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Abstract:	Safe drinking water and effective sanitation is a basic human right. The health of Aboriginal and Torres Strait Islander Peoples living on traditional Country in remote Australia can be supported or undermined by these essential services. Despite global and Australian commitments to the Sustainable Development Goals, water and sanitation service levels have regularly been identified as unreliable, unsafe, and of a lower standard than non-Indigenous and non-remote settlements. This research sought to identify the optimal conditions to enable consistent delivery of safe water and sanitation in remote Indigenous communities of Australia. Using a combination of literature reviews, interviews with key stakeholder groups and applied research findings, key conditions for improved water and sanitation outcomes were identified. These included technology for water and sanitation that is fit for purpose, people and place; capacity-building, training and ongoing support for local Indigenous service operators; and that all personnel involved in delivery require a level of cultural competency to the local and Indigenous context. These findings are intended to contribute to informing more sustainable water and sanitation outcomes in Indigenous communities.

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Introduction

Connection to Country (traditional estate) is core to the holistic view of social and emotional well-being of Aboriginal and Torres Strait Islander Australians (also respectfully referred to as Indigenous Australians in this article) (Rigby et al., 2011). Living on and connecting to Country extends beyond cultural contexts for Aboriginal and Torres Strait Islander Australians to provide positive physical and mental health outcomes (Green and Minchin, 2014, Lyons and Barber, 2021).

It is imperative for the health of community residents who live on Country that essential services, notably water, sewerage and power, are available and functional (Creamer and Hall, 2019, QPC, 2017). As of the 2016 census, approximately 18.4% of the Indigenous Australian population live in discrete remote or very remote communities (hereafter referred to as remote Indigenous communities)(ABS, 2016). As safe drinking water and effective sanitation (sewage management) constitute a basic human right, it is therefore essential to consider how to ensure sustainable and consistent delivery of these in remote and very remote communities (Hall et al., 2021b, Productivity Commission, 2021a, Beal, 2017).

Improved drinking water and sanitation standards across Australia should align with the Australian Government's commitment to attain the Sustainable Development Goals (SDGs), including realising SDG 6 'to ensure water and sanitation for all' (United Nations, 2015). Despite this pledge, service levels in remote communities have been noted to be at a lower standard and suffer more major disruptions than in non-Indigenous communities of a similar size and location and in urban areas (Productivity Commission, 2016, Productivity Commission, 2021a, Beal et al., 2019). Many services in remote areas have been recorded as not meeting basic regulatory requirements nor the Australian Drinking Water Guidelines (ADWG) (AECOM, 2010, ABS, 2007, Productivity Commission, 2016). Poor water, sanitation and hygiene-related issues have been identified as contributors to inequitable health outcomes in these communities for several decades (Ali et al., 2018, Bailie et al., 2010, Pholeros et al., 1993, Hall et al., 2017). Indeed, the Australian Government's voluntary review of its status of attainment of the UN Sustainable Development stated that:

"rural and remote communities in particular may not have the same level of access to water and sanitation services as urban centres. This is particularly the case for remote Aboriginal and Torres Strait Islander communities and can have important flow on effects to health outcomes."

(Australian Government, 2018, p.50).

It has been repeatedly documented that improvements to the supply and use of water and wastewater services are needed in remote Indigenous communities and are the responsibility of state and Territory governments or their sub-regional agencies (Hoverman and Ayre, 2012, Ross et al., 2014b, Jackson et al., 2019b, Beal et al., 2019, Beal et al., 2020, Hall et al., 2017). The 2020 review of the National Water Initiative, a collaborative initiative of national water reform between state and Territory government, stated that a renewed National Water Initiative should include a commitment to "ensuring access to a basic level of service for all Australians, including for safe and reliable drinking water" (Productivity Commission, 2021b, p.11).

There are significant public health benefits from adequate water and sewerage services, yet progress towards eliminating the gap in health equity between Indigenous and non-Indigenous Australians has not been on track. This is despite the consideration of the 'Closing the Gap' in Indigenous equity agenda of the past decade (NIAA, 2021). The recently-revised Closing the Gap agenda sets a stronger ambition; there is now a specific priority focus on remote community infrastructure including "essential service provision to Aboriginal and Torres Strait Islander communities, including water and sewerage…" (Australian Governments and the Coalition of Peaks, 2020, 86b(i)).

In response to this context, this research sought to integrate and build on previous work to identify the required conditions, in terms of structure, resources and other aspects, for consistent delivery of safe water and sanitation in remote Indigenous communities of Australia and to highlight some of the complexities around meeting those conditions. It was written by authors working and

researching in complementary areas within the field of water and sanitation services in remote Australia. Australia's commitment to attaining the SDGs, particularly SDG 6, provides a strong driver for water utilities and other relevant agencies and decision makers to explore how they can contribute to improving water services in remote Indigenous communities in Australia and potentially in similar settings outside of Australia. This research is provided to contribute to that guidance.

Methods

This research is based on the analysis and synthesis of existing literature including restricted access research reports by the collaborating authors, and four associated social research projects conducted variously by the authors between 2016 and 2019 relating to water and sanitation issues and services in remote Indigenous communities in Australia. These complementary projects included a review of priorities for meeting water, sanitation and hygiene needs (Hall et al., 2017), a trial of effective co-development models for water management (Jackson et al., 2019a, Jackson et al., 2019b, Beal et al., 2016, Beal et al., 2018), identification of opportunities for an urban utility to contribute to improving water service outcomes (ISF-UTS and QUU, 2017), and an exploration of roles and opportunities for the Australian water industry in ensuring safe water services for all Australians (Abeysuriya et al., 2019). This synthetical approach enabled a public sharing of the restricted access report findings while maintaining the commercial-in-confidence arrangement by the commissioning agency of some of the reports. This was considered by the authors to be of value to the user-focused audience of this journal.

