own was not an important step in the overall scheme of Indigenous self-governance (Crough 1994), however the burden of this role may be a major reason for its fracturing. Moran provides evidence from far north Queensland that the administrative workload required of Indigenous community local governments prevents progress on the more pressing applications of self-determination (Moran et al 2008).

Self-determination as a goal set out to provide a mechanism for empowering local Aboriginal decision-making over issues affecting local Aboriginal residents. This led to the rise of a multitude of Aboriginal organisations, but many struggled to build adequate capacity or failed under the pressures of financial performance and other administrative requirements. This has led to a 'governance vacuum' for the management of basic services. Crough reflected in 1994: "...why should Aboriginal communities be self-sufficient?" He asked that when State, Territory and Local governments are not financially self-sufficient, why is there a push for remote Aboriginal settlements to become so?

In a developed country such as Australia, adequate water and sanitation is among the most basic of social development requirements, or 'citizenship services' (Crough 1994:23; FRDC 1994:16). The wisdom of divesting financial and managerial essential service provision responsibilities at such an early stage of governance development to economically disadvantaged and often remote Aboriginal Councils with few mechanisms of governance support, must be questioned. The increased push for fiscal independence and the debate on withdrawal of public funds from these essential services may be a case of 'running before one can walk'. It can be argued that the quality of essential services provision, such as water supply, has been a casualty of this governance environment.

4.4 Funding the services to discrete Indigenous settlements

Lessons from human development illustrate that whilst income matters (UNDP 2006:21), and return on public investments is desirable, good public policy and public investment in water and sanitation is always linked to a significant leap in human health and economic development (Hutton 2008; UNDP 2006:21; FRDC 1994:24). For example, evidence illustrates that access to adequate water *quantity* can reduce vector transmission of scabies and trachoma (Cairncross and Valdmanis, 2006), chronic and debilitating diseases in the Australian Indigenous population. Review of the issues illustrates that for improvements in Aboriginal and Torres Strait Islander development, remote settlements must be underpinned by targeted investment in successful programs to address the known issues that hinder provision of adequate water and sanitation (UNDP 2006:21; HREOC 2001; Black 1998; FRDC 1994). However, public policy discourse on services to the regional and remote Indigenous population is

currently dominated by the quantum of public housing expenditure, the divesting of responsibilities to different levels of government and the context of welfare dependency; rather than evaluation and analysis of successes and failures of service delivery (Evans 2006; Eastley 2005).

Cost recovery is discussed as one method of alleviating expenditure from the public purse, and measures for water and sanitation to discrete Indigenous settlements are being discussed in federal-state bi-lateral negotiations (DoW 2006:44). Water pricing in low-income and welfare-dependent communities has serious social policy implications requiring careful consideration, and schemes that have trialled this approach have reported issues with debt recovery (DoW 2006:44; FRDC 1994). The degree to which this is related to accountabilities, performance indicators and management of water service delivery is unknown, however international experience illustrates that low-income communities can and will pay for an agreed level of service when it is reliably delivered (WaterAid UK 2007; Deverill et al. 2002). Once people have reliable access to a service, understand its benefits, and economic status is improved, then concepts of cost recovery can often be openly addressed.

The provision of water supply and sanitation services comes with a cost that has to be borne by users and taxpayers, and these proportions are usually decided by each community, local authority or national government. The right to water does not necessarily equate with water and sanitation being provided for free. When water is used for economic purposes it must be paid for, but for basic services, the cost can be handled in multiple ways, such as taxes, cross-subsidies or socially-sensitive tariffs. It is the sharing of cost between taxpayers and users, and the extent to which the poorest can be provided with low cost/ low-price services that should lead the debate (Van Hofwegen 2006).

National governments are primarily responsible for enabling the implementation of the right to water at a local level through legislation, regulation, policies, and work plans with associated budget allocations. A rights-based approach could lead to acceleration in achieving basic and improved levels of access to safe water. In practice, however, even though a legal framework may exist, the right to water is often not applied for a variety of reasons: lack of financial and human resources or absence of political will especially at national levels (Van Hofwegen 2006).

In Australian contexts, the rights-based approach should be based first on an open dialogue with Indigenous leaders and commitment on both sides to a continual improvement in access to services to an agreed basic level (recognising that this may be different in different regions).

Taking the steps to get the sequence right to improve remote water supply delivery, through programs that build on the significant body of work on the issues in both developing economies and Indigenous Australian contexts, should be first and foremost in any program for improving Indigenous health and livelihoods.

4.5 Mainstream National drinking water policy

Water management and security of drinking water supplies for urban settlement needs are at the forefront of public policy debates nationally. Large settlements in Australia require a high level of intervention to ensure the safety and quantity of supplies through government investment and subsidy. For more than 30 years there has been a shift in the way in which public water utilities are funded, from wholly public-funded services to those supplemented or fully funded through service charges borne by users. The corporatisation of public utilities has been closely followed by domestic water pricing, inducing a shift to valuing water as an economic good and providing one of the mechanisms for demand-side management. This shift has resulted in these water supplies becoming revenue *earners* for governments, rather than the previously major sources of public spending. Economies of scale are an important characteristic of these large supply schemes, effectively ensuring that although reliable access to safe public water supplies now bears a private cost, it is largely affordable. Indeed, funding models to urban water supplies are attracting growing criticism. In urban areas it is argued that drinking water is undervalued and that not enough water supplier income is retained for infrastructure maintenance (SRCECITA, 2002; Wahlquist 2007). In rural areas however, the economic returns of water supply schemes are not comparable to urban schemes, and historically it has been the practice that public investment and subsidy is required to maintain a base level of water services to ensure public health (FRDC 1994:17).

Diseconomies of scale in small water supply systems are recognised internationally as a significant barrier to the operation and maintenance of adequate and safe water supplies. This is certainly true in Australia, where these economies of scale are exacerbated by the extreme remoteness of settlements. Small rural water supplies are often geographically isolated and frequently remote from adequate technical skills and a supportive management structure to ensure their effective operation and management. For a range of other reasons, public health in rural areas of Australia is also recognised as poorer than that of the urban population (NRHA 2006:19).

The links between a lack of access to clean water and poor public health outcomes are well understood in history. Internationally, provision of sanitation and water supply to human settlements is recognised as providing the most powerful means of preventing infectious disease. Just over 120 years ago, one of the biggest public health leaps in the history of today's developed countries was made within a generation through targeted government investment in the provision of water and sanitation (UNDP 2006:21).

Government programs for the provision of water and sanitation around the beginning of the 20th century increased the life expectancies of people in Great Britain by 15 years within a generation. Although the industrial revolution led to substantial increases in material wealth, before improved sanitation, child mortality and life expectancy was equivalent to that of sub-Saharan Africa today. This underwrote the cities of London, New York and Paris, previously centres of infectious disease, to make vast improvements in human development (UNDP 2006:21).

The importance of effective public sanitation systems for the population has long been recognised in Australia, and Commonwealth policies of the past have supported the provision of water and sanitation as a means to remove barriers to economic growth and in support of principles of social equity (FRDC 1994:16). However, in light of urban water utility cost-recovery measures, there has not been adequate critique of the tensions between corporatisation policies and public good priorities in disadvantaged communities; given implications of cost recovery on debt management (DoW 2006) and possible further erosion of already marginal and largely welfare-based incomes. The way in which rural and remote water supply is funded in Australian context must be intelligently evaluated and designed with an appreciation of the realities of remoteness and low income customers, to remove this barrier to the quality of delivery of remote service provision.

4.6 Transferability of National trends for drinking water management

By international standards, Australia is well advanced in the management of drinking water quality in the majority population, through rolling revision of the national drinking water guidelines and improvements to supporting management systems enabling their application (NHMRC 2004). The 2004 revision of the Australian Drinking Water Guidelines not only included water quality limits, but a framework for managing drinking water (NHMRC 2004).

The Australian framework has moved beyond a compliance-based approach, to a risk management approach that enables water managers to weigh and prioritise risks to a population and focus water supply investment on the areas of greatest risk to public health on a system-by-system basis (NHMRC 2004). The water industry nationally has thus refocused compliance to risk management approaches which enable a more locally-relevant and flexible means of addressing public health issues in water supply schemes.

Risk management provides an opportunity to guide water supply intervention with Indigenous communities and begin where communities are at, recognising that many communities still don't have the water they need in the quantities they need it (ABS 2007b; EHNCC 2004), and the diversity of water supply and sanitation access, quality and reliability across the nearly 1200 discrete communities nationwide (Grey-Gardner 2007; ABS 2007b; FRDC 1994). In an environment of scarce resources, a hierarchy of risks provides licence for water management agencies to prioritise and manage water quality considerations in their appropriate order of relevance to public health and local priorities.

4.7 National standards and Indigenous community water access

Recommendation 17 of the Inquiry into Indigenous Health recognised drinking water as a key factor in improving health in Indigenous communities and sought cost details on provision of adequate water within three years, “where water supplies do not meet national standards” (HRSCFCA 2000:xix). Whilst the intention of the recommendation, to improve access to adequate water supplies, is sound, it is the provision of that to national standards which is one of the other major hurdles of provision at all.

In the Australian Indigenous context, for many of those working on water supplies in Indigenous communities, it can sometimes appear as though a rights-based approach backs externally-imposed water quality standards in an attempt for defensible process, rather than equality of outcomes. Across states, microbiological water quality testing results are sought as the measure of water quality delivered to consumers (and the implication being of service level) at high expense, despite all their limitations as a snapshot in time. Whilst a useful verification tool in a highly managed system where testing can be undertaken regularly and results receive an appropriate response, in remote areas this seems to equate to great expense with little gain. This is where emergence of the risk management framework (NHMRC 2004) offers great opportunity to shift the focus. A risk-based approach provides a mechanism to audit and address the greatest risks to a reliable and safe water supply first, and allocate scarce resources to rectification. There is already some evidence that it can also provide a framework for local resident participation in decision-making around water access priorities and provide some basis for addressing the hierarchy of community needs (Grey-Gardner 2007).

Whilst groundwater is largely noted as a microbiologically protected source, to a great extent, the reliance of discrete Indigenous settlements on groundwater sources (58%) (ABS 2006:27) challenge the ability for service providers, where they operate, and communities to meet national water quality standards in these locations due to deleterious physical and chemical parameters found in groundwaters (DOW 2006; Willis et al 2004; Hostetler et al 1998). Removal of these parameters requires surmounting the difficulties of the maintenance of complex treatment technologies (FRDC 1994), and for this reason the shells of many inoperable early-generation reverse osmosis units can be seen idle in remote areas. This reliance on groundwater and then the consumption rates of such technologies also have implications for sustainability, e.g. overextraction from groundwaters and the future of both the water source and the community that depends upon it.

The reliability and available quantity of water is often overlooked in the discourse which rejects the difficult realities of water quality provision in remote, arid and tropical regions (Blainey 1996). There is a growing body of evidence to suggest that water-related environmental determinants of health are more urgently linked to simply accessing sufficient water *quantity*, such as washing people, clothes and living areas (Hutton 2008; FaCSIA 2007; Nganampa Health Council Inc. 1987). The importance of adequate quantities of water and their sustainable delivery into the future needs be considered as a water management priority.

Grey-Gardner’s work illustrates the benefits of supporting local skills to address local water management priorities in small Indigenous communities (2007). This approach supports views raised by Crough (1994:24), who strongly calls for Aboriginal control over matters of importance to them, to “make room for Aboriginal people in the political structures of this country”. For decisions on water management and levels of service delivery to reflect local realities, empower local decision-making structures and make gains in equity of access, Indigenous people must be meaningfully engaged. Their input into informed decision-making on the means by which water is delivered to remote communities, the quality and quantity options from local supplies and on a practical division of responsibilities for reliable ongoing management will be crucial to improving service delivery outcomes in these locations.

4.8 Water supply reliability in the Kimberley region

The 1999 Community Housing and Infrastructure Needs Survey (CHINS) identified that equipment failure was the major cause of water restrictions in remote Indigenous communities in Australia, and that the region worst affected was the Kimberley (ABS 1999).

A water restriction refers to a restriction on the amount of water that could be used, or the purpose for which water could be used and included reasons such as drought, equipment breakdown, inadequate storage, maintenance issues and poor water quality (ABS 2001). The 2001 survey indicated water restrictions in Indigenous communities nationally affected 28% of communities with a population greater than 50, or nearly 30,000 people (ABS 2001c). In the 12 months prior to the survey, equipment breakdown was the primary determinant of water restrictions, causing 61% of restrictions to large community supplies nationally. In recent years, many of these 'large' communities with populations greater than 50 have secured or renewed essential service agreements with State governments and their service providers in WA, SA and the NT (CGA & WA 2000; Willis et al. 2004; IES 2005). In Western Australia, essential services (water, power, sewerage) in the 80 large, remote and town-based discrete Indigenous communities are maintained under the WA Remote Area Essential Services Program (RAESP).

Equipment breakdown was the only reported cause for water restrictions experienced in the Kimberley region, encompassing the Kullarri (Broome), Malarabah (Derby) and Wunan (Kununurra) former ATSI regions (ABS 1999). Size trends in the 2001 CHINS data indicate that the incidence of failure of water infrastructure is inversely proportional to population size (ABS 2001c), suggesting smaller communities are likely to experience more frequent water restrictions. Given these trends, with over 14,000 people in communities with populations less than 50 not covered by the CHINS survey (ABS 2001c), the population not receiving reliable water supplies could be expected to be much higher.

The situation does not appear to be improving. Although the overall percentage of large communities affected remained stable at 35%, water restriction data from previous CHINS surveys indicated an overall increase in the number of persons that were affected by water restrictions between 1999 and 2001, from 34 000 to 39 000 people (in remote communities mostly larger than 50 people) (ATSI 2000; 1999).

Despite a decrease in the numbers of communities carting water, little improvement in reliability of water supplies is reflected in the most recent community infrastructure survey (ABS 2007b). Changes to the survey questions in 2006 (report delivered 2007) mean that water restriction data appeared to decrease, however the inclusion of another category in the survey is revealing. For the first time, data on water 'interruptions' was collected, explicitly demarcating between situations where water supply to a community or permanent dwelling stops (due to infrastructure related reasons including equipment breakdown, lack of power or when water is turned off to undertake maintenance work, or due to non payment of accounts) and water 'restrictions' where supply was reduced (due to seasonal, quality or 'other' conditions) (ABS 2007a). This change provides a clearer picture of the number of communities experiencing periods where water access completely stops, which had been underestimated in previous surveys. Water interruptions affected over 50% of the population in large discrete Indigenous communities, and in 80% of affected communities, equipment breakdown was responsible (ABS 2007b). However, it is not possible to interpret from the data whether communities that experienced restrictions were in addition to those that endured interruptions or were comprised of them (ABS 2007b).

Evidence of water restrictions in the two prior CHINS, particularly in the Kimberley, provided the impetus for research to better understand the reasons for lack of reliability of water systems in the region. In 2004, CAT conducted a phone survey with 19% of 128 small remote communities (with populations less than 50) from the region to develop a more detailed understanding of the issues affecting water system reliability in these smaller Kimberley communities (O'Mullane 2004). The survey found that 79% of these communities had experienced system failure and that 'equipment breakdown' was a diverse category, not attributable to a singular mechanical determinant. Service delivery and maintenance were found to be major causes of equipment breakdown (O'Mullane 2004). An action research project was developed to explore in more detail the main causes of water system failure in the region and identify ways to address them. This report presents the data and learnings from that research project.

5. METHODOLOGY

5.1 Field investigation

Field work was primarily conducted over the period of July 2004 until July 2006, and therefore data reflects the water supply status and issues over that two year period. Targeted data collection field trips were conducted in October 2004, July 2005, August 2005, January 2006 and July 2006. Trips were also conducted more regularly by CAT Derby regional office staff throughout the period for the project management of the Regional 'Maintaining Homelands Power and Water' contract arrangements.

Research methods were selected to gain an understanding of the infrastructure, management and utilisation of water supplies in the case study communities.

The following data collection methods were utilised:

- facilitated community discussions,
- research visit observations,
- water infrastructure sanitary surveys,
- collation of historical hydrology and water resource data,
- water quality sampling where necessary,
- contractor's regular maintenance visit reports and
- interviews by CAT staff with residents, program managers, maintenance subcontractors, and regional health and education agencies.

Regular engagement and dialogue with residents from a number of communities enabled a more in-depth understanding of how the reliability of water infrastructure impacted on residents, and their priorities for improvement. Through these methods, a basic understanding of resident knowledge, e.g. skills and formal training, was also obtained.

Semi-structured interviews were also conducted with key residents of six communities during the course of the research project (Appendix 1), in addition to the many hours of informal discussions on water concerns and technical requests. With approximately one third of the communities there was a regular engagement or dialogue on water access during the study period.

5.2 Water infrastructure surveys

Baseline information on outstation water supply infrastructure performance and access issues was collected through observation and inventory, sanitary survey and discussion with residents throughout the project (Appendix 2). Information was collected on age and condition of infrastructure components such as storage tanks and treatment systems; local site hydrogeology, local catchment land use, water quality, road access, seasonal conditions and water 'histories' and collated in an internal database.

5.3 Historical hydrogeology

Regional hydrogeology information and historical water resource reports (where available) were obtained through the Department of Environment, Western Australia. In addition, microbiological and water chemistry tests were carried out at the request of residents where microbiological water quality was a concern, or where residents were interested in specific chemical constituents based on taste or odour or regional knowledge of past issues. Microbiological testing was carried out using the IDEXX Colisure fluorescing reagent method and incubated in the field, during transport or in the laboratory for

>24 hrs and enumerated using fluorescence lamp and the Most Probable Number method (Fricker et al. 2003; Stevens, Ashbolt, and Cunliffe 2003). Testing for chemical parameters was conducted by collecting water samples in the field utilising appropriate collection and storage methods and transported to a water chemistry laboratory for analysis of physical and chemical properties relevant to drinking water quality, as listed in Appendix 3.