The research scope of these projects covered the Northern Territory, Queensland and Western Australia as this encompasses the greatest proportion of the remotely-located Indigenous communities in Australia (Commonwealth of Australia, 2017). The interviewees in the projects, in combination, included representatives from water service providers, federal, state and local governments, peak bodies, local community, academic institutions and Indigenous organisations.

The social research projects were compliant with each collaborating university's Human Research Ethics Committee approval requirements, including maintenance of anonymity to protect the confidentiality and privacy of research participants (UQ #2016001540; UTS #ETH18-2599; and GU/ENG/15/14/HREC). It meant that the collaborating authors did not have access to social research data from a different university's project that, furthermore, responded to different initial research questions. To integrate them in this restricted setting, a harmonising tool was developed by adapting the 'Social, Technical, Environmental, Economic and Political' (STEEP) framework (Morrison, 1992), shown in Table 1.

The STEEP framework enabled each project team to re-examine their social research data through the questioning lens of the tool, to identify the nature of issues raised in their research interviews with respect to values and meanings and the infrastructure life cycle around water services. The outputs were shared among collaborating authors, illustrated with de-identified quotes to illustrate or elaborate the findings as relevant. The interview quotes do not have specific details regarding location and date to adhere to ethical clearance requirements to protect the identity of responding organisations and individuals. Furthermore, the quotes are used to illustrate an issue that was raised by multiple respondents. Given the synthetical approach, the total interviews and representatives from each sector could not be meaningfully quantified.

Table 1: STEEP framework for interrogation of existing social research projects (adapted from (Morrison, 1992)

	Meanings / Values	Planning and Installation	Operations & Maintenance Repairs and Replacements
Social	• Values and taboos around drinking water and sanitation?	• How are decisions made? Who is involved?	• Issues around operator skills and capacities • Staff retention issues • How people engage with the infrastructure (use/abuse, maintain) • Emergency response – who and how? • What access to support networks
Technological	• Views about convenience, safety, dignity, reliability, ease of maintenance	• What was the process for selecting from options? • Appropriateness of technology choices (for situation and operator)?	• Performance/ Service delivery standards • Quality/Quantity • Reliability of service • What happens when there are significant/major failures?

			• Decision making regarding replacement vs repair?
Economic (resources and constraints)	• Valued enough to pay for (water/ sanitation)?	• Economic analysis of costs, affordability?	• Who pays for the service delivery/ replacements/major repairs? • Funding, costs
Environmental	• Environmental issues of concern to stakeholders	• Source water quality • Effluent discharges	• Impact on waterways • Groundwater resources
Political / legal / institutional	• Preferences about power and influence • Views about what 'should' happen	• Drivers, Approval process, Standards • Ownership of infrastructure	• Who holds responsibility for operations? • Compliance (monitoring, reporting)? • What are the regulatory requirements re upgrades etc.

The literature review included targeted academic, grey and white literature gathered through a combination of keywork searches on journal database searches and the shared libraries of the collaborating authors, as well as new publication alerts. To enable coherent presentation of the findings from the literature review and the social research, they were grouped under sub-headings, and arranged under the four themes reported in the Results section.

Results and Discussion

Synthesis of the social research projects (including interview quotes) and literature resulted in the

identification of four broad themes of relevance to conditions for attaining sustainable outcomes:

water quality and quantity (incorporating contamination, palatability and consumption);

management, governance and financing (incorporating standards and costs); technology and

operations; and mutual learning. These results are displayed and summarised visually in Figure 1 and

are detailed in an integrated manner with the discussion and relevant literature to expand on the

themes. Key points under the findings are illustrated with de-identified quotes from the social

research interviews conducted with representatives from federal, state and local government, water

utilities, local community and Indigenous organisations. This section concludes with a discussion on

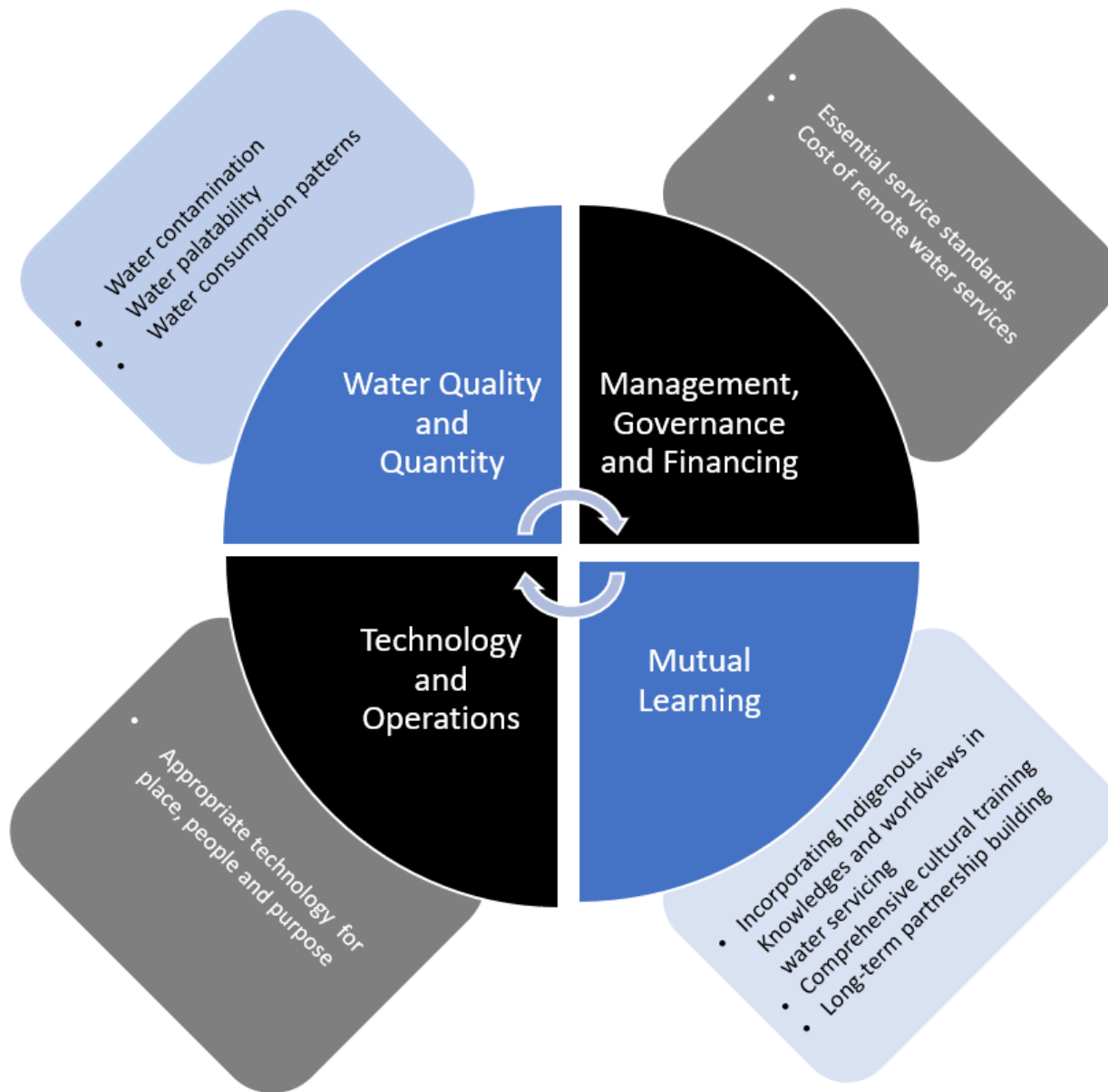how these conditions could be implemented.

Figure 1: Resulting themes from analysis of literature and social research on conditions for sustainable remote water provision

Water Quality and Quantity

Interviewees within the social research described a range of issues associated with supplying water of adequate quality and quantity that meet the drinking water guidelines as well as the needs of remote Indigenous communities. These included source water quality issues related to microbial and chemical contamination, and challenges for water service providers in building understanding of water supply sources and water use patterns that limit the ability to maintain water security. The respondents also documented how long-term water security issues are exacerbated in a changing climate due to unreliability of seasonal rainfall and increasing intensity and frequency of extreme weather events (Jackson et al., 2019b, Hall and Crosby, 2020).

Water contamination

Drinking water supplies in remote Indigenous communities are at risk of both microbial contamination and chemical contamination by naturally occurring elements in deep artesian (bore) sources (Hall et al., 2017). The naturally occurring chemical contaminants found in the drinking water, including arsenic, cadmium, nitrates, uranium and barium which tend to increase towards inland Australia, can require the installation of advanced water treatment technologies due to the health risks from high concentrations (Hall et al., 2017). Poorly maintained drinking water infrastructure was linked to heightened risk of water contamination, described as:

> "It's quite chronic in cases … [because] storage tanks [are] … rarely replaced … They're going to rust; they're going to corrode … Water supplies are 100% a [health] problem"

(Indigenous organisation representative).

Water palatability

Issues of palatability and aesthetics were also noted in communities reliant on bore (ground) water, a key water source in remote Australia, and desalinated water. There are implications for infrastructure maintenance as well, both at the household level and the water system (Anda and Dallas, 2005), described by an interviewee as:

"Hardness and total dissolved solids … generally salinity … pH is actually slightly too low …

iron, a little bit of manganese … the consequences [on the water are a lack of lather] in terms

of washing, [a build-up of scale] in terms of appliances"

(Water utility representative).

In response to palatability issues, many Indigenous community members prefer to drink rainwater

from household tanks rather than 'town' water supplied by service providers. Indeed, a study of

drinking water preferences in four remote communities indicated that rainwater was the primary

drinking water source for over a third of participating households (Beal et al 2019). The reasons for

this preference ranged from unacceptable odour and taste of treated (chlorinated) water, concern

regarding chemicals being added for treatment, and a lack of trust that town water was potable- due

in part to a high number of boil water alerts in some communities. The majority of people whose

primary drinking water source was rainwater did not treat their water; of those who did, boiling was

the preferred method (Beal et al 2019). Although rainwater can be a preferred source for taste, the

associated health risks from long-term tank storage and lack of treatment was a concern raised

especially by the government and local service providers (Hall et al., 2018, Aldirawi et al., 2019).

Additional implications for health arise in cases where soft drinks are consumed in preference to

water (Hall et al., 2017).

Water consumption patterns

There is documentation of high household and community-level water use in remote communities,

yet limited analysis of actual patterns of water use to distinguish between behaviours and

infrastructural issues, including leaks (Beal et al., 2018). Up to 75 percent of consumption has been

identified as used for outdoor purposes (Beal et al., 2014, Beal et al., 2019). This is in contrast to

water use outdoors constituting 25 percent of total household water consumption in urban areas

such as Sydney (Sydney Water, 2019). The key drivers of high outdoor water use beyond leaks

include dust control from roads and yards in areas with large unvegetated areas, cooling of the roof,

yard and driveway to create an evaporative effect during hot weather, washing down boats and

fishing or hunting equipment, physical amenity such as gardening, and social amenity including sorry camps (funerals) and extended family gatherings (Beal, 2017).

Efforts to monitor and understand water consumption- especially to identify leaks- are often constrained by available baseline consumption data across seasons and populations. These data are required to effectively target water management strategies at the community level (Beal et al., 2016, SACOSS, 2020). Interviewees observed that most communities do not have automated disaggregated meters and rely on manual meter reads. These are often conducted in an *ad hoc* manner, and high-level assessments based on the community supply meter are used instead to estimate average per capita use (Christie, 2010, Beal et al., 2016). This average can vary significantly from actual consumption values as communities and households are diverse in the number of permanent and visiting occupants.