5.4 Water service delivery interviews and risk analysis

Interviews were conducted with stakeholder agencies involved in local water service delivery to gain an understanding of the program management and funding structure of the water services program delivered in the study communities (Appendix 4). These were largely conducted intensively in early 2006, to inform a risk analysis of the service delivery structure by Popic (2007), a Summer Student under the annual CRC for Water Quality and Treatment Program. That report was completed under the umbrella of this broader research project and contributed significantly to gaining an external analysis of structural issues in service delivery. A detailed risk analysis was conducted on four case study communities and broadened in scope to include the entire water service delivery funding and management structure as a means of assessing its effectiveness and impact on the reliability of water supplies. The detail of survey instruments and interviewees from that work are reproduced here with further analysis.

Staff from the following agencies were interviewed:

- RAESP Program Managers – Parsons Brinckerhoff and regional (Derby) project management staff of the Centre for Appropriate Technology
- Maintenance contractors – Kimberley Regional Service Providers, Top End Contracting
- Indigenous Coordination Centre, Derby

Knowledge of the infrastructure upgrades prioritisation program was obtained through interview with CAT staff with a seat on the now defunct Housing and Essential Services Committee (HESC) for the period of the study.

The subcontractor (Top End Contracting) regularly maintains the power and water approximately monthly in 22 of the 24 case study communities. The subcontractor's service log sheets on maintenance repairs, faults and failures from the regular maintenance program were utilised as a data source and also entered into the database. Water system repairs information and the associated costs were recorded and entered into an internal database between 2004 and 2006. These provide valuable information on equipment failure, repairs and servicing over the course of a one year period. Data was also obtained from an interview with the subcontractor (Appendix 4). Records of resident reporting of water supply issues through the maintenance program management arrangement with CAT were also utilised.

5.5 Regional health and education provider interviews

Adult education providers in the region were interviewed to gain an understanding of the locally available options for community residents for further training in water supply management. This was largely in response to community requests, and in order to review available options against apparent gaps or identified needs.

Structured interviews were conducted with stakeholders involved in water supply related health and educational service delivery in the case study communities (Appendix 5). Educators were also asked to comment on participation rates and their experience of barriers to the uptake of their programs. Interviews with educational providers sought to capture a picture of the existing educational and capacity building opportunities available for communities in the areas of water and sanitation.

Interviews were held with:

- Derby TAFE
- Aboriginal Environmental Health Officer, Shire Derby-West Kimberley
- Karrayili Adult Education Centre

Interviews with health workers were conducted to obtain a snapshot of health practitioner experiences and possible links to water supplies.

Interviews were held with health workers from:

- Royal Flying Doctor Service
- Derby Hospital

5.6 Risk Analysis

Risk analysis methods were utilised to rank risks to community water supply reliability in the case study communities, based on collected water supply information and observation. The scope of the risk analysis approach was also widened to enable a more detailed identification of risks from not only the infrastructure and local management issues, but all levels of the funding, management, maintenance and governance of the case study community water supplies.

5.7 Technical Responses

As the research has come from within an organisation also project-managing a maintenance program, there has been the ability to both capitalise on the contractor's service visits for data collection and also alter management processes to improve elements of the program as the research progressed. This provided an opportunity for a responsive action-research and a 'no survey without fix' approach, where important suggested improvements, such as information management, water supply data collection, information requests and opportunistic capacity building, were taken up during operations. Responding to community technical requests and opportunistic capacity-building provided a mechanism for improved understanding of the issues affecting small water supplies in the region. However, some rectification requirements were far beyond the scope of this project and were reported to relevant agencies for action. They are also presented here in case studies to illustrate the extent of the issues.

5.8 Assessment of data coverage

Due to logistics, occupancy, access, seasonality and a range of other issues, the level of data coverage for each homeland community was not equal. For this reason, the level of 'data coverage' for each community was assessed (Table 1). A tally is provided, to more accurately reflect the level of detail obtained, out of a potential seven research elements, consisting of:

1. Sanitary surveys (denoted by an S)
2. Regular maintenance visit reports (M)
3. Research visits (at least one) (R)
4. Resident interviews (I)
5. Understanding of resident knowledge, skills or formal training (K)
6. Regular engagement/dialogue (E)
7. Historical hydrogeology and water resource data obtained (H)

Table 1 below provides summary statistics, indicating that data was collected on four or more research elements in 18 of the 24 settlements. For six of the 24 communities, the study obtained little data coverage beyond the standard maintenance program data (reflected in a tally of 1). For these communities, these data enable only a cursory analysis of infrastructure age and condition, but no detail on the adequacy of the supply in servicing the needs of the population or an understanding of local water management issues or community capacity. In contrast, a good coverage of the range of data sources was obtained with some communities.

Table 1: Qualitative assessment of data coverage for 24 community study sites.

Settlement ID code	Sanitary Surveys	Maint. Reports	Research Visit	Resident Interview	Knowledge Skills And Training	Engagement/ Dialogue	Historical Hydrology Data	Tally
Ba	S	M	R	I		E	H	6
Bw	S	M	R	I		E	H	6
Be	S	M	R	I			H	5
Bi		M						1
Bd	S	M	R	I	K		H	6
Bu		M	R	I	K		H	5
Bg			R	I	K		H	4
Dj		M	R	I	K		H	5
Ga	S	M	R	I	K		H	6
Ku		M						1
La	S	M	R	I	K	E	H	7
Ma		M						1
Mi	S	M	R				H	4
Mg	S	M	R		K		H	5
Mu	S	M	R	I	K	E	H	7
Ng	S	M	R				H	4
Pa		M						1
Pu		M						1
Ro	S	M	R	I	K		H	6
Ti	S	M	R	I	K	E	H	7
Wi	S	M	R		K		H	5
Ya		M						1
Yi	S	M	R	I	K	E	H	6
Yu	S	M	R	I	K	E	H	7

Table 2 presents data on the proportion of settlements surveyed with each method.

Table 2: Sample of qualitative data instruments utilised in the research.

Data element	Total	Proportion of settlements surveyed
Number of settlements in study	24	-
Number with research element coverage greater than 4	15	63%
S= sanitary surveys	15	63%
M= regular maintenance visit reports	23	96%
R = at least one research visit	18	75%
I = resident interviews	14	58%
K= understanding of resident knowledge, skills or formal training	13	54%
E = regular engagement/dialogue	8	33%
H = adequate historical water resource data obtained	18	75%
C = water chemistry tested	8	33%
W = water microbiology tested on at least one occasion	9	38%

5.9 Representative sample

This study focused on Kimberley homelands with populations of less than 50 people that had no service agreement with RAESP contractors (other than basic contract to CAT) and an independent water supply. From the scoping study by O'Mullane (2003; ABS 1999), there are approximately 128 homelands in the entire Kimberley region that met the study criterion and 15% would provide a representative sample (Broughton and Hampshire 1997), a total of 19 communities. Although the pilot study was largely able to randomly select and contact 19 communities over the entire Kimberley, the field study had to be restricted in its coverage of the Kimberley by funding from only one Shire. For this reason, 24 communities from this Shire were selected for the research and the results of this study are biased toward a description of the homeland water supply reliability conditions in the Derby West-Kimberley Shire. The survey did not include the remote Indigenous homelands within the Broome and Kununurra Shires. However in both Shires, distances to service centres and access issues could be considered to be at least comparable in the Broome Shire and most likely greater in the Kununurra region given the greater area of that Shire, the significant number of homelands accessed from roads other than the two major transport roads, and the lower population of that regional centre.

6. RESULTS

6.1 Community regional context

All 24 communities were further than 60 km from the nearest service centre, and up to 700 km. Fourteen settlements were permanently occupied, whereas five could only be seasonally occupied due to wet season access issues. Four communities were considered to be largely unoccupied during the course of the study. One community was intermittently occupied, for use as the site of an alcohol 'dry-out' program for former residents. There was evidence that some 'unoccupied' sites may be utilised infrequently by owners who reside elsewhere. All sites were used for the analysis, however in the four unoccupied sites, only the non-human data elements contributed to the analysis, i.e. sanitary survey, maintenance reports and historical hydrogeology.

The usual populations in the occupied study homelands ranged from five to 50 residents, an average population of 23 people in those homelands, comprising a total usual population of just under 450 people. Many of the homelands reported large population fluctuations during school holidays, especially the September holidays, and cultural events or meetings, such as gender-specific meetings or business meetings for regional bodies.

The 24 small homeland communities are each members of one of eight Resource Agencies in the region, responsible for administration of Community Development Employment Project (CDEP), housing maintenance, rent collection, collection of fees for and delivery of some municipal services, annual funding applications to government agencies and as a centre of communications - from locating residents to holding mail. During the course of the research, four of those Resource Agencies were closed down due to financial difficulties and one was put under the direction of a financial administrator, with many of its prior programs subcontracted out to other regional agencies.

In the following sections, the findings from the research are broadly grouped into the three main factors found to influence the reliability of water supplies: technology, governance and vulnerability.

6.2 Technology

6.2.1 Water Sources

Groundwater was the primary water source in 21 of the 24 case study settlements. One used surface water from a river, whilst two settlements utilised soaks. Eighteen communities had no back-up supply. One community had been drawing from a spring supply for many years, and finally organised the drilling of a bore themselves, due to ongoing water quality and quantity issues. Two settlements had new bores drilled through the planned upgrades program during the course of the study, however neither was reticulated and in both cases residents have laid their own poly-pipes to reticulate water, with varying levels of effectiveness.

Availability of regional hydrogeology information and records was an important factor in understanding the available groundwater resource at the sites, and ascertaining the likelihood of augmenting water supplies for supplies that appeared to be limiting. Water bore depths, age, quality and alternative sources were essential to understanding the available water sources. Often this data provided the key to determining if the source itself was limiting or if the bore infrastructure is so old as to be ineffective.

Most community water supplies were based on old stock bores, and many were drilled more than 30 years ago. In part for this reason, records providing hydrogeology detail were exceptionally difficult to obtain. Initial enquiries to obtain groundwater data were restricted by expensive data searching options given by the private sector who are contracted to drill new bores and collect these data.

Given that this community water supply data is usually available in the public domain, in WA this proved difficult to obtain, and a lack of integration of agencies restricted the ability to find good coverage of groundwater information. After extensive enquiries, groundwater information on multiple West-Kimberley bores was obtained covering a period of 12 months.

Information available from government records included water bore location, coordinates, datum, maps, depth, water levels, water quality, lithology, hydrographs and site details. Unfortunately the government records database was not updated after the mid 1990's so on occasion the Department had to be contacted for more recent information.

Difficulty in obtaining data was primarily due to changes in the responsible state agencies multiple times in the past ten years, and the impact of private groundwater contractors on data storage and retrieval has been to break continuity of State groundwater records. For the years prior to 1995, the WA Water Authority held the data which now is held by the Dept of Environment after the state water supplier was corporatised. For the years after 1995, new data was collected by private groundwater contractors and lodged with the Department. The data systems were never integrated and one must obtain separate permissions from multiple agencies to collect historical data for a single community supply.

Once obtained, due to the lack of a system of numbering bores at the borehead, it was often difficult to match data to a given bore if there had historically been multiple bores drilled in close proximity.

Catchment land uses were noted during site sanitary inspections and checked against regional maps and old groundwater records. Most catchment landuse was greenfields and current or former cattle stations, focusing the source risk management requirements to bore-head protection.

6.2.2 Pumping Equipment

Dependence on groundwater means that most communities rely on maintaining a functional bore, a working pump and a reliable power source. One third (8) of the study communities rely on diesel powered pumps for water supply, over half (13) utilise solar pumps, two utilise petrol engines and one relies on a windmill to provide water supply (Figure 2).

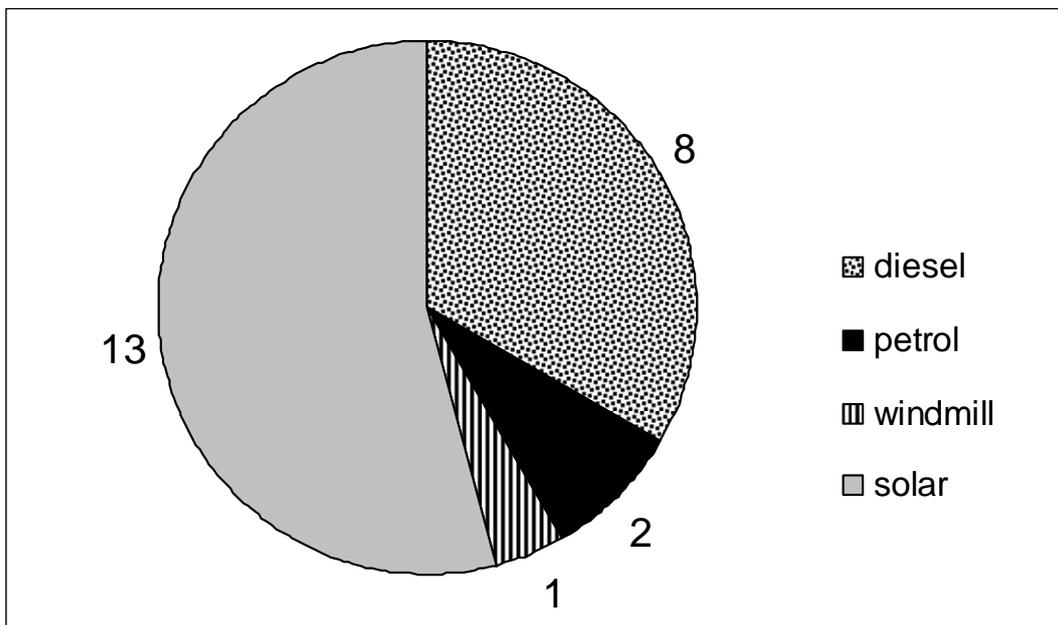


Figure 2: Primary water supply energy source

Most pumping equipment was more than 10 years old, and almost a quarter (5) had been in service for over 15 years (Figure 3). Generators were often much older, but generally have a longer service life as they can be stripped and rebuilt more readily than pumps.

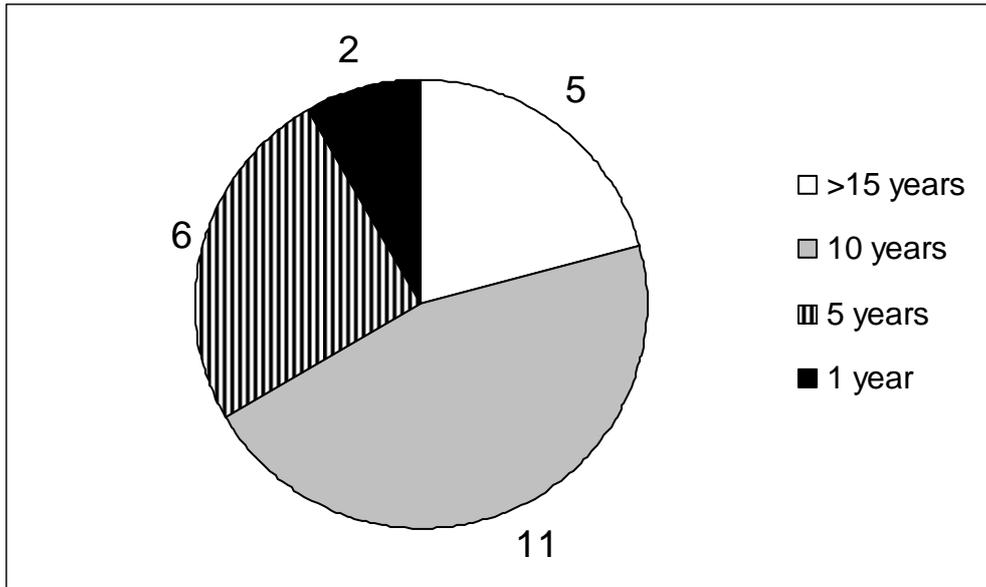


Figure 3: Age of pumping equipment

6.2.3 Water Storages

Storage tanks were of varying ages, sizes and quality (Figure 4). Water storages perform an important function in holding water before (usually) gravity reticulation to a community supply. Storage tank construction, age, capacity and condition can therefore have an important impact on water supply security, particularly in remote locations. Almost half the case study communities had poly tanks, in fair condition. One quarter had older style, galvanised iron tanks and most were in good condition. Approximately one quarter of the communities had very old fibreglass, bullet-style storage tanks, or old corrugated iron, and these tank types were mostly leaking and in poor condition. Two communities had no on-site water tanks.

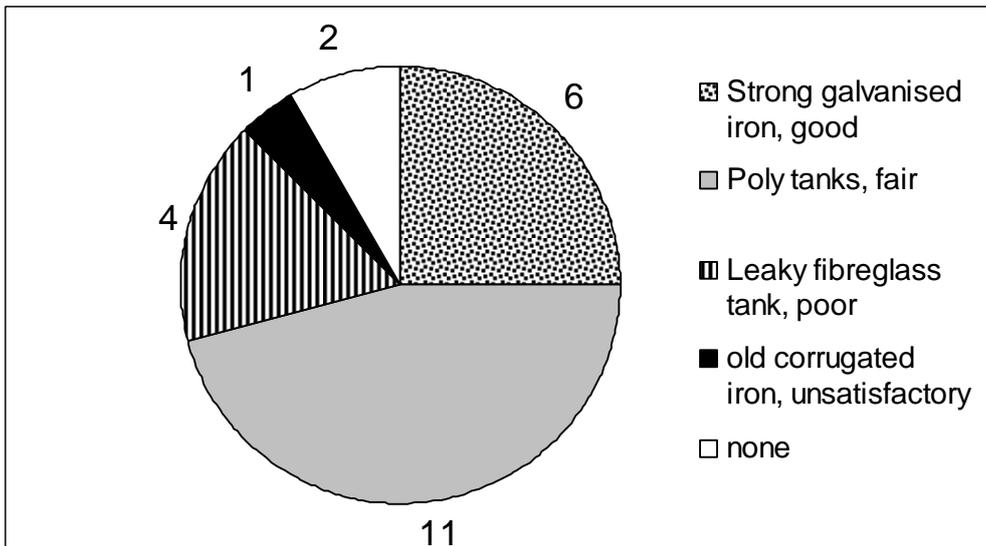


Figure 4: Storage tank materials and condition

Given the remoteness of the communities, at least five days storage capacity is desirable. The size of the tank provides some security to water supplies by providing a 'buffer' time period for response, in the event of a pump or bore failure, between when the failure occurs and when repairs can be made. Just over half of the community water supplies had storage tank capacities greater than 5 days (Figure 5). Two of the case study communities had no water storage facilities and one third had capacities of 1-4 days.