A lack of understanding of drivers of water consumption can lead to inaccurate targeting of water use (Ross et al., 2014b, Beal et al., 2018). In the social research, interviewees identified the value of improved technologies for metering and monitoring household water use to inform infrastructure planning and strategies for engaging communities in water conservation activities. One stated:

> "Smart meter or near real-time data allows us to identify leaks, we notify housing, housing is able to get work orders out and leaks are fixed"

(Water utility representative).

Reliance solely on quantitative water consumption and quality data may not provide the required understanding of the context of household and community water use. Ross et al (2014b) detailed how smart metering complemented by social engagement and qualitative data can enable demand management programs to be targeted more effectively to the local context rather than a standard promotion of lower water consumption practices.

Management, Governance and Financing

Arrangements for accountability, planning, financing, administering, regulating and monitoring were identified in the interviews and literature as key aspects for enabling long term sustainable outcomes (Ross et al., 2014a, Jackson et al., 2019a, Jackson et al., 2019b). These detailed how the complexity of roles and responsibilities, government funding priorities, water service provisions to public housing residents and land tenure arrangements have contributed to confusion and inefficiencies that undermine sustainable water services. Key issues raised by interviewees related to this complexity and confusion in standards for essential water services and in the cost of remote water services.

Essential service standards

Under the Australian Constitution, state and territory governments are required to provide residents with municipal and essential services (Australian Government, 2010). The legacy of forced removal from traditional lands to missions (reserves) resulted in many Indigenous communities now being located on the outskirts of townships. This has meant that Indigenous communities can be excluded from service provision through state or local government oversight or provided with different essential services to those provided to non-Indigenous communities (Wensing, 2015, SACOSS, 2020). One interviewee said:

> "Whereas any other [non-Indigenous] town in the state has the capacity to get a question answered or has access to their data on water quality as a citizen of the state, Aboriginal people in Aboriginal communities do not"

> (Water utility representative).

The inconsistencies in service provision for Indigenous communities were described in a review by the Australian Government (2010). The review identified arrangements for water and sanitation services in Indigenous communities in Australia as "complex and inconsistent", with some funding arrangements "(equating to) lower standards of service than that provided to non-Indigenous Australians living in communities of similar size and location" (Australian Government, 2010, p.210).

These arrangements create ambiguity for Indigenous communities regarding which agency is responsible for delivering services within their community. One interviewee stated:

> "…It is amazing how many different agencies can say 'this isn't my problem, it's the (Department of Housing)', then the (Department of Housing) says 'it's not my problem, it's the (Department of Water)'… and it just leads to confusion and inaction. It's not clear"

(Water utility representative).

Cost of remote water services

Many remote Indigenous communities are almost completely dependent upon government for services and local economic activity, including employment and development opportunities (Moran, 2016, Ross et al., 2014b). A majority of the community population live in public or social housing managed by government or community housing providers (Productivity Commission, 2016). Water services are typically included as part of rental agreements with no consumption charges for water use or individual water meters installed on public housing (Ross et al., 2014b, Nous Group, 2017, Beal et al., 2018).

Provision of housing services in remote Indigenous communities involve a significant and unavoidable revenue-cost shortfall by the service providers, driven predominantly by the significantly higher costs for servicing remote communities (SACOSS, 2020). Maintenance and repair activities in remote Indigenous housing often ranges between 1.4 and 4.5 times the cost of equivalent activity in 'mainstream' or urban public housing, and can be reportedly up to 47 times higher for specific items (Nous Group, 2017). Cross-subsidisation is enabled in some jurisdictions for state-wide sustainable outcomes to compensate for the higher costs (Nous Group, 2017).

Complex reporting and maintenance processes can result in long lead times for repairs and fixing leaks, and also create confusion around responsibilities (Hoffmann, 2001). A 'siloed' approach to management across agencies without integrated place-based solutions risks issues being overlooked

(Jackson et al., 2019b). Funding for appropriate levels of public housing maintenance was raised as a key issue and barrier to effective household water management in the interviews. One interviewee stated:

> "The public housing maintenance budget per household is very small given the relative costs of labour and providing maintenance services in remote communities"
>
> (Indigenous organisation representative).

In response, improved coordination in property management and tenancy management was identified by interviewees as providing the greatest potential for positive gains.

At a community-scale, land tenure is important for sustainable outcomes, including for water services. Under current Australian law, any permanent fixtures on land are the property of the landholder (QPC, 2017). Service providers require clear tenure arrangements in place to provide certainty for their ongoing investments and activities relating to service provision (Creamer and Hall, 2019). However, land is usually held collectively by residents of remote Indigenous communities, with an Indigenous organisation or Traditional Owner acting as trustee (QPC, 2017). This can lead to diverse processes for service providers to secure tenure, compared to processes in non-Indigenous communities, resulting in a complexity of tenure arrangements that vary between and within the various jurisdictions (Wensing, 2015). Separate native title interests overlay tenure across many remote Indigenous communities, potentially adding further confusion (QPC, 2017).

Technology and Operations

Sustainable water services are reliant on functional technologies – namely technological infrastructure that is designed, installed and operated to meet water quality and quantity requirements (Ross et al., 2014a). Challenges described by the interviewees and in the literature related to the selection of technologies appropriate to people, place and purpose, ensuring adequate skills and capacity for operation and maintenance, and compliance with the Australian Drinking Water Guidelines (Hall et al., 2021b).

A positive example of these considerations is seen in the 'Safe and Healthy Drinking Water' pilot program in some of the outer Torres Straits islands. It was co-designed and managed by state government agencies with responsibility for health, infrastructure, water and Indigenous partnerships, the local Indigenous council and the island-based, Indigenous water operators (TPHS, 2017). Existing water treatment infrastructure was reviewed then improved for suitability for the location and purpose; minor infrastructure improvements were implemented; and water operators were supported through tailored training and long-term mentoring. The outcomes of the pilot included reduced drinking water contamination and increased operator skills and knowledge (Hall et al., 2021a). The importance of such technologies that are fit-for-purpose, people and place was repeatedly raised by the interviewees, such as:

"A lot of the communities have good quality drinking water, at least initially …we often quickly see a lack of maintenance, meaning that everybody goes back to using their old water source– because the big fancy system doesn't work"

(Research representative).

This focus on a bespoke water and sanitation system has been more recently recognised by Infrastructure Australia's 2021 plan that calls for utilities to:

"genuinely commit to delivering fit-for-purpose, fit-for-place and fit-for-people water services to Australians living in remote and isolated communities … through approaches that recognise and respond to the unique conditions in these parts of the country"

(Infrastructure Australia, 2021, p.11).

The current lack of tailored approaches was described in the interviews as potentially having arisen from system designers from urban water treatment and supply options not considering the whole-of-community perspective and setting that includes remotely located staff and fluctuating population size during cultural gatherings. This can lead to water technologies and practices being

introduced in remote Indigenous communities which may not be ideally suited. One interviewee stated:

> "We need to come up with a much more tailored approach. If we're going to put infrastructure in, we really need to think about what capacity is there to operate and maintain it? And if there's a shortfall, how do we help to meet that?"
>
> (Federal Government representative).

The social research highlighted that decisions regarding water infrastructure can often made by engineering and technical officers who may be constrained by a funding environment that preferences capital expenditure and large infrastructure projects. This is in contrast to small-scale, locally relevant and collaborative water management activities that can also build capacity within communities (Jackson et al., 2019a).

Without close engagement with community members, the resulting infrastructure was noted at times to be inappropriate for cultural norms, dignity and social practices that were not identified by the implementers or service providers in advance. This was described as:

> "… They [utility providers] spoke to people about them, then put them in. But people didn't use them because they felt really conspicuous because they were outdoors, and everyone could see when they were going to the toilet and this was culturally uncomfortable... You need to talk it through properly with everyone"
>
> (Federal Government representative).

Gaining a clear and deep understanding of the local context was detailed by interviewees as essential for service infrastructure, including monitoring technologies. They detailed that this required concerted and culturally appropriate consultation to ensure the technologies are desired, understood and used by residents with the capacity to maintain systems with long-term relevance, described as:

"[A] very important lesson in the context of what I observe … is that you can develop your own view of what the problem and what the solution is. But if you don't take the time to listen and unpack it all you can find that you have your own way of thinking and it's not necessarily taking the whole situation into account"

(Project management representative).

Mutual Learning

Water service provision and management in remote Indigenous communities typically operates from a non-Indigenous, technocratic perspective. This has limited appreciation of Indigenous perspectives of water that connect people integrally to their environment (Jackson et al., 2019b). This was described by one interviewee as:

"You can't ignore the fact that you can provide the hardware, you can teach people to wash their hands and all of that, but at the end of the day it's a Western practice in a Western model that's been inflicted on Indigenous people, and they've been forced to accept it. It kind of assumes that there is no place for Indigenous ways"

(Indigenous organisation representative).

In recent years, there appears to be a growing appreciation by non-Indigenous Australians regarding Indigenous ways of managing water (Jackson and Moggridge, 2019, Berry et al., 2018). Literature describes opportunities for mutual learning and sharing of Indigenous and non-Indigenous worldviews relating to the management of water resources, cultural values and water services, potentially resulting in different but more appropriate outcomes (Nelson et al., 2018).

Aligned with this growing respect and consideration for Indigenous ways of knowing and doing is an appreciation of and the cultural competency to respond to Indigenous history, cultures and contemporary social dynamics. This is identified in the literature as key to achieving alternative and sustainable arrangements for essential services delivery (Hunt, 2013). Interviewees reiterated that where minimal training of non-Indigenous staff in cultural awareness occurred, community

engagement was often conducted in culturally insensitive ways. The importance of comprehensive

cultural training and ongoing learning was outlined by an interviewee:

> "… you're well-meaning, maybe, but not necessarily conscious of where your thinking
>
> is coming from. Or where your prejudice is coming from which might just be not
>
> being aware of people's systems and their strengths"

> (State/Territory government representative).

Partnership-building in improving sustainable outcomes for essential services in remote Indigenous

communities was identified as critically important, yet strict project timelines and high rates of staff

turn-over can limit or inhibit partnership building (Jackson et al., 2019b). Interviewees suggested

that remote outcomes were often compared to urban delivery, rather than the higher costs and

other aspects reflecting unique and expected differences to urban customers. This comparison with

'city costing' was reflected by an interviewee as:

> "Engaging with a number of individual customers is expensive and complex…
>
> Partnering with other organisations who want to achieve other benefits in
>
> communities, like adult education etc., where the activities are complementary.
>
> Building a relationship with customers is one of the benefits for us"

> (Water utility representative).

Despite the intention for authentic dialogue and collaboration regarding water management, the

outcomes can be limited where local communities are cognisant that governments have the power

to influence the flow of funds and opportunities into the community (Jackson et al., 2019b). This was

described by an interviewee as:

> "Don't underestimate the fear within remote communities, of the 'State/outsiders'
>
> wanting to take-over control. It took us a long time to get over it with the
>
> (Indigenous) councils we have been dealing with. Some initially refused our support
>
> because they feared the State wanted to take over their services"

(Government agency representative).

In contrast, literature documenting initiatives that built sector capacity for locally controlled collaboration and partnership through 'learning by doing' can contribute to mutual learning over time (Jackson et al., 2019b, Beal et al., 2018, Hall et al., 2021b).

Implementation of these conditions

These documented conditions highlight possible opportunities for water services utilities and state and Territory governments to initiate a range of engagement values and approaches with Indigenous communities. Utilities working with Indigenous communities could ensure that initiatives are based on trust, integrity, collaboration and partnership- as outlined within the discussion of mutual learning. These can be supported through the relevant state or Territory government agencies through initiatives including regulatory changes and subsidy design and introduction. A long-term perspective should be taken to ensure a legacy in the community of strengthened capacity to achieve strengthened water service outcomes – including under the renewed National Water Initiative. Remote Indigenous communities must be recognised and respected as key client-partners with agency, and utilities and government agencies should approach initiatives with an orientation for mutual learning.