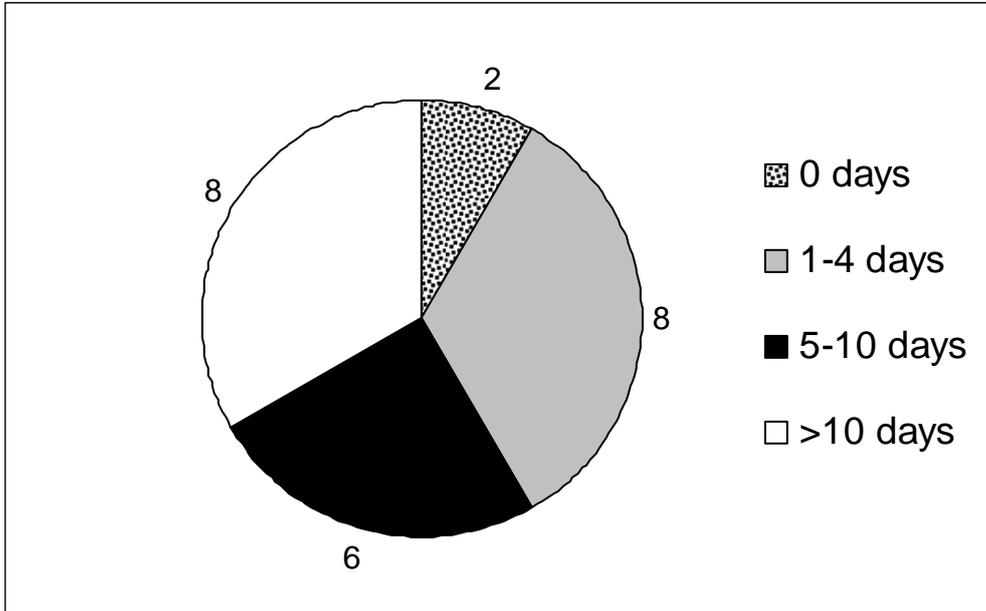


Figure 5: Number of days storage tank capacity

6.2.4 Redundancies

Most of the water supplies had no formal redundancy built into the water supply or back-up (Figure 6). Four communities had backup groundwater bores that were equipped or could easily be equipped with local equipment and one community had a rainwater supply which they quarantined for use as a back-up.

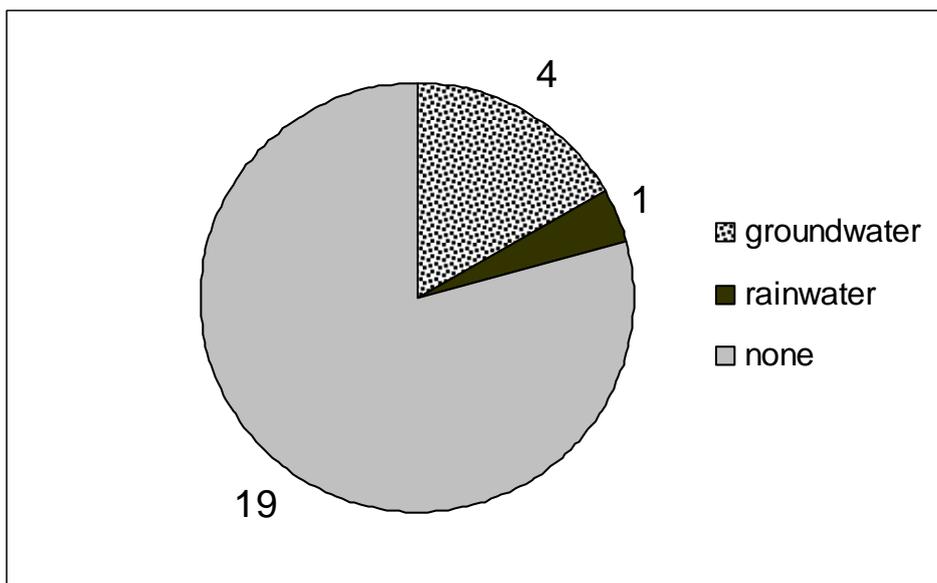


Figure 6: Source of backup supply in the surveyed communities

6.2.5 Water Restrictions and Failures

Water restriction and failure data recorded throughout the study from the above sources was most complete between October 2004 and September 2005, due to improved data recording and surveillance by the research team. Therefore, restriction data presented in the results is analysed only for this 12-month period.

The definition of a water restriction was the same as that used for the CHINS survey; that is, restrictions on the amount of water used and/or the purpose for which water can be used over a 12 month period. It thus includes instances where water may only be supplied or used at specified times during the day, or if the quality restricts its uses to non-drinking purposes (ABS 2007a). Water failures were recorded separately but are reported with restriction data for the purposes of this report to enable comparison with CHINS data.

75% of the case study communities experienced water restrictions during the study period (Figure 7). Fifteen communities experienced water restrictions up to five times in the year. In five communities there was no information obtained about water restrictions. Only one community experienced a year without any restriction to their water supply, and two communities experienced only one restriction. One community experienced water restrictions more than five times during the year.

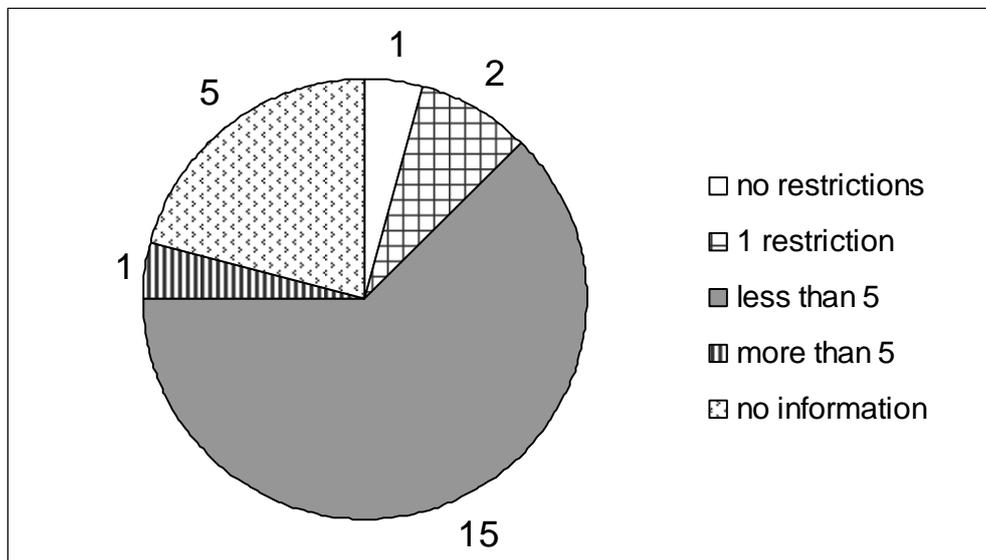


Figure 7: Number of communities experiencing water restrictions and frequency of restrictions.

There were 52 water supply restrictions or failures recorded during the 12 month period in the 19 communities from which restriction information was obtained. There was a diversity of reasons for restrictions in the water supplies (Figure 8). The most common, causing 12 instances, was related to the water source. Source-related restrictions included having no formal or reticulated supply, use regimes that outstripped the source (insufficient source), or a quality problem with the source such as algae or ‘hard’ water complications. For example in one case a build-up of hardness minerals caused the mains pipe to block and split, resulting in a catastrophic failure of the water supply. In two cases where use regimes outstripped the supply, storage capacity was a limiting factor. In nine other cases, pipe failures caused a water restriction. Eight of the nine pipe failures were due to old pipes bursting and one was due to fire damage. Storage tanks failed in six cases, including liners bursting and tanks splitting and leaking from age.

Solar controllers failed and shorted out, causing six water supply restrictions during the year. Pumps, power sources and bore infrastructure were reasons for five individual water supply restrictions (a total of 15 incidents). These included reasons such as pumps seizing (both old and new pumps), power sources such as solar panels and generators failing and bore casings leaking or deteriorated from age.

Water treatment systems were responsible for restrictions in two cases, mostly due to complications with UV globes.

One community had no on-site water supply for the first half of the study period, and then a bore was drilled and solar pump installed. The pump failed less than one month after installation and is still waiting to be replaced under the upgrade and emergency replacement program. Having no supply was recorded as a (permanent) water restriction to the source, and one restriction was also recorded for pump failure. The community have since plumbed the bore with a diesel generator and borrowed a submersible pump. A second community remained without a water supply at the end of the study period, recorded as one (permanent) restriction to the source.

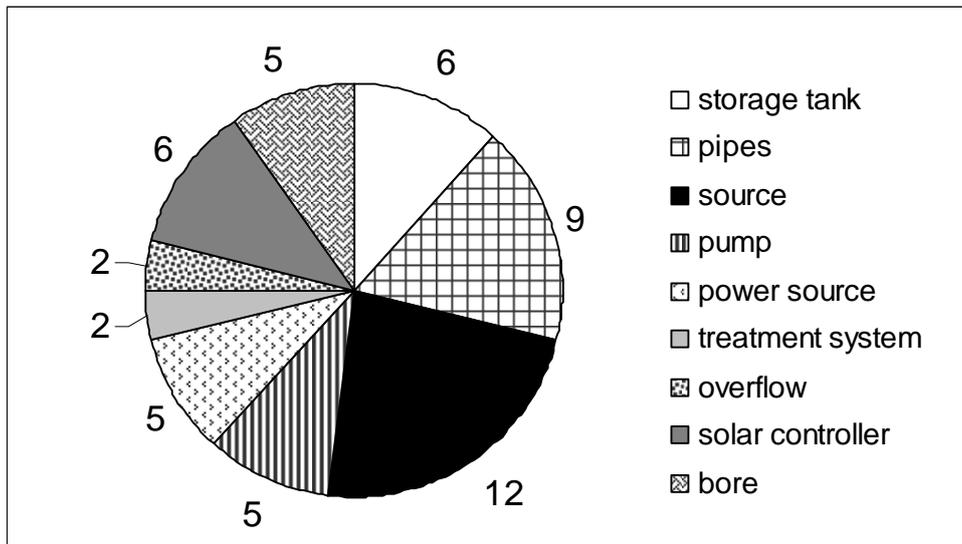


Figure 8: Number and site of the 52 water restrictions experienced by 19 communities in the 12 months from October 2004 to September 2005.

The results indicate multiple reasons for failure, but with a considerable proportion related to the source and distribution system. These results suggest that water resource management and the preventive management of reticulation systems from damage were major issues. Pump failures were fewer than anticipated. In the absence of secondary or backup supplies, the theory that storage tanks increase water supply security was somewhat undermined, as storage tanks were the sites of 6 water system failures during the study period. However, this was largely related to the age of tanks, as most were more than 10 years old.

6.2.6 Water Quantity and Quality

A total of ten communities reported ongoing problems with maintaining adequate quantities of water (Figure 9). Only in some cases did this mean that the water required by the community was outstripping the available source.

In two cases, the bore and groundwater source were adequate, but the storage tanks were of insufficient capacity to supply the community. This resulted in a situation where the storage tank filled, the float switch would signal the solar bore pump to stop pumping, and then overnight the solar pump could not pump water as the storage tanks drained from use, leaving the community without water. In these cases, knowledge of water use and design of additional storage tank capacity would overcome this problem and provide enough water to last through the nights.

In two cases it was very clear that the quantity of groundwater supply was a limiting factor, and augmentation of the water supplies would be necessary. However, in the absence of water metering and water use data, it was not possible in most cases to ascertain the quantity of the supply. It was

thus not possible to assess whether household water usage was conservative or excessive relative to other communities, or whether there were leaks underground in the distribution system.

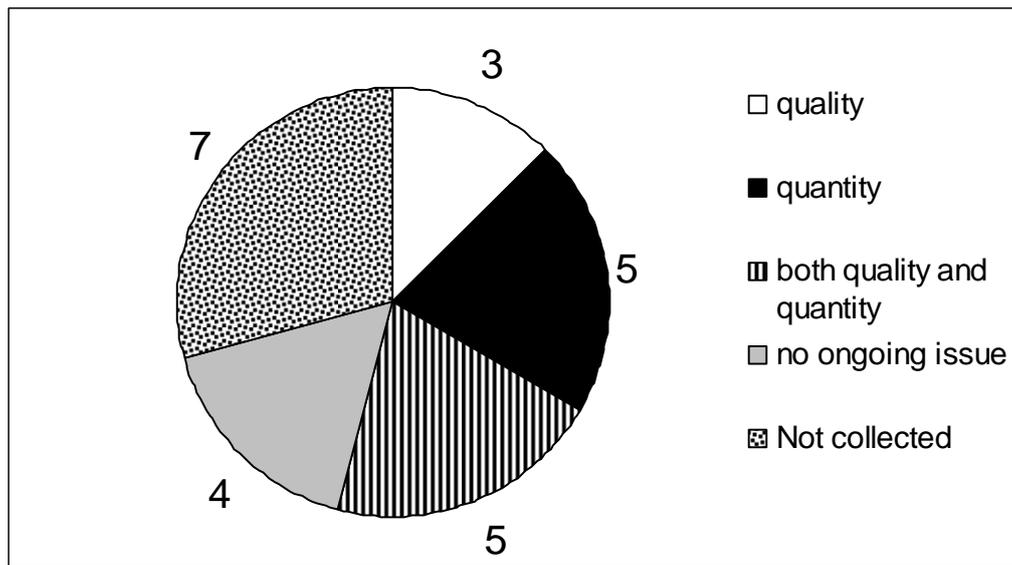


Figure 9: Number of communities reporting ongoing water quality and/or quantity issues during the study period.

A total of eight communities reported ongoing water quality issues during the study period. Only three of these were isolated to water quality issues alone, arising from excessive salt or calcium concentrations in the water supplies and the issues manifested as both aesthetic (palatability) and structural problems (such as causing pipe blockages or other equipment failures).

Five of those communities reporting quality issues also reported problems maintaining sufficient water supply quantities, and in three cases, the lack of enough water was the causative factor in reducing water quality. These kinds of water quality problems included ‘milky’ water associated with bores forking (uptake of fine silts by pumps) and microbial quality issues associated with drawing down small waterholes or spring supplies. Only one community reported recurring issues with microbial quality; however that groundwater-fed water system was fitted with a UV treatment system.

The vast majority (19) of the communities had no form of water treatment (including disinfection) (Figure 10). Only five (20%) had ultra-violet (UV) disinfection systems, and in two cases these were the sources of water restrictions. The installation of UV disinfection systems did not appear to correlate with water supplies of greatest microbial risk, as all five communities with UV systems were reliant on groundwater sources (surface water having higher risks of microbial contamination).

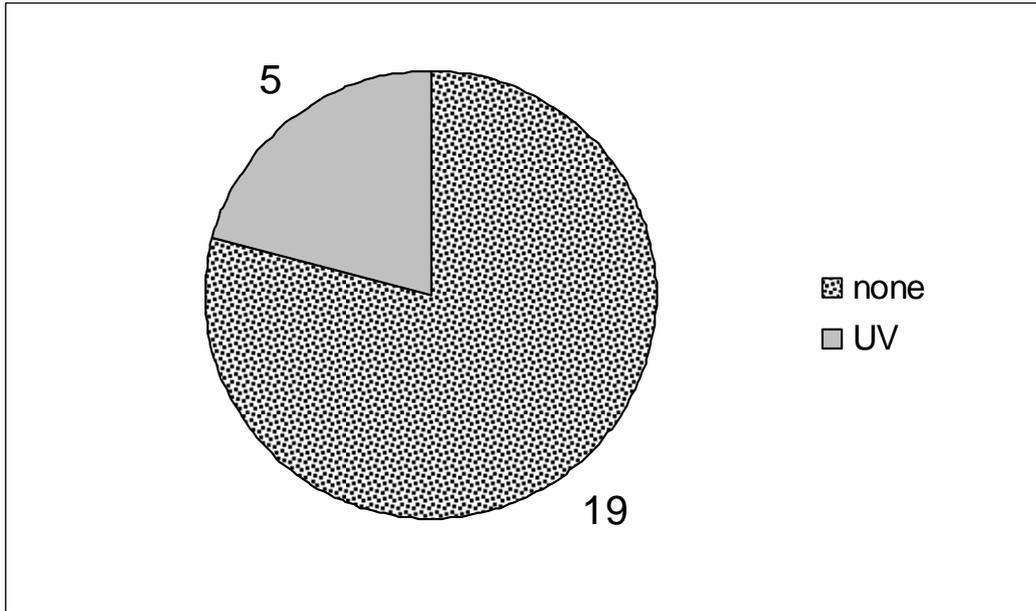


Figure 10: Proportion of communities with water treatment systems and type of treatment.

6.2.7 Water Quality Source Protection

Very few of the water supplies studied had any of the most basic water quality protection measures in place. Only six of 24 bores had basic perimeter fencing. It was observed that many bore and surface water supplies were regularly traversed by animals such as cattle, horses or emus, exposing them to risk from faecal contamination or damage. Cattle can smell fresh water, and were known to break off taps, meters or pressure valves in order to get water during the dry season.