The approaches to implement these values could be through advocacy, research and knowledge support, and direct engagement for on-the-ground initiatives. Initial starting points could include building relationships and opening dialogue with key stakeholders, including Federal Government departments delivering the UN Sustainable Development Goals and Closing the Gap initiatives, and state and territory governments that are responsible for water and sanitation delivery. Acquiring a mandate and legitimacy to be involved in remote Indigenous community services beyond utility core business is recommended, as well as identifying and securing long-term funding. Through cultural competency, utilities could build the necessary capacities and organisational attributes for making a

positive contribution towards safe water and sanitation outcomes in remote Indigenous communities.

Conclusions

Safe drinking water and effective sanitation is not provided equitably to all Australian households and does not always meet basic human rights or regulatory standards. For those living in remote communities, this lack of essential services contributes to the gap in health outcomes between Indigenous and non-Indigenous Australians. To contribute to closing this gap, this research identified four key conditions to support consistent and sustainable delivery of safe water and sanitation in remote Indigenous communities of Australia.

Firstly, water potability and palatability needs to be ensured. Currently, water quality can be affected by microbial and chemical contamination, water can be unpalatable, and the security of water sources can be compromised by changing climatic conditions. Secondly, adequate funding for water and sanitation services is required to cover the higher costs of remote water services and ensure appropriate and prompt response rates for maintenance and repair. Furthermore, the differences in land tenure and essential service governance structures that result in complex, conflicting or overlooked provision leading to siloed government services and potentially unclear responsibilities between agencies must be addressed. Thirdly, technology for water and sanitation that is fit for purpose, people and place is crucial to effective and sustainable outcomes in combination with appropriate skills and capacities for local service operation and maintenance. Finally, the above aspects can be better facilitated through a respect for and understanding of cultural and historical aspects of the communities' competency to respond to Indigenous history, cultures and contemporary social dynamics, an appreciation and adoption of Indigenous ways of managing water, and authentic partnership development of sufficient duration and collaboration.

These above aspects are relevant to Australia's commitment to attaining the SDGs, particularly SDG 6, and towards the refreshed efforts for meeting the Closing the Gap targets in Indigenous equity

and a renewed National Water Initiative. The findings are relevant to inform policy and practice to enable decision-makers and utilities to allocate adequate resources and design appropriate processes to more rapidly close the gap in Indigenous equity and meet Australia's international commitments and contribute to building safer, healthier communities in remote Australia.

Acknowledgments

Declaration of Interest Statement

The authors declare no conflicts of interest.

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Reviewer Response Form

Dear editors and reviewers,

Many thanks for your considered review comments on our article 'Safe water and sanitation in remote Indigenous communities in Australia: Conditions towards sustainable outcomes' (Ref: TWAR-2021-0063) submitted to the Australasian Journal of Water Resources.

In the table below we have detailed our responses to each of the comments. In the draft manuscript, we have provided the revised/updated text of their paper in the colour BLUE, while leaving the unchanged text in BLACK.

We look forward to moving towards publication in your journal.

Kind regards,

The authors.

Table: Reviewer comments and author responses

Source and comment	Authors' response	Location of change
Editor		
Thank you for your paper on this topical and important topic. Both reviewers also see great value in it and the paper could be further improved by additional clarification of the framework, methodological approach and data interpretation methods, which would then strengthen the evidence in the findings. We will look forward to seeing a revised version in due course.	Thank you. Each of these aspects has been revised in response to the reviewer comments below.	n/a
Reviewer #1		
This paper draws on existing literature, unpublished reports, and interview material to assess conditions for improved water and sanitation in remote Indigenous communities in Australia. It provides an overview of four key conditions: water quantity and quality; management, governance and financing; technology and operations; and mutual learning. The paper is grounded in current policy contexts and provides relevant recommendations. It provides a valuable contribution to the literature on drinking water services in remote Indigenous communities in Australia.	Thank you. (No response required)	n/a
Core comments:		
1) Methods 1a) This paper makes a significant contribution to the literature by synthesising and analysing published and unpublished work, and identifying 4 key conditions for safe water and sanitation. It would be helpful to the reader to understand more about the methods that were used to conduct this synthesis and analysis.	1a-c: We have revised the Methods section with more detail and trust this addresses Reviewer #1's comments 1a, 1b and 1c. 1d: Given the synthetical approach, the total interviews and representatives from each sector could not be	Methods

1b) Line 8 refers to the research being "based on analysis and synthesis" of existing literature and previous projects. Although Table 1 reports results from using a framework, it is not clear which projects/literature were the sources for the cells within the table. Making this explicit would help the reader understand more easily which projects/literature contributed to which insight. 1c) Further to (b) above, Line 2 on the first page of the Results and Discussion refers to "synthesis" having occurred. There are many formal synthesis methods available and it would be useful to know which were used. If it is the STEEP framework in Table 1, please explain the process in more detail. 1d) The interview vignettes are a very valuable contribution of the paper. It would be helpful to detail how many interviews there were in total to draw upon across the four projects, what proportion were from different types of interviewees, and if there was any particular process used to identify and select quotes against each of the four conditions.	meaningfully quantified. This is explained through additional wording in the Methods section.	
2)Implementation 2a) The subsection titled "Implementation of these conditions" focuses on water service utilities. Lines 26-43 refers to the Productivity Commission's recommendation for State and Territory governments to commit to a basic level of service as part of NWI renewal and the new community infrastructure targets under the Closing the Gap Agreement. These important policy reforms relate to governments rather than utilities. It would be helpful for the reader to understand what the role of government agencies (not including state-owned water utilities) is in establishing these conditions. For example, regulatory changes, the design of programs for subsidies, among others.	Thank you- this is helpful advice for delineating of responsibilities as well as clarification of agency roles. The wording has been adjusted to reflect both of these aspects.	Results and Discussion-Implementation of these conditions
3) Mismatch between Figure 1 and Management, Governance and Financing 3a) The content of the Figure does not appear to match up with the key points in the section. For example, "Grant Writing" doesn't seem to feature in the text	Thank you for this close reading to identify this oversight. The text in the Figure has been revised to reflect the key headings and findings.	Results and Discussion
Supplementary comments		
* Some minor typos or style issues (apologies for lack of specificity - lack of page numbers makes it difficult):	Thank you for identifying these typos. All have been corrected.	Throughout document