Most bores had only minor or non-existent protective concrete collars and many were unsealed at the surface, offering little protection against potential contamination from preferential flow down the bore shaft. Many storage tanks were also open (missing lids or not constructed as closed systems) to birds, frogs and other animals and therefore potential faecal-related contaminants. Another mechanism for maintaining quality in water supplies is through positive pressure in the distribution system so that in the event of breaks in the system, water will flow outward. Some communities had pressure issues, particularly where systems were intermittent due to frequent restrictions. Some systems were reliant on pressure pumps for reticulation, which coupled the risk of water failures to the risk of energy outages and resulted in a less reliable system. Other pressure issues stemmed from where storage tanks or their float switches were not built or configured to sufficient height to deliver pressurised gravity feed at all tank levels, implicating poor design and construction as the causative factor.

Pipes were often buried only shallowly (30 mm), or not buried at all, also exposing them to risk from damage from soil compaction or breakage from cars traversing over them, or damage from cattle walking over them and fires. Fire damage was responsible for two pipe failures in community supplies during the study period, whilst damage from cattle caused an additional two pipe failures.

6.3 Governance

6.3.1 Service delivery

In the scoping study for the research, it was identified (O'Mullane 2003) that maintenance and service delivery impacted on water system reliability. During the course of the field research, it became very clear that the governance of service delivery, not just the technical output of a service regime, had important impacts on the quality and reliability of the service that residents received. The governance of water service delivery to these small outstations in the Kimberley was documented, and the

experiences of residents recorded to provide an overview of the performance of the governance structure. The performance is discussed in following sections.

6.3.2 Program Funding Arrangements

The program funding arrangements were found to be convoluted, and largely ad-hoc, relating to water supplies in the Kimberley homelands.

Originally ATSiC/ATSiS, then the Commonwealth Department of Families, Community Services and Indigenous Affairs (FaCSIA) provided grant funds under the CHIP (Community Housing and Infrastructure Program) to their WA State office in Perth. The state office would then route the funds through the Regional ATSiC offices. More recently the state office apportioned some essential and municipal type services to the WA Department of Housing and Works (DHW). DHW would administer those funds under a program called the Remote Area Essential Services Program (RAESP), and by agreement with the Commonwealth, secure a portion of these funds for the delivery of basic energy, water and sanitation services for a list of 91 communities with populations greater than 200. DHW then engage a Project Management agency to manage maintenance and capital replacement programs for water and power infrastructure in these communities, and emergency capital replacements for smaller communities below this population threshold, on an ad-hoc basis.

In selected small communities of less than 50 in WA, a portion of these grant funds were awarded on an annual (but sometimes provided on a three year) basis, through a state-wide process of competitive submissions for smaller communities for housing, water, infrastructure, sewerage and municipal services funds. These submissions were usually made by Aboriginal organisations/Resource Agencies across WA, to fund ongoing maintenance and delivery of basic services to their communities and homelands. Federal ATSiC/FaCSIA would then sort the submissions into regional areas and these were then channelled back through to the regional outposts of ATSiC/FaCSIA staff, now known as ICC's, or Indigenous Coordination Centres. ICC regional staff (previously ATSiC regional councils and their staff) were then responsible for assessing the quantum and need for the requested funds and make recommendations to the State office in Perth, based on regional knowledge of the community and the level of need. The CHIP funding guidelines (FaCS 2005) and local ATSiC Regional Council priorities provided a framework for how regional ATSiC/FaCSIA staff should assess these submissions. Once the recommendations had been made, these were reviewed by Perth ATSiC/FaCSIA, and if approved, Federal ATSiC/FaCSIA in Canberra were notified, and an agreement could then be signed between the service delivery agency (Aboriginal Council, Resource Agency or Indigenous Local Government) and the regional ATSiC/FaCSIA staff.

From interviews with regional stakeholders within the funding model, it was their impression that there were considerable equity issues with this approach. It has been cited by Kimberley regional ATSiC staff that they were aware of a significantly disproportionate distribution of CHIP funds between Goldfield, Pilbara and Kimberley regions, and within the Kimberley, the Malarabah Region was thought to be the recipient of a considerably lesser proportion. Questioning/criticism of this imbalance from regional organisations led to a change in funding application process. The WA region's grantee organisations were required to submit eSub applications using a "zero-based-budgeting" process to identify the true cost of delivering essential and municipal services. This was to be used to enable a comparison of the overall regional budgets. This was an intensive activity requiring considerable time from grantee organisations, but was later not used by the State office in the apportioning of grants to recipients.

The main points from the above observations are that the funding to obtain basic services such as housing, energy, water supply and sewerage, was tenuous. These services were delivered via a competitive process in which applications were assessed against those from across the state and ultimately decided upon by officials over 4000 km away. The very process of obtaining water and sanitation services funding therefore relied heavily upon the local Aboriginal organisation's capacity to complete the submission documentation and then to a large extent their existence hinged upon its success to obtain that income stream to deliver the service. It then relied on the locally-identified priorities to be deemed to align with those funding priorities determined in the State capital. The process did not appear to have an adequate method of ranking need and quality of service across regions or homelands, as a basis for apportioning funding. The lack of a guaranteed funding stream

therefore ensured that organisations providing essential services existed tenuously between respective funding rounds. This had an obvious impact on the continuity of capital works and repairs, contributing directly to reduced water services reliability and continuity in homelands.

6.3.3 Homelands Maintenance Program

It was under this funding arrangement, that a program called the 'Maintaining Homelands Power & Water' Program ('Homelands Maintenance Program') arose, for the servicing and maintenance of basic water and power infrastructure in a subset of small Indigenous communities with populations of less than 50 people (known as homelands) in the Kimberley region. In 2000, ATSIC staff and regional councillors observed weaknesses and risks with several small, individual Communities and their Resource Agencies managing the delivery of essential services to approximately 21 homelands that "slipped through the gaps" in the RAESP program, and encouraged CAT to tender a submission to manage a regionalised water and energy service delivery program. Notwithstanding the efforts and good intentions of those involved, the basis of this program also proved to be financially tenuous. It relied on the right combination of individuals in the Derby ICC and a regional Aboriginal organisation (CAT) having an 'ear to the ground' on the issues of community needs and problems of service delivery, including failing water supplies, sanitation and lack of electricity. In regions where staff were not as proactive, residents were less fortunate and services were largely non-existent. The regionalised Homelands Maintenance Program is the only one of its kind in the whole of the Kimberley: a region with three ICC offices, 16,000 Aboriginal people (DIA 2005), and 160 outstations with populations of less than 50 people (ABS 2001c). Attempts by regional agencies to expand the program to the other two regions of the Kimberley were unsuccessful during the study period.

The regional office of CAT operates as the Program Manager of the Homelands Maintenance Program. As Program Manager, CAT manages a competitive tender process to select a regional contractor to conduct a planned maintenance regime for basic on-site power and water supply system maintenance. The program maintenance consists of regularly changing oil, fuel and oil filters in generators and regular servicing of generators, which most commonly provide household and water pumping energy in the homelands. Solar pumps, solar panels and controllers are also serviced and on occasion, responsive minor repairs are made to these items, mains pipes and storage tanks.

The tender process was advertised annually and at the request of the Program Managers was recently approved to be extended to three year duration, to provide certainty for the contractor upon whom the maintenance ultimately relies. Almost all (21) of the case study homelands in this study have their water supplies maintained by the contractor under this program at an average frequency of once per month. Recently, a portion of this contract (Larinyuwa Community) has been let to a regional Aboriginal corporation, along with the offer of capacity building, and a firm performance-based contract/agreement.

For the 91 large communities (with populations greater than 200) in the state, a completely parallel program of service delivery exists. The Program Manager, at the time Parsons Brinckerhoff, performed a similar program management function for power, water and sewerage system maintenance with funds from the WA Department of Housing and Works (DHW), by program managing the RAESP. The RAESP Program Manager appoints a maintenance contractor to conduct servicing and maintenance; in the Kimberley this company is currently the Kimberley Regional Service Providers (KRSP). Where the two parallel structures cross over, is where the RAESP Program Manager is (or has been) also charged with the responsibility for overseeing the capital/planned replacement and emergency (major) breakdown repairs for the smaller Homelands Maintenance Program.

The FaCSIA Terms and Conditions for the Homelands Maintenance Program gives the program manager (CAT) the responsibility to deliver planned maintenance and basic repairs/preventative maintenance costs and minor contingencies, but not the replacement of capital items (see following section). Planned and emergency replacements were meant to be paid for through the Program Manager of the RAESP Program (Parsons Brinckerhoff), however experience illustrates that going to the Program Manager for planned replacement, emergency (major and minor breakdown) repairs takes too long to provide timely service, and so low-cost contingencies are often absorbed in to the Homelands Maintenance Program budget. Capital or planned replacement has proved to be non-existent through the RAESP Program Manager and this may be in part due to the larger

responsibilities of large community water supplies overshadowing the smaller homeland community program. This means that all of the 24 community essential services systems are well overdue for replacement and are kept going with “band-aid” treatment through the Homelands Maintenance program.

Communication appeared to be an issue between the Homelands Maintenance and the RAESP Program managers. The custodian of the funds for emergency repairs needs to have a local conduit of information regarding emergency water failures in homelands and a sufficient pool of contractors who can be mobilised at short notice. This was not evident under the current arrangements.

Coordination between the two parties regarding the necessity of planned upgrades or a communication mechanism between the recipients of the upgrades (homeland residents) and the capital replacement service provider, could potentially improve the capital replacement completions, or greater autonomy of the two programs.

There also appeared to be little accountability between the level of water services provided and the departmental body funding the program. To some extent this gap was filled somewhat informally by regional ICC staff, but from the study it became apparent that this was with varying levels of effectiveness.

Communication appears also to have been a key factor in the improvement of the homelands maintenance program. On the ground, contact with communities from the Homelands Maintenance program is by three main means:

1. Where the contractor on his regular maintenance visits could detect problems with any major leaks, breaks, water (and power) service issues and can responsively make minor repairs, and
2. CAT regional Program Management staff making occasional visits to communities when passing by, or out on other duties to check on residents’ water (and power) services, and
3. Community residents directly notifying CAT staff of any failure, breakage, or loss of service by phoning, or dropping in to the CAT office when they are in Derby.

In this way, the Program Manager has semi-regular contact and an understanding of how water systems are functioning. This also appears to build organisational knowledge of how a water/energy system is going, and which ones may be getting so old as to need replacement soon. Notification by community residents appeared to be stronger where they knew the face and name of the CAT staff member (through this or related roles), who had been in the organisation for a long time. This appears to have been key to improved service delivery.

6.3.4 Capital Replacement

Sensing the local coordination issues, the Housing and Essential Services Committee (HESC) was formed by local agencies to undertake a prioritisation process for capital replacement. Meetings were designed to bring together state government funding providers for housing, power, water and waste management to prioritise capital budget expenditure for the following financial year/quarter by region. These meetings were to be held annually, and stakeholders in essential service delivery could attend to coordinate and contribute to the determination of priorities. Attendees included staff and representatives from:

- RAESP Program Managers (ARUP, then later Parsons Brinkerhoff)
- Homelands Maintenance Program Managers, CAT
- ATSIC then ATSI staff

There were two meetings held between 2001 and 2002. The meetings attended involved presentations from the service providers on the scale of their program, with some reference to future

planned replacement/upgrade of larger community essential services, but no plans were presented for the planned replacement of the smaller community essential services.

The prioritisation process picked up systems that were broken or had suffered catastrophic failure, but progress was slow. Often it was known that there were ailing components of existing functional water supply systems, but there was no long-term plan to replace obsolete systems that were being revived beyond their effective service life. Once they failed, these systems would be added to the bottom of the list of communities awaiting a major upgrade, but in practice, repairs were continually made through the maintenance program to keep them working in the short term in order to prevent residents having to go without water.

This led to a situation where ageing infrastructure, continually 'revived' beyond its reasonable working life, would result finally and predictably in a critical water system failure. Repair of such failures often resulted in long delays for the water supply to be restored. If the failure required replacement of major capital items, this would require the separate service provider agency with minimal community contact to mobilise separate field staff to conduct emergency replacement of the failed infrastructure. To some extent, the Homelands Maintenance program could informally negotiate to address these problems and plug smaller gaps in service response.

However, whether for lack of finances, human resources or other unknown reason, it was apparent that this situation resulted in upgrades then being afforded to those with broken supplies, over those with inadequate supply or those facing the biggest risks to supply. This style of 'failure management' thus actually decreases the reliability of these small water supplies, by allowing preventable failures to occur to the water systems.

A suitable analogy would be when a car owner knows the brakes are failing on their car, because they're getting less and less effective. Someone provides you with support to clean them, grease them and reinstall them, but the pads continue to wear. You can't have them replaced until they actually fail (failure replacement methodology), and the result is that you crash into something (catastrophic failure). By that stage you will probably need a new car, instead of just replacing the brake pads. If you lived somewhere remote, there would be a long wait for the new car. Also, the supplier might take a long time to get the kind of car you need. So like the car with no brakes would make a person's life more vulnerable (exposing them to risk of collision), the water supply with no systemic attention *before* it fails, makes the population depending on it more vulnerable, too. The remote homeland community cannot attract water supply asset replacement funds until the water supply has a catastrophic failure, placing them without water supply or with compromised supply (and the associated health risks) for some time until appropriate capital replacement can be organised. Vulnerability of water supplies is discussed further in Section 6.4 following.

It was also not clear who was responsible within the program for developing a list of planned upgrades, certainly a number of stakeholders pointed to examples where they had tried to provide warning that a system was soon to fail, but to little tangible effect. This does not appear to be from lack of goodwill, rather a lack of clarity around roles and quite probably a lack of resources to meet both the current acute replacement needs and that of a longer-term replacement program.

This caused great frustration, not only from residents, but also from individuals within the various stakeholder bodies at all levels of the system. Sometimes this leads to people 'bending the rules' to help out a homeland they know of in a particularly tough situation, and of course this relies on trust, good relationships and knowledge of the issue. Unfortunately this also raises issues of equity, and the communities that may not be well known by relevant agencies can miss out.

6.3.5 Homelands services delivered

Almost all (21) of the case study homelands in this study have their water supplies maintained by the contractor under this program at an average frequency of once per month. Seasonal restrictions or diversion of human resources to pressing water rectifications meant that the contractor did not visit all 21 communities every four weeks during the study period, but averaged a four week visitation. Three communities that are thought to be largely unoccupied were visited approximately once per year or as appropriate. Analysis of the visitation data from contractor maintenance log sheets for the 12 months from October 2004 to September 2005 illustrate that a total of 231 community visits were made, with

an average of 12 maintenance visits per community per year. Excluding those three communities thought to be unoccupied, a minimum of five visits and a maximum of 17 visits were made in that year to each community, varying due to occupancy and occurrence of water system failures requiring repairs.

Communities who tended to meet the contractor as he worked and knew his name and face, generally stated that they were satisfied with the routine maintenance program and the contractor's service frequency and interaction with them over the past four years. Before this time many could remember getting intermittent services, and expressed that they were glad that someone was regularly checking in on them.

During interviews and discussions with community members and Resource Agencies, many people commented on their confusion at who was responsible for which aspects of their water supplies, and who to go to when things went wrong. Whilst most were aware of the contracted maintenance program, the complexities of which agency can repair and which can replace particular elements of infrastructure – and where the funds came from – was confusing.

Some of the more aware residents remarked that when broken things weren't replaced, they often used the tactic of phoning as many of the stakeholders that they could think of to tell them about the problem. In only one community did one of the residents state that they were aware of any prioritisation process for determining upgrades. One community leader, who in their permanently occupied homeland had been carting their water for over seven years, described not understanding why his promised new bore had not yet eventuated. He described telling his Resource Agency, CAT, KRSP, the local Shire Environmental Health Officer and the regional Indigenous Coordination Centre manager. He described a succession of people who had come to inspect his community and the water and sanitation hardware that they did not have, but still he had no functioning bore, pipes, toilet or storage tank. In late 2006 this community was supplied with a new bore and a storage tank on a stand, but no pump or pipes with which to access the water. By early 2007, they had obtained a pump from their Resource Agency and installed 600 m of their own makeshift 100 mm poly reticulation pipes and a generator and were using the raw 100 mm pipe end to deliver water to the community, for showering and for filling water coolers and jerry cans for drinking and cooking (Figure 11). At June 2007, the issue remained unresolved and the Program Manager stated that they were waiting to award a contract for the reticulation works to be completed.



Figure 11: Drinking water storage for a small permanently-occupied community whose bore had been installed but not reticulated into the community.

Although this particular case was an extreme example of an absence of timely service, coordination with the community or local agencies, there were others recorded during the study. A nearby community had a similar experience of its bore being redeveloped, where it was not reticulated and they laid their own pipes and similar issues with the storage tank not being connected to the community soon after it was completed.

Other issues that were raised by residents of the case study communities relating to the governance of water services included:

- Community leaders and local young men themselves reported wanting to learn how to do servicing and maintenance from the contractor, and sometimes would look over his shoulder and he would explain basic things as he worked
- Lack of understanding what services they were entitled to, and from whom
- Lack of understanding about who they paid rent, service charges and other charges to, and for what
- Frustration at a lack of attention to a recurring water shortage in a community, caused by inadequate tank capacity. Unless this tank is broken it would not be scheduled for replacement and once broken, the community would have no water whilst they waited on the list for a replacement.
- For proactive communities who sought it, obtaining information about their bore and local water resources was difficult

Overall, the governance structure was confusing to many stakeholders and not well understood both by homelands residents and staff involved in service delivery and funding agencies. The confusion over which agency was delivering which aspect of the service was likely related to the competitive nature of grantee organisations bidding for service delivery funding. This meant that service delivery could and in some cases had changed hands frequently prior to CAT taking on the local program. Homeland communities beyond the reach of this program are likely to be in a much more confused and ill-served state. There is a need for a coordinated approach to ensure basic services are funded. There is a need to ensure that those services that are funded are delivered, and that those services are delivered based on need. There appeared to be great benefits in a high level of communication between service delivery agencies and recipients, but this communication did not extend through all levels of the service delivery system and so the messages regarding which water supplies were in need are not making it into the prioritisation process.

6.4 Vulnerability

6.4.1 Security and vulnerability

Many of the concerns expressed by residents about their water services revolved around the issue of water security – having dependable access to water. Most of their comments therefore identified factors that contributed to a lack of water security and made their water supply situation more vulnerable. Moran and others define vulnerability as insecurity and sensitivity in the well-being of individuals, households and communities in the face of a changing environment, and implicit in this is their responsiveness and resilience to risks that they face (Moran 2007; Moran et al. 2007). Drawing from the earlier analogy, just like the car with no brakes would make a person's life more vulnerable, the water supply with no systemic attention, a lack of support and skills makes the people who live there more vulnerable too.

Vulnerability is not a static concept, but one which evolves with residents' changing circumstances. Examining residents' perceptions of their water supplies forces a shift in perspective from external notions of welfare (viz water quality) to people's own perceptions of their wellbeing (viz reliable water supply). By shifting to this style of analysis, the needs of the target community can be discerned, and the gap between what is required and what is delivered can be assessed.

6.4.2 Residents' water concerns

The expressed perceptions of residents on vulnerability and their water supply needs provided a valuable social context for the analysis of water system reliability data, i.e. what does it mean for residents if a tank fails or a pipe breaks in a location 400 km from the nearest service centre?

Residents' articulated concerns about their water access provided valuable insight into perceptions of remote water supply needs, risk and vulnerability.

Reflecting a known vulnerability, and perhaps a reaction to unreliable supplies, residents expressed a desire to have more local responses to water quality and quantity problems. Issues such as communications, microbial risk factors, water storage capacity, the presence of a back-up supply, disinfection methods and community skills came through very strongly as being important factors in reducing the vulnerability of homelands water supplies.

Perhaps not surprisingly, residents wanted more information on water responses such as contamination response measures like disinfection, ability to obtain fire fighting pressure and volume, and ways of managing or monitoring local water consumption.

Local demand management was important to most of the participating communities, due to limitations on water supply, and some were actively practicing it. One male community leader explained his strategy of convincing other residents to use water wisely like this: "I'm a bit hard on them, too. I tell them, if you're going to use water, it has to mean something".

A number of communities had a fear of externally imposed water quality standards, giving the impression that they had had negative experiences in the past of external parties dosing their water with additives. Upon being offered an opportunity to obtain water testing, one resident remarked: "You can only test it if you don't put anything in the water!". Even though water testing was often asked for by community residents wanting to know the composition and safety of their water supply, in many cases it was a tentative request as the anti-additive sentiment was expressed many times through the course of the research. Some residents described a 'strong taste' or 'stinging smell' after previous water testing interventions, and when probed, by deduction this was most likely to be chlorination. Though rarely tested in these locations, chlorine is most commonly used in remote areas as a 'bomb dose' (aiming for hyper chlorination, however doses are unknown) in response to detection of microbial contamination. It is often used with a poor understanding of appropriate concentrations and the importance of adequate mixing and the taste and odour effects have clearly had a lasting impact on residents. Dosing was described in a number of cases as involving dropping a number of [pool chlorine] white tablets into storage tanks. Where residents could remember these cases, they had little understanding of why the water had been dosed, indicating a lack of consultation.

A small number of communities put an emphasis on communicating with the servicing and maintenance contractor. These were usually the more proficient of the informal water operators that wanted to keep abreast of the status of their water equipment. One community leader underlined the importance of communication with the service contractor and of younger male residents to learn about the water system: "...yeah he does a good job. He comes in and talks to us and explains what he's done and what needed fixing. It's good for the young ones to know here".

Water quality in one community had been a consistent and ongoing problem. They were reliant on a very shallow coastal aquifer that was recharged directly in response to local rainfall, and frequently it was over pumped by local water use. This led to the extraction of fine silts and clay as the supply drew low. When asked about their water, a female community leader said "we got to put cordial in it to disguise the taste, that one milky" and also described drinking stronger tea to avoid the taste.

One community described how they were living with regular shortages of water: "...it's low. We cook early in afternoon when the water's there." In this case, their solar pump would stop pumping on cloudy days, often leaving the storage tank quite low by the evening.

The importance of and need for backup water supplies, was frequently expressed. One resident stated that "[To] catch rainwater would be good for the wet season, when someone can't come and fix him [the main bore], we can still drink that water".

Expressing a feeling of vulnerability about their single bore supply powered by an ageing old Lister generator, one community leader stated: "we've just got that one [old generator], and he's getting old. [If] he breaks what have we got?"

Another vulnerability identified by residents was having enough water in the event of fires, which seasonally occur in the Kimberley on a broad scale. "...we get big fires out here. What can I do with my house? We could try drain that little storage tank, use everything we got, then what?" Fire fighting was often mentioned as a key concern when discussions about water supply turned to quantity.

In essence, a shortlist of key issues were expressed over and over again by residents across the different homelands:

- intermittent supplies/unreliability
- needing more local water skills
- importance of dialogue/interaction with the maintenance contractor/service provider
- a need to manage quantity in both short term cycles and into the future
- importance of a backup supply (to mitigate issues of distance)
- consideration of water for local fire response
- issues of communication when failures occurred
- fear of externally imposed standards
- understanding of their service entitlements, and who was responsible

Remote residents were very conscious of their increased vulnerability to water system failures due to the large distances from service centres and wet season accessibility. Given these geographic realities, many wished to equip themselves to better meet water supply challenges before or in conjunction with seeking outside help.

Ten communities requested technical assistance and advice on 24 water and related technical issues during the course of the research. Residents wanted more information on ways to respond to such issues as rainwater collection and storage, hard water treatment, pressure booster pumps, using lower quality water for irrigation, sanitation options, ponding and mosquito control and training in water supply maintenance.

Where water systems had failed in the past, residents articulated feelings of vulnerability or uncertainty about their overall security of living, namely having to go to 'town' (nearest regional centre, in this context was Derby, Fitzroy Crossing or Halls Creek) to tell relevant people in the service delivery system until the system got repaired, either staying with relatives or sleeping rough (sleeping outside with minimal bedding). Talk of 'town' usually led residents to make comments that 'town' is often associated with 'trouble'; grog (alcohol), undesirable contact with other groups of people, humbugging (relatives undesirably exercising reciprocity obligations to impose on family to acquire a share of their money or goods at hand) and rivalries with people on the fringes. Residents often discussed that when back at home; they could just be with their immediate family and stay away from the trouble.

These discussions elucidate indirect social impacts of unreliable water services; the forced but notably only temporary migration into regional centres, having a range of negative social implications for homelands residents. In practice during the study period, even when major water supply failures occurred, any cases of permanent migration to town were not observed. Although reasons for the desire to live on their own land defy simplistic generalisations, to some degree the residents' opinions of town life clearly illustrates strong social reasons to stay on homelands, and avoid the troubles of townships. It was observed that in many cases, people were enduring very difficult water situations in order to stay on homelands. A common coping strategy was to cart water in and conserve it until a problem could be rectified.

These observations also provide reasons to strengthen communications to help avoid any necessary short term migration, or for during wet seasons where travel to regional centres is often not possible for many homelands. Aside from the obvious public health impacts of a lack of water and therefore water-borne sanitation, these social determinants provide additional reasons for homelands residents to strengthen their skills to manage water issues locally.

Residents had a range of coping strategies that they employed to deal with their water issues, depending on the skills and experiences of their kin. Many communities had a resident informal water supply operator, with wide variation in skill levels and abilities between locations. Some informal water supply operators had the advanced level of skills to be able to strip a generator, service a pump and lay reticulation pipes, whilst others had buried pipes (or laid their own), sealed storage tanks or carted water from other locations when water supplies failed. Often these skills were obtained through previous experiences as station workers, Essential Services Operators (trained on larger communities for basic water operation & maintenance duties) or TAFE (the state Training and Further Education Board). In one community a young resident was undergoing formal training with Kimberley Regional Service Providers (KRSP).

In 15 homelands these 'informal' water supply operator roles were clearly defined by the residents (e.g. "that's Harry's job"), and in others the role may have been shared by a few residents. In the communities where it was clearly defined, it was usually men who occupied the role; and in all 15, the person who occupied the role was also the community leader/head or role model for other younger people in the family. Over the course of the research it became obvious that these roles were increasingly being shared, and one male community leader expressed his reasons for this: "Yeah I know how to do all that water supply, pump, tanks, but the young ones they got to learn and I got to spend my time building them up". This illustrated informal, internal community training by the more experienced operator. He was showing others how to perform the basic operations and checking of the water system, largely in order to free his time for the more important pursuits of community leader to approximately 40 people and mentor to 20 resident young men.

At the root of the expressed needs to have more local responses to water issues was the need for increased local operator knowledge and training. A number of educational options in water supply or environmental health exist in the study region. However, the existence of jobs for people completing the courses, and problems associated with courses being delivered in town was considered to be an important factor in the retention of students. Pursuing these training options usually requires that water supply operators leave the community for the study periods, and this can have important ramifications on the homeland left behind. Interestingly, the skills required for local water management were somewhat less than those delivered in many of the formal courses, and were largely on issues that would be easily transferable through learning in the field, such as chlorination, fencing, burying pipes, sealing tanks and recording tank volumes used. Some residents also had the skills to change oil and fuel filters and manage pumping regimes but felt little ownership over the infrastructure.

Differing perceptions of the reliability of water supplies became obvious through the course of the research. Generally, the water system characteristics that emerged for a reliable supply according to residents was one that dependably delivered the appropriately useful quantity at an appropriate quality (not getting sick was high on the agenda). Having a water supply that could meet the water needs across the community and that could be locally supported for minor repairs if necessary were also key characteristics. Residents also generally wanted the peace of mind of some minor external support for regular servicing and major support for more technically challenging upgrades. Residents also wanted more information about their supplies so they could inform visiting staff or contractors of any relevant water supply history.

Often, the community 'vulnerabilities' aligned with one of three characteristics: (1) a particular sub-set of physical elements of the water supply system (e.g. ageing infrastructure, hard water, source issues); (2) the uncertainty in the external governance arrangements; or (3) increasing local skills and training. A useful picture developed of what makes a water system vulnerable to residents of these communities.

6.4.3 A Proposed Vulnerability Indicator

A range of factors have been described that contribute to water system reliability, that were not simply structural or technological issues. A baseline of functional infrastructure is required, in conjunction with local skills and capacity development.

The possible mix of influences on the infrastructure upgrade prioritisation process made by external parties has included issues of equity, personalities of individual staff and their perceptions of the 'commitment' of communities to stay on their homelands. Conjecture on whether people are living in their homeland or not often clouds assessments of need that can skew towards communities most often visited by agency representatives. Given that such system assessments are often made by non-specialists, they are also prone to have little basis in real water supply requirements or understanding of human health risks.

In this environment, there may be a niche for an assessment tool or indicator which can assist non-technical regional agents to simplify and standardise their assessment of water infrastructure vulnerability. If field agents could assess water supplies based on the primary components that make these water supplies most vulnerable, it would assist funding bodies to prioritise those community water supplies on a planned upgrade list on such merit. It is understood that occupancy is an important factor in expenditure of public funds, and an indicator would assist with separating the two components of assessing water upgrades into social and technical. Regional field agents could concentrate on understanding the social elements such as occupancy and capacity building needs. This may also help to break down the size of the problem of water infrastructure funding into smaller, more frequent upgrades to component infrastructure, as opposed to failure management requiring complete system overhauls. A pro-forma would be easily manageable by field agents or could enable the assessment to be made under the existing regional maintenance program.

To this end, a 'vulnerability indicator' is proposed as a way of assessing upgrades based on need and an understanding of what contributes to water system reliability in these remote homelands. This could sensibly inform the prioritisation process by government and stakeholders, rather than the currently unstructured allocation processes.

The impact on residents from malfunctioning or damaged essential infrastructure or compromised water quality is greater where they have few remedial options or alternative supplies. Key characteristics that were found to increase the vulnerability of the Kimberley water supplies were:

- distance from service centres,
- if the community has a telephone,
- the number of times they experienced water restrictions,
- number of times they were cut off by road in a 12 month period and
- microbial contamination risk,

Remedial characteristics that reduced vulnerability included:

- the number of days water storage capacity,
- presence of a back-up water supply and
- use of a disinfection method.

Deciding on the best tools or interventions that can be utilised to reduce the greatest infrastructure vulnerabilities requires an analysis of the interactions of these factors in reducing risk.

The 'vulnerability score' (Vs) is calculated by incorporating risk factors on the numerator (summed or multiplied according to their effect on the water supply) and remedial or risk reduction measures on the denominator, as per Figure 12 below.

$$Vs = \frac{(\text{travel time} + \text{duration unoccupied} + \text{cut off by road} + \text{phone}) \times \text{microbial risk factor}}{(\text{number of days water storage} \times \text{backup water supply} \times \text{disinfection})}$$

Figure 12: Equation for the proposed vulnerability score.

The score incorporates key physical elements of water system vulnerability:

- travel time to nearest regional centre, which is important for obtaining assistance on water failures (number of km)
- duration unoccupied each year, as this can illustrate an unreliable supply or a difficulty in living in a place (number in weeks)
- if the community is seasonally cut off by road (factor 100 if yes, 0 if no)
- presence of telephone communications (factor 150 if no, 1 if yes)

These figures are then multiplied by a 'microbial risk factor', which helps to contextualise the severity of the impacts of distance. In a supply with a low microbial risk, the impact of travel times and road access on people (as it pertains to water quality) are somewhat buffered. In the denominator, further buffering effects are quantified that pertain to quantity and quality, including:

- number of days water storage capacity
- presence of a backup water supply
- knowledge of or presence of a disinfection method.

The microbial risk factor provides a method for estimating the relative risk of the source water quality based on field assessments, and is determined by the multiplication of three aspects of microbial risk, the first relating to the source, where:

- 1=soak (greatest risk)
- 0.8=carted
- 0.5=river
- 0.1=bore (lowest risk)

Soaks were considered to be of greatest risk as these were usually very low inflow pools (sometimes stagnant) and open to contamination from animals drinking and defecating. Carted water was considered to be the next highest risk in these environments (regardless of source), as it involves the reuse of containers which may have sat stagnant for some time, in hot environments and necessarily involve greater handling in transfer to where they are finally used. Greater handling provides increased opportunities for contamination. River water was considered a lower risk than carted water, as the rivers were mostly fast flowing and from catchments with low anthropogenic impacts.

The second component of the indicator provides detail on the condition or hygiene of the water storage, where:

- 1=unprotected (no cover from contamination, possible leaks or breaks in storage)
- 0.5=partial protection (perhaps a lid but no leaks or breaks, partially compromised)
- 0.1= protected (tank has cover/lid, in good condition, no leaks or breaks)

The last component of the indicator describes the presence of a disinfection method, where:

- 1=none (risk remains),
- 2=disinfection (the risk is halved if water is disinfected).

The microbial risk factor is obtained by multiplying these three factors.

The denominator attempts to enumerate the proportional effect of three mitigating strategies for reducing vulnerability of community members to water supply failures by assigning numeric values to the proportion of effect these may have on reducing vulnerability.

1. size of water storages (capacity in number of days)
2. presence of a backup water supply (0.5 = none, 2= backup available)
3. disinfection method (2= disinfection, 1= no disinfection)

In this way, it is possible to use the final vulnerability score across groups of communities to rank need, but also to assess the potential impact of alternative mitigating strategies in an environment of scarce resources, e.g. increasing storage capacity in a remote location with pump or generator reliability issues may assist in providing increased security in the event of a failure.

An example below illustrates calculation of the vulnerability score.

A community is located 600 km from the nearest regional service centre, is cut off by road during the wet season each year and has no phone. The residents thus spend 12 weeks per year away. The community water supply is sourced from a spring, which feeds a protected storage tank with three days storage capacity. The water is delivered to residents undergoing no disinfection. They have no back-up supply if the primary supply fails. The vulnerability score would be:

$$Vs = \frac{(\text{travel time} + \text{duration unoccupied} + \text{road cut off} + \text{phone})}{(\text{number of days water storage} \times \text{backup water supply} \times \text{disinfection})} \times \text{microbial risk factor}$$

Travel time = 600
 Duration unoccupied = 12 weeks
 Road cut off = 100
 No phone = 150

The microbial risk would be: $1 \times 0.1 \times 1 = 0.1$
 Number of days water storage = 3
 No backup water supply = 0.5
 No disinfection method = 1

The calculation would yield:

$$= \frac{(600+12+100+150) \times 0.1}{3 \times 0.5 \times 1}$$

$$= 58$$

Vulnerability scores were calculated for all surveyed communities and the data were plotted against adjusted community occupancy and road distance data (ABS 2001)¹ to develop a representation of the risks to the study community water supplies and potential effects on community stability. An enlarged plot illustrating more clearly the data from two communities is presented in Figure 14.

The risk factors have been plotted across the horizontal axis in both plots. The mitigating factors reducing vulnerability are displayed along the upper horizontal axes, and include: number of days' community on-site water storage capacity, availability of alternative water supplies and availability of disinfection technologies.

The 'vulnerability score' responds well to the community water supplies identified as having the greatest water risks from the field work. A pattern emerged in the plot of vulnerability, that based on the research on the state of the existing infrastructure and key vulnerabilities described by residents, is representative of the communities that were considered to be most vulnerable to water system failures.