o 2nd page of Water palatability subsection ▢ Line 32 "associated health risks long-term tank storage" o 2nd page of Cost of remote water services subsection ▢ Line 17 "greatest potential for potential gains" o 2nd page of Technology and Operations subsection ▢ Line 51 "as potentially have have"		
Reviewer #2		
The topic of the paper is a strength of the paper- this is an area worthy of more research attention in Australia and elsewhere. The themes generated and findings present a valuable summary of key issues in water services provision to Indigenous communities however it is questionable as to whether this paper is presenting more than a literature review of the topic (see comments on the Weaknesses) as the evidence is drawn from several existing studies in a hybrid of review and apparent re-analysis of raw data from those studies (and some additional literature)- although it is not at all clear how or whether data from these studies was used in the synthesis or 'harmonising' across the projects- as the authors state they have done (using an integrative framework called STEEP, which is not explained or justified)- has been achieved.	This critique is helpful. The authors identified a gap in the literature but more so in the knowledge and practices of water utilities and relevant government agencies for appropriate technology and delivery in remote communities. This triggered the development of the studies and the decision to synthesise into this user-focused journal article. A particular value in this paper was that not all of the contributing studies were publicly available. This synthesis enabled a public sharing. A clearer justification of the paper's value is provided in new wording in the Methods.	Methods
The methodology and methods for this study are not clearly explained or justified and this is a significant weakness of the paper in its current form. The authors must justify the approach (including a clear explanation of the analytical framework which is currently absent), provide details of how the analysis was done and what specific data (from across and within the different projects) is being analysed and reported on in this paper- in order to provide a rigorous, transparent and defendable foundation for the findings. I have provided detailed comments on this in my notes to the authors. Currently the methods are not adequately described or appropriately justified, and the evidence presented is also vague and non-specific in many instances and therefore the basis of the claims is weak. For example, it is not clear where the direct quotes presented are from (i.e. which projects) and when they were generated (i.e. no dates).	We have revised the Methods section with more explanations as suggested. Also see our responses to Reviewer #2's detailed comments below.	Methods
The authors should assume readership outside of Australia and provide concise detail on some policy and other terms etc that audiences outside of Australia are unlikely to be familiar with.	This is a helpful point. For this reason, the authors detailed the terminology (with references) for referring to Indigenous Australians and remote communities.	Introduction

	Additional wording has been added to explain the Closing the Gap approach and the NWI.	
Detailed comments:		

Introduction
 	
   a) Page 1
Need to explain/define 'essential services' (p. 1, line 14) and how essential water services is the focus here
 	
   b) In the introduction, some re-organisation of text would improve the flow/logic, for example the start of para 3…does the author/s mean that ' should align'… or the goals underpinning the standards should align…with the SDGs…? More clarity of expression needed here.
 	
   c) Page 2
line 1, need to explain the 'Closing the Gap' agenda. This para then returns to the SDGs…Need to more clearly make the link (just a sentence or two needed) between essential service provision in water and health.
 	
   d) Need to briefly explain the NWI (need to assume international readership who are not familiar with all the Australian policy settings etc)
   e) Need to explain the responsibilities for provision of essential water services to remote Indigenous communities- it shouldn't be assumed that the readership already knows this.
   f) Line 28- say 'minimum' of what?
   g) The authors should specify what they mean by 'conditions' and 'outcomes'
   h) Line 35- clearly/concisely explain what the 'revised effort' referred to is
   i) Line 53…reference to 'this research' and then 'it was written'- edit for grammar and clarity of expression
   j) Page 3 Line 16- what is being referred to here? The literature or the research projects? Needs to be clear. I think it's the projects?
	A) 'Essential services' are now defined as water, sewerage and power
	
	b) Apologies- a word was missing, and now reads 'should align'. This clarifies the ambition sought through the SDGs.
	
	c) Wording has now been rearranged to present the Closing the Gap and SDG references together respectively. In addition, some linking words have been added between essential services and the Closing the Gap agenda.
	
	d) The NWI reference has been revised to explain its purpose and the final NWI review report has been added.
	
	e) Additional wording has been added to explain where this responsibility lies.
	
	f) This sentence has been revised and the word 'minimum' removed.
	
	g) 'Conditions' have been defined with addition wording as 'structure, resources and other aspects'. 'Outcomes' has been removed from the last paragraph of the Introduction as it was superfluous.
	
	h) This is now described as 'The recently-revised Closing the Gap agenda'
	
	i) Several words have been added for clarity.
	
	j) Several words have been added for clarity.
		Introduction

Methods section	a) The range of interviewees have now been identified in Methods. This new wording explains	Methods