¹ although this data may vary slightly from year to year depending on the wet season

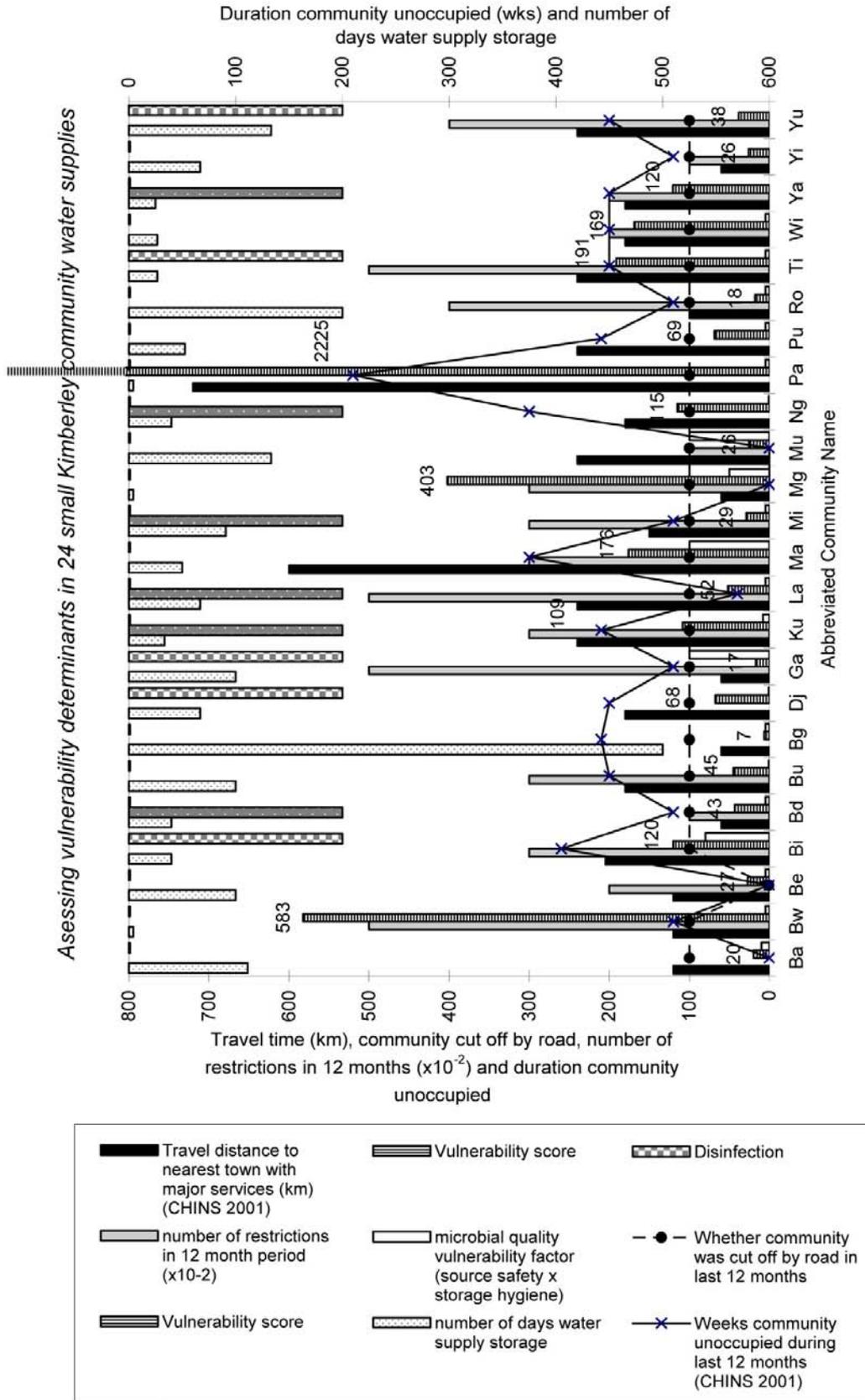


Figure 13: Water restrictions compared against key characteristics of the 24 study communities that influence water supply reliability; see also Figure 14 following for magnification of two communities' indicator values.

All communities were more than 60 km from the nearest town; the furthest being over 600 km away from a service centre, represented by black columns. Note that community vacancy periods generally increase with distance from service centres.

Distance, combined with the capacity and condition of infrastructure available on the site, has clear ramifications for vulnerability to water supply failures. Figure 14 presents a magnification of plotted data from two communities for clarity.

Communities with high risk factors (bottom horizontal axis) and low ‘buffering capacity’ in remedial factors (upper horizontal axis) will return a high vulnerability score, such as community ‘Mg’ (403).

From Figure 14 community ‘Mg’ had three water restrictions over 12 months, no backup supply and little storage capacity. Community ‘Mi’ has a lower vulnerability score of 29, due to the availability of a backup supply and 9 day’s storage capacity. If community ‘Mg’ were to connect a back-up supply such as rainwater tanks or augment storage capacity, their relative risk would reduce by dividing by the number of days of augmented storage capacity. For microbial risks, installation of a disinfection measure would reduce their risk by half.

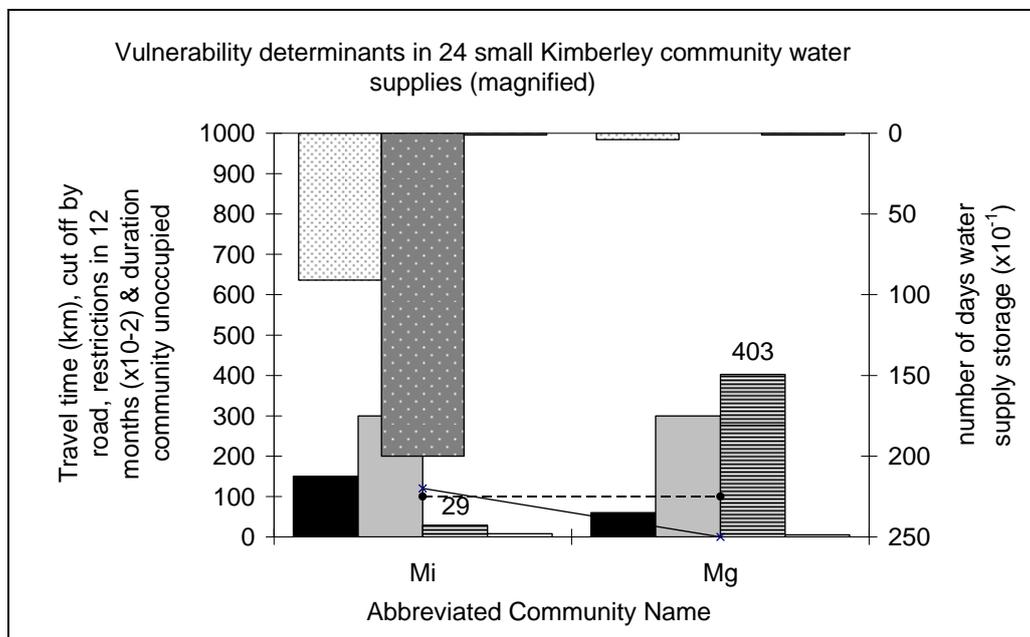


Figure 14: Magnified plot of reliability determinants for two case study communities (magnification of Figure 13)

Although coarse, the vulnerability score describes the interaction of a number of key determinants of water supply vulnerability and their affect on residents of remote homelands as identified in this project. This vulnerability indicator requires further research to assess its applicability to other regions. This type of indicator may assist infrastructure funding agencies by utilising a ‘rapid assessment’ tool for collating key data on small water systems. The scoring process would provide a defensible method for prioritising the allocation of scarce resources to upgrades of community water supplies based on greatest risks, rather than responding to failures.

Further research is required to refine and validate this indicator and assess barriers to its potential as an assessment tool for funding agencies.

6.4.4 Flexibility of Risk Management

One main limitation of the vulnerability score however, is that it does not integrate notions of the self-assessed community skill level and local ability for water management. Self-assessment is important as skill levels will usually be assessed by residents relative to their particular water system configuration and therefore relating to their ability to manage their own supply well, as opposed to an external assessment (e.g. a certificate level of competency).

Based on the research findings, a community assessment of priorities for local water management should also be considered when determining water supply investment priorities in these communities. One method which offers an opportunity to record community assessments of water supply risks is a facilitated water risk management approach. This research has clearly illustrated that operator knowledge is a crucial potential 'risk' or source of strength for the reliability of a remote water supply.

The Community Water Planner (NHMRC 2005) is a tool which assists field practitioners to develop a risk management plan for small water supplies, based on the national framework for drinking water quality in the Australian Drinking Water Guidelines (NHMRC and NRMMC 2004). Grey-Gardner illustrated that with due facilitation guided by the Community Water Planner (NHMRC 2005), the risk management process was transferable to water supplies in a small, remote Indigenous community context (2007).

One way to link considerations of infrastructure installed to the available local skills could be through modification of the Risk Management framework (NHMRC 2004; 2005; CRCWQT 2004), to also include a self-assessment and subsequent 'risk treatment' for community knowledge. A lack of community water operator knowledge, or a lack of support of them was shown through this research to potentially lead to big risks to water supply and therefore to human health, and could be incorporated into a risk assessment process.

The current risk management framework as defined through the Community Water Planner is largely confined to the community's water supply system. From this research it was observed that in small remote communities, the 'water supply' defies narrow definition as a conglomerate of a discrete source, pumps, storage tanks and pipes, but rather encompasses a broader combination of community characteristics that determine if the water management needs of a community are met, safely and reliably. In these small homelands, the consideration of 'water supply' encompassed:

- current source
- presence of a back-up source
- the conventional water system components such as pump, storage tanks, pipes and energy source
- type of energy source for pumping and relative to community skills
- level of community water knowledge (skills)
- number of people holding the knowledge
- ability for local responses to water risks (fire, contamination, loss of supply)
- beneficial use of low grade water sources (e.g. grey water)
- availability of water for shade trees, kitchen gardens, possible enterprise
- presence or absence of external service support
- governance of water supply service delivery (e.g. funding structure and method of administration)
- an understanding of resident entitlements under service delivery programs (where they exist)
- an understanding of the governance structure

The risk management framework is flexible enough to include broader elements of water access in remote locations, and through participatory processes it is possible to tailor the risk assessment to

include community priorities. The risk management approach could and should be applied in small Indigenous community contexts and broadened in two main ways; firstly the consideration of contributing social factors of water supply risks (e.g. local skills) and the consideration of a 'whole of water cycle' approach to the water supply, not just the traditional tanks and pipes. This approach would include applying the risk assessment to all water concerns in a community as part of supporting a more integrated local water management capacity.

The vulnerability indicator could then be considered as a means for funding agencies to assess overall prioritisation of upgrades across and between communities at the larger scale.

7. SUMMARY AND CONCLUSIONS

We now return to the research questions to summarise the findings and make conclusions on the key areas for attention.

7.1 How are water systems in Kimberley homelands performing?

Residents in Kimberley homelands are experiencing major difficulties in maintaining reliable water supplies.

Water systems in the case study homelands in the Kimberley were frequently unreliable, with 75% experiencing water restrictions or interruptions within a 12-month period.

Water system components were largely ailing, indicating a need for further upgrades and replacements to be made to key infrastructure such as storage tanks, pumps and bores. Distance and wet season access clearly have an effect on water services in remote locations, but this is a constant and people have developed coping strategies accordingly. Ageing infrastructure was being revived beyond its expected service life and this contributed to high rates of water system failures.

Ageing infrastructure was being revived beyond its expected service life and this was a causative factor in precipitating high rates of water system failures.

Seasonal extremes appeared to play more of a role in exacerbating the duration of water supply failures rather than contributing directly to their cause.

Small improvements to homeland water source issues identified in the two prior state environmental health needs surveys (EHNS)(EHNCC 2004) were detected in the study area, such as two cases of new bores where residents had previously had to cart water. This indicates action has been taken in response to water source issues identified in the survey. However, EHNS does not provide indicators of water *quantity* or *reliability*, just the presence of a system and if water quality had been tested.

Two water sources have been improved since the previous WA EHNS. The EHNS detects the presence of a water supply and its source; however it does not record its operational status and so can not alone be used as a measure of water supply access.

Water system performance in the case study communities was largely a mix of 'getting by' for the larger systemic issues, punctuated by failures that required long delays in repair, and using local innovation with support from an external service contractor for smaller, regular maintenance. Many communities were very positive about having the maintenance contractor regularly checking in on them.

The maintenance program was perceived by homeland residents to have improved the reliability of their water supplies in comparison to the past.

Homeland residents put great emphasis on communication and engagement with service providers in reducing their vulnerability to water failures.

Local improvements to water supplies undertaken by residents included the laying of their own reticulation pipes, plumbing (and drilling in one case) their own bores, carting water and enforcing local water restrictions on fellow community members. Remote residents were generally persevering under sometimes very difficult conditions, and were not permanently leaving their homelands despite intermittent and unreliable water supply access. Therefore the effect of withholding appropriate support services to these communities could be said to increase risks to health of residents through under-resourced water systems.

Remote residents were not permanently leaving their homelands despite intermittent and unreliable water supply access.

Residents were conscious of their increased vulnerability to water system failure given their remote locations, and had often taken steps to reduce this vulnerability.

Greatest water quality risks identified in the water supplies were those which could be mitigated through local protection works, such as fencing bores, burying pipes and enclosing storage tanks. These are also relatively low cost improvements that would result in a large impact on water supply quality.

The largest water 'risks' to humans appeared to be the simplest to fix and source protection offers great opportunity for mitigating these.

Overall, in order of priority the water problems were firstly quantity – maintaining a reliable supply, and secondly, microbial quality issues. Thirdly, hard water was also an issue in a number of communities and exacerbated the poor performance of ageing infrastructure.

Water quantity – having enough water, reliably, was the most common problem across the case study communities.

There were six communities where the underground water resource was limiting. Managing water use can be a relatively uncomplicated process and was already practiced in some communities. Working with residents to understand the available water resource and possible management strategies can support local efforts to conserve and better manage the resource. It is generally more complicated to adapt households and communities with water-saving technologies in these locations, but this could be part of a community response as they demand it.

Good technical information about the water resource combined with community knowledge of uses and experiences of it is essential to underpin local responses to managing consumption within water resource limits. Engagement processes may help facilitate improved local water management, and provide a mechanism for facilitators to feed back to service delivery agencies the levels of need.

Source protection measures such as burying reticulation pipes, fencing water infrastructure and disinfection are all relatively low cost but can have a big impact on water quality. However, simple and comparatively inexpensive source protection methods have not been prioritised under existing service support mechanisms due to the current paradigm of failure management and a lack of specialist water input into the funding allocation process. From the technical assessments and community interviews, water quality was much lower on the list of key water supply issues than the management responses from service delivery stakeholders would suggest. The service delivery stakeholders sought to prioritise water quality testing over other programs of water supply investment, when this was found to be of lower risk than water quantity and the need for local water management.

Residents had more difficulty maintaining a consistent supply than a good quality supply, due to ailing infrastructure and water source management issues.

When prompted, residents of some communities would speak of their local knowledge of how to keep water clean and healthy in natural sources, e.g. rivers, soaks and rock holes, however, once the water was in pipes and tanks, they felt their knowledge was not relevant and so often did not apply it. This is far from the case as most risk management concepts within the water supply system are based on similar understandings of source protection.

Local water supply skills and knowledge appeared to have a strengthening effect on water services reliability, enabling residents to cope better with the uncertainties in the funding environment and the water services delivered.

There is an opportunity and a need to link local knowledge to water supplies to reinforce existing knowledge and improve community ownership and participation in water management.

Fifteen of the homelands had 'informal' water supply operators, meaning that they were unrecognised within the service delivery structure. However, these operators played a key role in maintaining the

water supply and responding to failures, and their roles were well-defined within the community by local residents. These operators asked for more information on a broad range of water management issues. In these communities, residents were actively working to fill this water management gap, and a few operators had formal technical qualifications. However, these technical skills did not adequately provide the contextual management skills for assessing risks to the water supplies and managing it as a system, and operators relied on pieces of knowledge picked up from informal sources.

There was a gap in the service that was delivered, the skills available locally and what is needed to manage the water supply risks identified.

The minimum skills required for improved local water management were often much less than, but different to those that would be covered in a formal water training course. These minimum skills related mostly to quantity management and source protection. These are knowledge areas that could be developed through facilitated participatory processes in the field, and supported with an infrequent revision or refresher to this process. Where informal water supply operators were actively questioning the service and teaching others in their community how to operate their supply, residents were less vulnerable to repair and failure difficulties.

For the past few years, in larger communities in the Northern Territory, Power Water Corporation has conducted formal training of Indigenous ESOs to maintain remote water supplies. A scaled-down version of this sort of annual training could be considered for the informal water supply operators on homelands, perhaps to be included in the pool of ESOs trained by the larger water services providers in WA and added to their existing contracts. A funding stream for this type of training should be considered to improve local water management and therefore the longevity of capital water supply infrastructure.

The minimum skills required for improved local water management were different and much less than those that would be covered in a formal water training course.

Where informal water supply operators were actively questioning the service and teaching others in their community how to operate their supply, residents were less vulnerable to repair and failure difficulties.

7.2 Does the apparent trend of increasing failure rate with decreasing community size extend to small Kimberley homelands?

Failure rates from water supplies in the 1999 survey of community housing and infrastructure (ABS 1999) did not include communities with populations of less than 50 people. However, the data showed an inversely proportional relationship between community size and failure rates; the smaller the community, the more frequently they experienced water failures (Figure 15). This research question sought to understand if this trend extended to the smallest of Indigenous communities.

Failure rates of water supplies were very high in the 24 case study homelands in the Kimberley, when compared to the 1999 survey, with 75% of the communities reporting water system failures at least once in the 12 month period from 2004 to 2005.