a) A clear summary of the social research projects (perhaps in a table or figure) would be an efficient way of presenting all the information required (see notes below) to provide evidence of what data, methods and analysis was actually conducted as a basis of this study and what the details of the actual projects are and the data collected within them (for example what locations/communities do they also relate to etc)- currently this is not at all clear or comprehensively explained. … Detail on what the data used in this study is (i.e. how many interviews? Who with (Indigenous people, essential services providers, govt??? How were the interviewees selected and why?), and how it was accessed and re-analysed from the social research projects identified also needs to be included along with an explanation/justification of how and why these particular projects were selected and why they represent an appropriate sample for this study. What were the selection criteria applied?	how the focus was on synthesis and integration of research findings from the social research and literature review. The detailed explanation of each project was limited to critical details to meet word limits. The reasons for selection of these particular projects is now further explained further to draw attention to that fact that the authors are researchers in complementary areas in the field, contributing their own pre-existing social research with the intention of making a useful contribution through integration and synthesis. Additional detail was provided above in response to Reviewer #1's about quantification of the interviews, where we stated that, given the synthetical approach, the total interviews and representatives from each sector could not be meaningfully quantified.
b) There needs to be a much stronger justification and explanation of the STEEP framework and how and why it was used to analyse the data. The current presentation of the framework is entirely unclear- what are the different columns in Table 1 and what do they mean? This needs to be clearly explained and justified.	b) The wording has been revised to address this comment – to more clearly justify the need and value of the STEEP tool as a questioning framework for re-analysing the existing social research.
c) Did the ethics protocols for the research projects cover re-analysis of data in the form it was undertaken in this project? i.e. were all named authors in this study named on each of the ethics applications? This needs to be clearly explained.	c) Additional wording about the ethical clearance has been provided to explain that the collaborating authors did not have access to social research data from a different university's project that, furthermore, responded to different initial research questions.
d) How was the review of literature undertaken (search terms/journals/approach?) and how does the analysis of the social research projects relate to this literature review? This should be detailed in this section. The studies were conducted over quite a range of time- how do the authors account for what might have changed and the different contexts and circumstances of the different projects in this study?	d) Additional wording has been provided to describe the process of literature collection and review.
e) Line 1 How was the analysis and synthesis of the social research projects achieved? Was computer software (i.e Nvivo used). Was the raw data accessed (there is a reference to 'interview quotes)- this should be detailed in the Methods section.	

	e) Additional wording has been added to explain the purpose of the quotes from interviews. NVivo was not used in the STEEP analysis so was not mentioned.	
Results a) Given the lack of detail in the Methods (as noted above) the Results do not give a clear sense/evidence of the scope or scale of the problem as there is not evidence of how many people and who identified the range of issues noted. b) Page 7 Line 14. What is meant by 'sources' here? I assume you mean the interviewees noted this. But who?? c) Line 45 All direct quotes should have dates. Page 8 d) What location is being referred to here in this quote? All remote Indigenous communities? Needs qualification e) Line 50- what is meant by 'outdoor' water?- explain (watering gardens etc) f) Page 9 Need to be specific about where and what contexts are being referred to- line 5- in remote Indigenous communities? g) Line 32- community engagement in what? Page 11 h) Line 39 shortfall for who? Govts/service providers? Page 12 i) Line 15. Interviewees in which of the social research projects? Need to say if across all or in only one? Or some? Page 14 j) Line 15- what is meant by the 'social research' here- I assume it's the analysis of the 'x' social research projects… This paragraph implies that the decision making of engineers and tech officers is the issue…however it is not clear how their decisions can't contribute to 'collaborative water management' in the next sentence…be careful not to make broad assumptions or to gloss the complexity of this situation. Re-wording is needed.	a) The Methods section has been significantly enhanced through additional wording and thus provides clearer content of the analytical processes. b) The term 'sources' has been checked and now only refers to water sources. The alternative use has been replaced by 'respondents'. c) The interview quotes do not have specific dates as the Methods sections clarifies that these were conducted between 2016 and 2019. d) Specific locations or even regions are not provided with quotes to protect identity as per the ethical clearance conditions. The Methods details that the interviews were conducted regarding remote communities in Northern Territory, Queensland and Western Australia as this encompasses the greatest proportion of the remotely-located Indigenous communities in Australia. e) This has been changed to 'used for outdoor purposes'. f) As per response above to 'd', specific locations or even regions are not provided. g) This wording was superfluous and has been removed. h) 'service providers' has been added.	a) Methods b) Results c) Methods d) Methods e) Results f) Methods g) Results h) Results i) Methods j) Results k) Results l) Introduction m) Results n) Results o) Title p) Results and Conclusions

k) Need to say what you mean by 'mutual learning'- i.e. the co-production of knowledge between Indigenous and non-Indigenous people and organisations (or something similar- and reference this process as many others have theorised and written about it including Indigenous scholars)	i) The interview quotes do not have specific details on them for the reasons provided above. They are intended to only be used to illustrate an issue that was raised by multiple respondents. Wording to this effect has been added to the Methods.
Page 17	
l) Line 13. As noted earlier…need to explicate what is being referred to as 'conditions'.	j) The wording has been softened so that a generalisation is not unintentionally made. Also, a new paragraph break has been inserted to describe potential problems with infrastructure outcomes.
m) Line 19- 'values of trust…etc' Need to say why 'values' are important here. Does this link back to the STEPP framework which suggests 'values' should underpin improved conditions- this wasn't explained in the Methods section so it's unclear to me.	
n) What is the relationship between 'engagement' and improving conditions for better service delivery and outcomes from that?	k) The key reference cited here is from Nelson et al (2018)- commissioned and published by Murray Lower Darling Rivers Indigenous Nations (MLDRIN). It was selected, along with Sue Jackson's publication, as it was assumed that Inidgenous peoples would have been adequately involved of co-authoring this work given the organistaion and the authors' repuutations. 'Mutual learning' is defined in paragraph 2 of this sub section.
Page 18	
o) Line 4- are you only referring to Indigenous people in remote communities? This needs to be clear.	
p) Line 47- Indigenous ways of managing water are an extremely important part of finding solutions to essential services delivery issues however there wasn't evidence presented here of these.	
	l) The definition of 'conditions' was provided in the revised Introduction.
	m) Additional wording has linked these values back to the mention of such in the 'Mutual Learning' sub section.
	n) The wording has been simplified to 'direct engagement'.
	o) This paper is only focused on remote Indigenous communities so the focus is hoped to be clear- including in the title.
	p) Indigenous ways of managing water are already referenced in the Mutual Learning sub section

	(Jackson and Moggridge, 2019, Berry et al., 2018) and again mentioned in the Conclusions.	