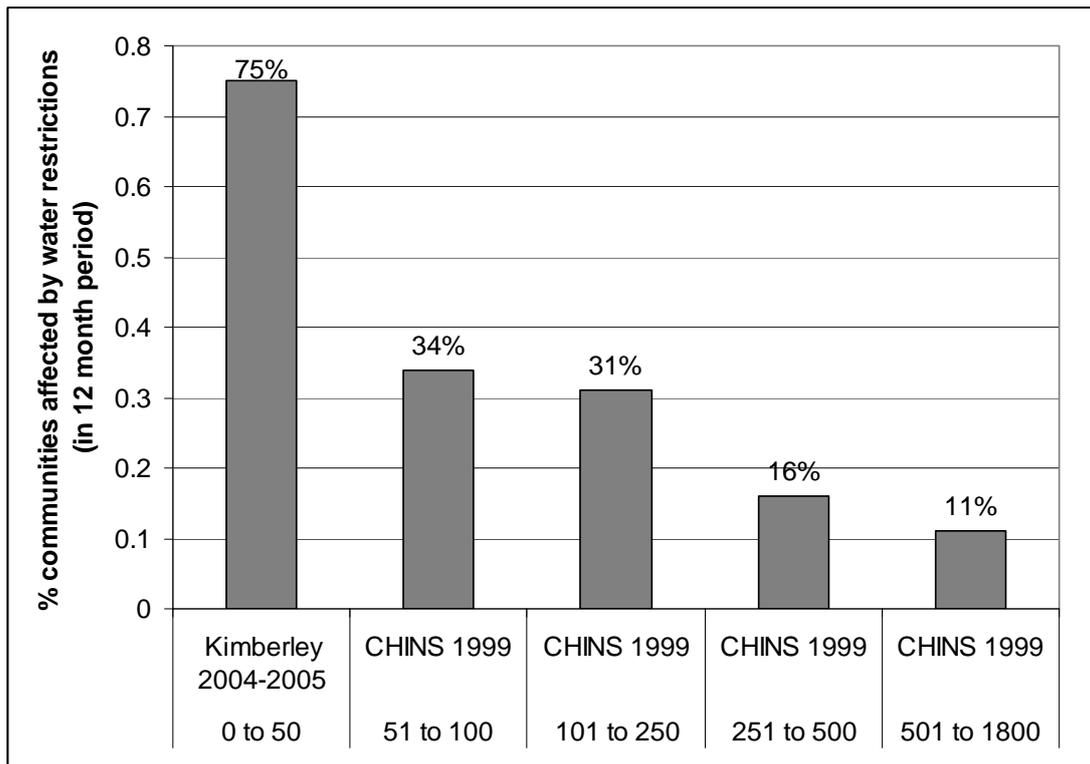


Figure 15: Comparison of water system failures based on community size, CHINS 1999 data and Kimberley water reliability study.

Water supply failure rates are much higher in small communities of less than 50 people than their larger counterparts.

The greater frequency of water system failures in small communities illustrates the need for improved water support mechanisms to assist these communities to develop local water management capacity and improve reliability of water systems in remote homelands.

7.3 Are there systemic management, investment, environmental, historical or other factors which have contributed to this outcome?

7.3.1 TECHNOLOGY

Given the remoteness of homelands, the seasonal extremes and relatively low remote population, water infrastructure needs to be robust enough to handle infrequent maintenance and be appropriate to the local skills so that it can be largely locally managed. In the event of a major problem, ideally it would be managed locally until further help could arrive. There does not appear to have been any process that considers the most vulnerable elements of water systems that require strengthening under these remote extremes, or the ability for supplies to be locally managed.

The service delivery structure had a lack of emphasis on key infrastructure items required and equipment lifecycles for a functioning water system. There appeared to be little understanding of the reality of and critical need for water supplies to be partially locally managed.

Failure management and the reviving of ailing infrastructure beyond its service life directly contribute to the high failure rates of small water systems in Kimberley homelands.

Within regional arms of government there was a focus on improving access to water testing, seemingly driven by dual but contradictory considerations: a fear of the ramifications of recording high failure rates in such a testing regime and a desire to deliver quality water. Concerns over meeting water quality guideline limits were disproportionate to actual needs, and this appeared to overshadow more pressing problems with continuity of supply. The focus on water quality test outcomes is inconsistent with the broader framework approach advocated in the Australian Drinking Water Guidelines (NHMRC 2004) which calls for risk management of supplies. However, at the hands of government staff unfamiliar with the approach, the ADWG was often reduced to a quest for meeting guideline testing limits.

Continuity of supply and regular appropriate management regimes were more urgent in most cases to residents than water quality testing, in agreement with the risk management approach to drinking water management.

Certainly the risk to residents from no water/lack of water for basic drinking and sanitation was found to be of greater concern than a lack of testing. That is not to say that protection of water quality is not important, but that water quality testing on its own will not deliver better water quality. Residents need to be able to respond locally to the outcomes of a positive result of a water test, and have a way of determining the cause. Risk management provides a preventative method for addressing water quality in remote areas that is within the reach of local residents. Capacity building for risk management is likely to deliver greater outcomes of water safety for the investment.

The application of a facilitated risk management approach in these contexts provides a framework to enable community residents to self identify risks to their water supply (and therefore human health). Defining a mechanism to link these back to governments and service provision agencies would not only serve to build capacity for governments and their service providers to understand the ranking of risks relative to community priorities but provide a defensible funding framework from which to deal with the greatest water supply risks first.

Water risk management offers a framework to enable residents to identify risks to their water supplies, build capacity of both residents and governments and provide a defensible funding framework from which to address the most pressing water supply risks.

7.3.2 GOVERNANCE

Transparency of the water service delivery governance system, from funding arrangements through to delivery and accountability of services was shown to have a profound effect on water system reliability.

The root cause of equipment breakdown was related to a lack of maintenance to the whole water system over the long term and inadequate replacement regimes. This was exacerbated by a lack of understanding by community residents of their water services entitlements.

If citizens in these communities were more informed about their entitlements, it is likely that they could exert enough pressure on local politicians and government staff to improve the situation. However, most residents were unclear about who was responsible for replacement of infrastructure, where the money came from, or who to call beyond the maintenance contractor when things went wrong. Resource agencies clearly performed a role of assisting residents to navigate this understanding, but staff turnover and resource agency closure in all but the most tenacious agencies undermined their ability to perform this role. In any case, residents should not have to agitate for receiving a service to which they are already entitled as this is an ineffective way of obtaining equity in service delivery.

An increased understanding is also required within funding and service delivery agencies about the water issues in remote homelands to ensure funding is targeted at areas of greatest need.

Greater awareness of the challenges of managing small, remote water supplies is required within the agencies responsible for funding water services.

There appeared to be little contact between the recipients of the service and the departmental body funding the service delivery program.

To some extent this gap was negotiated somewhat informally by regional ICC staff, but with varying levels of effectiveness. Greater feedback loops from residents to funding agencies on the service provided would help to increase accountability of service delivery. Improved accountability measures could include performance criteria in service delivery contracts, such as field officer inspection and site inspection of capital works. Greater information is required at the community level so that residents can assert their rights to services already allocated where they may not be received, and help to increase the accountability of service providers.

One stakeholder commented that a community had been waiting for over a year for a new bore after being earmarked as having no water supply. The examples given in the results about storage tanks delivered and installed but not connected to the reticulation system also back up this claim. There is a need for inspection of works by project managers, or at the very least, photographs of finished work from contractors or by residents to illustrate the completed works.

Over and above the issues of distance from service centres, the biggest vulnerability to the reliability of water supplies appears to be the coordination between external management bodies for prioritisation and actioning of upgrades.

There is a case for the funds for maintenance and replacements to be administered by one agency, with appropriate accountability measures in place to the end-users.

A lack of accountability and coordination exacerbates responses to water supply issues and compromises the quality and it could be argued, the value for money of services delivered.

The process of assigning upgrade priorities was not transparent and long delays in being prioritised and receiving the upgrade were observed.

Residents were grateful for the regular contact with a servicing and maintenance contractor, and generally thought that their water supplies had been more reliable since this program had been running, and responses to critical failures had improved.

The Maintaining Homelands Maintenance Program enabled the important basic water servicing issues to be kept in check, and residents reported improved water service reliability since the program had been operating.

Ready access to discretionary funds helps to improve responsiveness of maintenance program to small water failures.

Emergency replacements tended to operate more rapidly than planned replacements, as the maintenance contractor and Project Manager had a delegation to spend up to a certain amount on these. This enabled the contractor and/or Project Manager to expend the funds to purchase (e.g. a replacement tank for a split one), and install it as soon as possible. This was not possible for more expensive upgrades, such as generators, overhead storage tanks and new bores or pumps.

This water service delivery system to these homelands is based on 'failure management', not proactive replacement, and in remote areas this institutionalises water system failure.

This creates a situation where the contractor and the residents are waiting for a failure to happen, but powerless within the structure to prevent it from happening, only to delay its occurrence. Through necessity, water systems are generally 'revived' repeatedly, well beyond their intended service life. Then, once it occurs and depending on the time of year (e.g. wet season, school holidays) the time it takes for repair and therefore the impact on residents can vary widely from a week for the water supply to be restored to a number of months. How long this takes depends on what went wrong, which part/component needs replacing and how long it will take to rectify.

Long wait times for scheduled upgrades increases the workload on the maintenance contractor, as he is frequently required to 'bail out' failing water supplies. Failure management institutionalises water failures.

How communities cope during that time depends on their own internal coping strategies for resilience, which largely depend on the knowledge and capacity of local operators and the availability of local materials and assistance. In some cases this had resulted in communities getting access to contingency funds from resource agencies that were assigned for other purposes, just to get them through.

Access to water resource information also influenced the ability of community residents, resource agencies and service providers to respond to water source failures and the ongoing management of water quantity. Access to hydrogeology information and previous bore reports for the region provides a valuable baseline for future water supply planning. This information was difficult to access, requiring permissions from three different government departments and a person in Perth to physically meet with officials to obtain access to it in an electronic format. Although by definition this data is free and available to individual communities who want their own bore information, many did not know of its existence, who held it or how to get it. Resource Agencies too, often did not know about the data and their long-term record keeping was often inadequate. Part of the difficulty in obtaining the data was that access to it is restricted for private service providers. CAT was given permission to access the data given its not-for-profit status and research work. This raises issues for the current funding model, given that service providers are often contracted private entities and may not be able to access this information for the purposes of water supply management contracts, which are now almost always for-profit enterprises. It is not known how Resource Agencies are considered under the data access restrictions.

There is a need for improved availability of water resource information to inform water system planning and management (n.b. quantity was critical, quality secondary).

Historical water resource information was difficult to access for communities and service delivery agencies.

GPS coordinates and regional or station names must be matched to old coordinates or place names to approximate the right bore in an area. In the Northern Territory, all bores are labelled with a metal plate embossed with a unique reference number that can be used to access bore information from the department responsible for natural resources, or even now accessed online. This kind of system could be usefully applied to WA.

There is no system of labelling of bores in WA, and so matching water bore information to records was often a challenge.

The secondary issue for communities once they have the information is having it interpreted by people with the technical knowledge to understand it, and communicated in a way that enables residents to understand what it means, to be able to use the information in water planning. This is also the case for the range of other technical considerations in community water planning, such as health considerations of grey water use, disinfection methods, rainwater harvesting and many more. These reasons provide strong argument for a facilitated and participatory water risk management process.

There appeared to be the possibility for individuals to exert great influence on which water supplies get funded upgrades, and sometimes based on views of who was 'committed' and 'deserving' of the upgrade. Whilst this can enable balanced decision-making on the allocation of a scarce resource, it also can leave parties open to inadvertently defining somewhat inequitably, the 'deserving' or 'good' communities requiring water upgrades, or in reaction to pressure from the 'squeakiest wheels'. Implementation of a technical basis for assessment would increase the transparency of this decision-making process and facilitate an efficient allocation of funds to the sites of greatest need.

The combined use of regional field officers/facilitators and robust, transparent criteria for decision-making offer opportunity for ensuring water system upgrades occur based on need.

7.3.3 VULNERABILITY

It was identified that reliability of water supplies was linked to the vulnerability of a community to the negative effects of uncoordinated governance and ageing technology.

Informal community water supply operators strengthened the ability of the community to respond to water system vulnerabilities.

Water risk management approaches provide an opportunity to meet the sometimes competing needs of service providers, funding agencies and serviced communities. The Community Water Planner provides a guide to the assessment of water risks in small supplies (NHMRC 2005), and this could be extended to the 'whole-of-water cycle' in a remote community context. 'Whole-of-water cycle' refers to consideration of all aspects of water use, distribution and waste disposal in a community that may affect local water source and supply.

Grey-Gardner used a risk management approach in conjunction with the Sustainable Livelihoods Framework Asset Pentagon (Moran et al. 2007; Grey-Gardner 2007; DFID 2001) as a participatory tool to facilitate community members to map their own assets that could be used to improve their local water management issues, encouraging remote residents to consider their own role in supporting improvements to their water supplies.

The vulnerability analysis identified a list of five key infrastructure elements that could help to strengthen a remote water supply system against failures, in addition to community capacity building:

- the number of day's water storage capacity (greater than 5 is desirable),
- presence of a back-up water supply,
- use or knowledge of a disinfection method,
- if the community has a telephone,
- microbial contamination risk (source protection).

In order to improve water system reliability in these homelands, the response will require planned investment in key infrastructure components and the facilitation of water risk management process to strengthen resident responses to water issues.

The vulnerability score proposes a method for assessing water supply upgrades based on the consideration of key elements of a water system in concert, rather than just fixing individual components as they fail.

The vulnerability score requires further testing to assess its effectiveness in other regions, but broadly provides an indication of the factors necessary to strengthen remote water supplies.

In conjunction with water risk management, this approach will help to build capacity in both communities and governments making investment decisions on service delivery priorities and ensure more efficient expenditure of funds.

Public policy understanding of a facilitated community water planning approach based on risk management will be required to improve water system reliability and reduce vulnerability of homelands water supplies.

8. RECOMMENDATIONS

1. Securing safe and adequate water and sanitation supplies for remote communities should be considered one of the highest priorities for improving remote Indigenous health.
2. Funding agencies should switch from 'failure management' to proactive management of water supplies (e.g. planned replacement programs) in line with usual national and international practice, to reduce the already considerable negative health and social impacts on Aboriginal people living remotely.
3. There is a need for funded, forecast planned replacement programs for infrastructure, and in order to prioritise water system upgrades, technical assessments of risk (to quality of supply) and vulnerability (to total lack of access, failure) should be conducted by a water-based technical agency.
4. Water risk management should be implemented and facilitated on a regional basis in small homeland water supplies to improve their ability to self-manage water risks on a whole-of-water cycle basis.
5. Community water risk management planning should be facilitated by regional field officers, ideally on an annual basis, to allow residents to self identify and manage local water supplies on an ongoing basis. This would promote a regionalised 'case management' approach to ensuring adequate water supply support. Appropriate agencies to conduct this could be through government water providers, shire councils (through environmental health officers), a national water industry body, or regional technical organisations.
6. Funding agencies should include a funding stream for capacity-building for local water management in water supply infrastructure budgets due to the critical role of local operators in maintaining operational water supplies in remote regions. A scaled-down version of annual Indigenous ESO training could be considered for the informal water supply operators on homelands, perhaps to be included in the pool of ESOs trained by the larger water services providers in WA and added to their existing contracts.
7. It is recommended that the proposed vulnerability score be tested on water supplies from another area to check its usefulness as a planning tool for prioritising future water system upgrades in small homeland communities. Key infrastructure components are recommended to be targeted for upgrades in these communities: large capacity storage tanks, a back-up supply and source protection measures.
8. It is recommended that a scoping study be conducted on a format and funding options for a national framework/network for water operators in Aboriginal communities (whether serviced or not), to provide a technical network for knowledge sharing much like the Aboriginal Environmental Health Worker network. The forum could be through regional annual Indigenous water operator workshops, or a less frequent national forum on water management for Aboriginal residents and operators, invited training providers, government funders and associated industry to discuss technical, training and management issues of remote water supply. This could help to increase and support the water management abilities of remote Indigenous people, potentially improve skills towards future employment in the industry and build capacity of government decision makers to understand remote water supply issues.
9. Greater accountabilities to both government agencies and service recipients should be built into remote water service delivery. This could be through a process of citizen reporting direct to funding agencies or in the form of a biennial (and perhaps national) report delivered to the National Water Commission or the Human Rights and Equal Opportunity Commission on water and sanitation management in Aboriginal settlements. State and Territory service providers should be compelled to collect a nationally-standardised set of key statistics on the reliability and safety of water supplies to report up to these federal agencies.

10. The water source protection group within the WA Department of Water should extend their technical support assistance to small remote communities for water source information and planning advice, covering hydrology, hydrogeology and catchment management (WSPs), potentially through regional field officers assigned to a group of communities.
11. Funding and overall program management for upgrades, service and maintenance should be handed to a government agency with technical expertise in water management so as to improve how water needs are assessed and understood, e.g. the WA Department of Water, as opposed to the Department of Housing and Works. The subcontracting structure could remain but contract include service reliability, quality and capacity building as performance indicators for regional service providers.

9. REFERENCES

- ABS. 2001. Community Housing and Infrastructure Needs Survey Data Dictionary, edited by A. B. o. S. o. b. o. A. a. T. S. I. Commission: Australian Government, Canberra.
- ABS (Australian Bureau of Statistics). 1999. Housing and Infrastructure in Aboriginal and Torres Strait Islander Communities: Australian Bureau of Statistics on behalf of Aboriginal and Torres Strait Islander Commission, Australian Government, Canberra.
- . 2001a. Community Housing and Infrastructure Needs Survey Data Dictionary, edited by Australian Bureau of Statistics on behalf of Aboriginal and Torres Strait Islander Commission: Australian Government, Canberra.
- . 2001b. Data Dictionary, 2001: Housing and Infrastructure Needs Survey, Australia. Canberra: Aboriginal and Torres Strait Islander Commission, Commonwealth Government.
- . 2001c. Housing and Infrastructure in Aboriginal and Torres Strait Islander Communities. In *Australian Bureau of Statistics on behalf of Aboriginal and Torres Strait Islander Commission*: Australian Government, Canberra.
- . 2006. National Aboriginal and Torres Strait Islander Health Survey 2004-05, edited by D. Trewin. Canberra: Commonwealth of Australia.
- . 2007a. Community Housing and Infrastructure Needs Survey Data Dictionary, Australia, 2006, edited by P. Harper. Canberra: Australian Government.
- . 2007b. Housing and Infrastructure in Aboriginal and Torres Strait Islander Communities, Australia, 2006, edited by B. Pink. Canberra: Australian Government.
- AIHW (Australian Institute of Health and Welfare). 2006. Australia's health 2006. In *AIHW cat. no. AUS 73*. Canberra: Australian Institute of Health and Welfare.
- Altman JC, Gillespie D and Palmer K. 1998. National Review of Outstation Resource Agencies: Centre for Aboriginal Economic Policy Research, Tallegalla Consultants Pty Ltd and the Australian Institute of Torres Strait Islander Studies.
- ATSIC (Aboriginal and Torres Strait Islander Commission). 1999. ATSIC policy for Outstations, Homelands and New and Emerging Communities, edited by Housing Infrastructure and Heritage Branch: Aboriginal and Torres Strait Islander Commission.
- Baillie R, Carson B and McDonald E. 2004. Water supply and sanitation in remote Indigenous communities - priorities for health development. *Australian and New Zealand Journal of Public Health* 28 (5):409-414.
- Black M. 1998. 1978 - 1998 Learning What Works: A 20 year Retrospective View on International Water and Sanitation Cooperation. In *UNDP - World Bank Water and Sanitation Program*.
- Blainey G. 1996. Memo: John Howard. *The Independent Monthly* (April 1996):40-43.
- Broughton B and Hampshire J. 1997. *Bridging the Gap: A Guide to monitoring and evaluating development projects*. Edited by A. C. f. O. Aid, Canberra.
- Cairncross S and Valdmanis V. *Water supply, sanitation and hygiene promotion*. In *Disease Control Priorities in Developing Countries*, Jamison, D, J Breman, A Measham, et al., Editors. 2006. 2nd Edition. New York: Oxford University Press.

- CGA (Commonwealth Government of Australia), Government of Western Australia, and ATSIC (Aboriginal and Torres Strait Islander Commission). 2000. Bilateral Agreement for the Provision of Essential Services to Indigenous Communities in Western Australia: Commonwealth Government of Australia, Government of Western Australia and ATSIC.
- CRC for Water Quality and Treatment. 2004. A Guide to Hazard Identification and Risk Assessment For Drinking Water Supplies. In *Research Report 11*.
- Crough G. 1994. Aboriginal Sovereignty and Self-government. *Social Alternatives* 13 (1):22-24.
- Deverill P, Bibby S, Wedgwood A and Smout I. 2002. *Designing water supply and sanitation projects to meet demand in rural and peri-urban communities, Book 1: Concept, Principles and Practice*. Edited by Water Engineering and Development Centre, Loughborough University. Leicestershire, UK.
- DFID (Department for International Development). 2001. Sustainable livelihoods guidance sheets. London: Department for International Development.
- DIA (Department of Indigenous Affairs). 2005. Overcoming Indigenous Disadvantage in Western Australia - Key Indicators Report 2005. Perth: Department of Indigenous Affairs, Government of Western Australia.
- DoW (Department of Water). 2006. Report for the Minister for Water Resources on Water Services in Discrete Indigenous Communities. Perth: Government of Western Australia.
- Eastley T. 2005. Vanstone says remote Indigenous communities becoming 'cultural museums'. *ABC Radio Interview AM - Friday, 9 December, 2005 08:04:00*.
- EHNCC (Environmental Health Needs Coordinating Committee). 2004. Environmental Health Needs of Indigenous Communities in Western Australia - The 2004 Survey and its Findings. Perth: Government of Western Australia and Commonwealth Department of Health and Ageing.
- Evans C. 2006. The end of ideology in Indigenous Affairs - a speech to the John Curtin Institute of Public Policy, 10 March 2006. In *Online Opinion*. Australia.
- FaCS (Department of Family and Community Services). 2005. Community Housing and Infrastructure Program - Program Guidelines 2005-06. Canberra: Australian Government.
- FaCSIA (Department of Families Community Services and Indigenous Affairs). 2007. National Indigenous Housing Guide: Australian Government, Canberra.
- FRDC (Federal Race Discrimination Commissioner). 1994. Water: A Report on the Provision of Water and Sanitation in remote Aboriginal and Torres Strait Islander communities. Canberra: Commonwealth Government of Australia.
- Fricker C, Warden P, Silvagio D, Gleesman E, Tananaha R, Rust J and Eldred B. 2003. Comparison of five commercially-available methods for detection of coliforms and *E. coli*. Paper read at American Water Works Association Water Quality Technology Conference, November 2003, at Philadelphia.
- Grey-Gardner R. 2007. Remote Community Water Management Final Report. Alice Springs: Desert Knowledge Cooperative Research Centre.
- Hearn B, Henderson G, Houston S, Wade A and Walker B. 1993. Water supply and Aboriginal and Torres Strait Islander health: an overview. *AGSO Journal of Australian Geology and Geophysics* 14 (2/3):135-146.

- Henderson G and Wade A. 1996. Aboriginal and Torres Strait Islander Water Supplies. In *A Research Section Occasional Paper No 7*. Canberra: Australian Institute of Aboriginal and Torres Strait Islander Studies.
- Hostetler H, Wischusen J and Jacobson G. 1998. Western Water Study (Wiluraratja kapi) Groundwater quality in the Papunya-Kintore Region, Northern Territory. Australian Geological Survey Organisation, Canberra.
- HREOC (Human Rights and Equal Opportunity Commission). 2001. Review of the Water Report, edited by Aboriginal and Torres Strait Islander Social Justice Commissioner. Sydney.
- HRSCFCA (House of Representatives Standing Committee on Family and Community Affairs). 2000. Health is Life: Report on the Inquiry into Indigenous Health. Canberra: Parliament of the Commonwealth of Australia.
- Hughes H and Warin J. 2005. A new deal for Aborigines and Torres Strait Islanders in Remote Communities. Issue Analysis No. 55. Centre for Independent Studies.
- Hutton G. 2008. Unsafe water and lack of sanitation. Problem Paper, Copenhagen Consensus 2008. Swiss Tropical Institute, Copenhagen.
- IES (Indigenous Essential Services). 2005. Annual Report. Darwin: Indigenous Essential Services Pty Ltd, Power Water Corporation on behalf of Northern Territory Department of Planning and Infrastructure.
- Memmott P and Moran M. 2001. Indigenous Settlements of Australia, In Australia: State of the Environment 2001: Technical Paper Series 2. Canberra: Environment Australia.
- Moran M. 2007 (in press, accepted 9/2/2007). Demand Responsive Services: An Analytical Framework for Improved Administrative Practice in Indigenous Settlements. *Australian Journal of Public Administration*.
- Moran M. 2007. The Interethnic Practice of Local Governance in a Remote Aboriginal Settlement in Australia: Centre for Appropriate Technology and Desert Knowledge Cooperative Research Centre.
- Moran M, Wright A, Renehan P, Szava A, Rich E, and Beard N. 2008. The Transformation of Assets for Sustainable Livelihoods in a remote Aboriginal Settlement. Alice Springs: Centre for Appropriate Technology and Desert Knowledge Cooperative Research Centre.
- NACCHO (National Aboriginal Community Controlled Health Organisation). 2007. Close the Gap - Solutions to the Indigenous Health Crisis facing Australia. Melbourne: Oxfam Australia.
- Nganampa Health Council Inc. 1987. Report of Uwankara Palyanyku Kanyintjaku (UPK Report) - An Environmental and Public Health Review within the Anangu Pitjantjara Lands: A cooperative initiative by the Nganampa Health Council Inc., South Australian Health Commission and Aboriginal Health Organisation of SA.
- NHMRC (National Health and Medical Research Council). 2005. Australian Drinking Water Guidelines - Community Water Planner: Australian Government.
- NHMRC (National Health and Medical Research Council) & NRMCC (Natural Resource Management Ministerial Council). 2004. Australian Drinking Water Guidelines: Commonwealth Government of Australia.
- NRHA (National Rural Health Alliance). 2006. Healthy regions, healthy people - Position Paper. ACT.

- O'Mullane M. 2003. Water System Reliability - A Survey of Small Indigenous Communities in the Kimberley. In *CRCWQT (Cooperative Research Centre for Water Quality and Treatment) Summer Scholarship Project Report*. Alice Springs: Centre for Appropriate Technology (CAT).
- Popic D. 2007. How can remote Indigenous communities implement improved techniques in water quality management in small water supplies? In *CRCWQT Summer Scholarship Project Report*. Alice Springs: Centre for Appropriate Technology, CAT.
- SRCECITA (Senate Reference Committee on Environment, Communications, Information Technology and the Arts). 2002. *The Value of Water: Inquiry into Australia's management of urban water*. The Parliament of the Commonwealth of Australia.
- Stevens M, Ashbolt N, and Cunliffe D. 2003. *Recommendations on change the use of coliforms as microbial indicators of drinking water quality*. Canberra: NHMRC (National Health & Medical Research Council).
- UNDP (United Nations Development Program). *Beyond scarcity: Power, poverty and the global water crisis* 2006 [cited 13-12-06]. Available from <http://hdr.undp.org/hdr2006/>.
- UNHCR (United Nations Human Rights Commission). 2003. General Comment 15, The right to water. Articles 11 and 12 of the International Covenant on Economic, Social and Cultural Rights.
- Van Hofwegen, Paul. 2006. Water, Environment and Development: Progress and Initiatives, World Water Council. In *The East Asian Seas Conference*. Marseille, France.
- Vanstone A. 2005. Vanstone says remote Indigenous communities becoming 'cultural museums'. ABC (Australian Broadcasting Corporation) Radio. 'AM' Program Interview, with Tony Eastley. Friday, 9 December, 2005.
- Wahlquist A. 2007. Household water price system labelled a joke. *The Australian*, 12 March.
- Walker B. 2001. Can we afford the future? paper read at the Community Technology Conference. Perth: Remote Area Development Group, Murdoch University.
- WaterAid UK. 2007. *Can pay, will pay 2007* [cited 03 May 2007]. Available from http://www.wateraid.org.uk/uk/what_we_do/where_we_work/bangladesh/5486.asp.
- WHO (World Health Organisation). 1997. *Surveillance and control of community [water] supplies. Guidelines for drinking water quality. Second edition Volume 3*. Geneva.
- Willis E, Pearce M, Jenkin T, Wurst S and McCarthy C. 2004. *Water Supply and Use in Remote Indigenous Communities in South Australia*. Adelaide: Flinders University and Dept of Aboriginal Affairs and Reconciliation (DAARE).

APPENDICES

Appendix 1: Community Semi-Structured Interview Questions

1. Is your water system easy to use?
2. Taste/smell/look of water? Has it ever made you sick?
3. Do you ever need to use water where there isn't a tap? What do you use to transport your water when you need it, to where you need it? Is this okay for you?
4. How many drums of water do you use? How often do you turn the bore on?
5. Do you ever run out of water? What do you do when you run out of water?
6. How many and how often do you have visitors? How many visitors can your house handle?
7. Do you ever go visit regularly? Who takes care of the bores when you go away?
8. How do they get their water from over there, in the communities you visit? Do you think it is a better system?
9. Is there someone else you ask in the community to fix your generator? Do you get asked to fix other people's generators?
10. Who fixes your water system? Does he do a good job? Is he a good man? Would you like someone to show you how to fix your water system?
11. How did you look after the water in the old days, before you had the bores? Was the water better then or now?
12. Does anyone test your water that it's good to drink? Would you like to learn how to do this?

Appendix 2: Community Water Supply Infrastructure Data fields collected

Category	Data Field
Community details	Community Name Primary Community Contact Contact details Approx. Popn. Analysis popn Occupancy Status Location Housing Access Year established Resource Agency Nearest family Community aspirations Community works required Household energy source Energy Supply Detail
Water Supply	Water System Detail Community Water Views Primary Water Supply Water Treatment Formal back-up Water supply In-formal backup water source Primary water pump energy source Backup water pump energy source Estimated age of primary water pump (years) Primary supply storage tank Estimated age of primary storage tank (years) Approximate total storage capacity (kL) Number of days storage (@ baseline 100L per person) Number of restrictions in 12 month period 04-05 Types of restrictions Source Protection Measures (sanitary survey) Water Quality concerns Primary Water source install date

Category	Data Field
Water Supply (cont'd)	Bore depth (m) Initial Static Water level (m) Yield (m ³ /day) (year) Easting Northing Most Likely WIN Site Id DoE Site bore reports & maps available Predominant Water Quality Parameter Predominant Water Quality Parameter Value pH EC (uScm) Year sampled/ estimated Predominant geology expected depth to WT relevant Hydrogeology info Hydrogeology Reports Overflows Existing Water System Issues Water Quantity Details Water Quality Details Other water issues? Technical requests
Maintenance Contractor R & M Costs	Oct04- Sept05 Oct05-Sept06 (INCOMPLETE DATA) TOTAL\$ 2 YRS
Maintenance Contractor Trips	Oct04- Sept05 Oct05-Sept06 TOTAL TRIPS 2 YRS Repairs History Additional Information Water Failures
	CHINS_ Reported usual population of community (obs) CHINS_ Name of nearest town with major services CHINS_ Travel time to nearest town with major services (obs) CHINS_ Whether community was cut off by road in last 12 months CHINS_ Whether community has a telephone EHNS 2004 water priorities EHNS 2004 water score

Appendix 3: Drinking water quality chemical and physical properties analysed.

Element	UNITS
E. coli	-
pH	-
EC	uS/cm
TDS	mg/L
Aluminium	mg/L
Alkalinity	mg/L
Arsenic	mg/L
Barium	mg/L
Bicarbonate	mg/L
Boron	mg/L
Cadmium	mg/L
Calcium	mg/L
Chloride	mg/L
Copper	mg/L
Fluoride	mg/L
Hardness (CaCO ₃)	mg/L
Iron	ug/L
Iodine	ug/L
Lead	ug/L
Mg	mg/L
Nitrate	mg/L
Nitrite	mg/L
Radiation	Alpha & beta
Silica	mg/L
Sodium	mg/L
Selenium	ug/L
Sulphate	mg/L
Uranium	mg/L
Zinc	ug/L

Appendix 4: Semi-structured interview questions, service delivery stakeholders

Program managers and maintenance contractor staff interviewed: Parsons Brinckerhoff, Kimberley Regional Service Providers, Derby Indigenous Coordination Centre.

1. Do you find the complexities of the organisational structure difficult to do your job?
2. Do you find the community is frustrated with the complexity of the organisational structure? Are they calling you for CAT or somebody else's responsibility?
3. Do you feel there is adequate accountability for each organisation, so they fulfil their roles and obligations to the community?
4. What do you see as the challenges to water supply and maintaining water quality?
5. Do you have any suggestions on how to improve water supply and water quality?
6. What do you feel are the challenges with working with communities, particularly outstations?
7. Do you get many enquiries about water from community members? If so, what was the nature of the enquiry?
8. What is the extent of communication you have with small outstations?
9. What sort of relationship do you have with the communities?
10. Do you have recommendations on how to improve community participation and how capacity building can take place?

Maintenance contractor interviewed under RAESP: Top End Contracting.

1. How often do you recommend specific systems to be maintained and replaced? Balginjirr? Bedunburra? Mingalkala?
2. Do you ever find the systems are being mismanaged or misused?
3. Do you ever find people are not taking care of their water quality? Contamination through transfer for example.
4. What sort of preventative mechanisms do the technologies have against extreme weather conditions?
5. Do you think it would be easier for you to maintain the systems if they were all the same, or do you think it wouldn't make much difference because these areas are still difficult and far away to get to?
6. Do you get a lot of community members hanging around and wanting to know and understand what you're doing and how you're doing it?
7. In your opinion, how do you think the water supplies could be improved in the communities? If at all? Have any community members suggested ways to you?

Appendix 5: Semi-structured interview questions, Health and Education staff

Interviews conducted with educators at Shire of West Kimberley Derby, Karrayilli Adult Education Centre and Broome TAFE:

1. What is the structure, duration, content of courses available on environmental health and environmental management?
2. Is there anything specifically designed for day to day management of water supplies and water quality, hygiene, using water/power technologies?
3. Who are the courses aimed at? What age/sex attend them?
4. Is there anything specifically designed for adults, remote communities?
5. How do you present your material?
6. Do you go out to communities and remote outstations?
7. Do the students support one another?
8. What are the benefits, rewards and positive outcomes you offer your students?
9. Where do people go, how do they use the knowledge they have gained after they have completed your courses?
10. Do you get inquires to offer community-based education regarding environmental health and environmental management?
11. What are the challenges you come across to provide these services, why do you think they are so hard to offer or for people to attend? How do you think these can be overcome?
12. Do you offer back up support if students have cultural obligations during the length of the program?
13. Do the communities accept the knowledge they have acquired?
14. Would you be interested in working in a partnership with CAT to offer something to specific communities?

Interviews conducted with health workers at Derby Royal Flying Doctor Service and Derby Shire Hospital:

1. What (if any) health issues/diseases do you come across that you think are linked to poor water quality?
2. Do these target age/sex groups within the population?
3. Which are specific to remote outstations?
4. In your professional opinion, which practices could be easily employed to reduce these health issues (related to water)? What barriers are there in employing them? Are people aware of them?
5. Do you find that patients are generally worse/same/better in outstations/homelands than larger Aboriginal communities?
6. What suggestions would you make to those that are installing/maintaining and managing water systems?
7. Who do you see as having most responsibility for taking care of the ill? Is this different to who may be causing the illness to occur?



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CRC for Water Quality
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The Cooperative Research Centre (CRC) for Water Quality and Treatment operated for 13 years as Australia's national drinking water research centre. It was established and supported under the Australian Government's Cooperative Research Centres Program.

The CRC for Water Quality and Treatment officially ended in October 2008, and has been succeeded by Water Quality Research Australia Limited (WQRA), a company funded by the Australian water industry. WQRA will undertake collaborative research of national application on drinking water quality, recycled water and relevant areas of wastewater management.

The research in this document was conducted during the term of the CRC for Water Quality and Treatment and the final report completed under the auspices of WQRA.

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