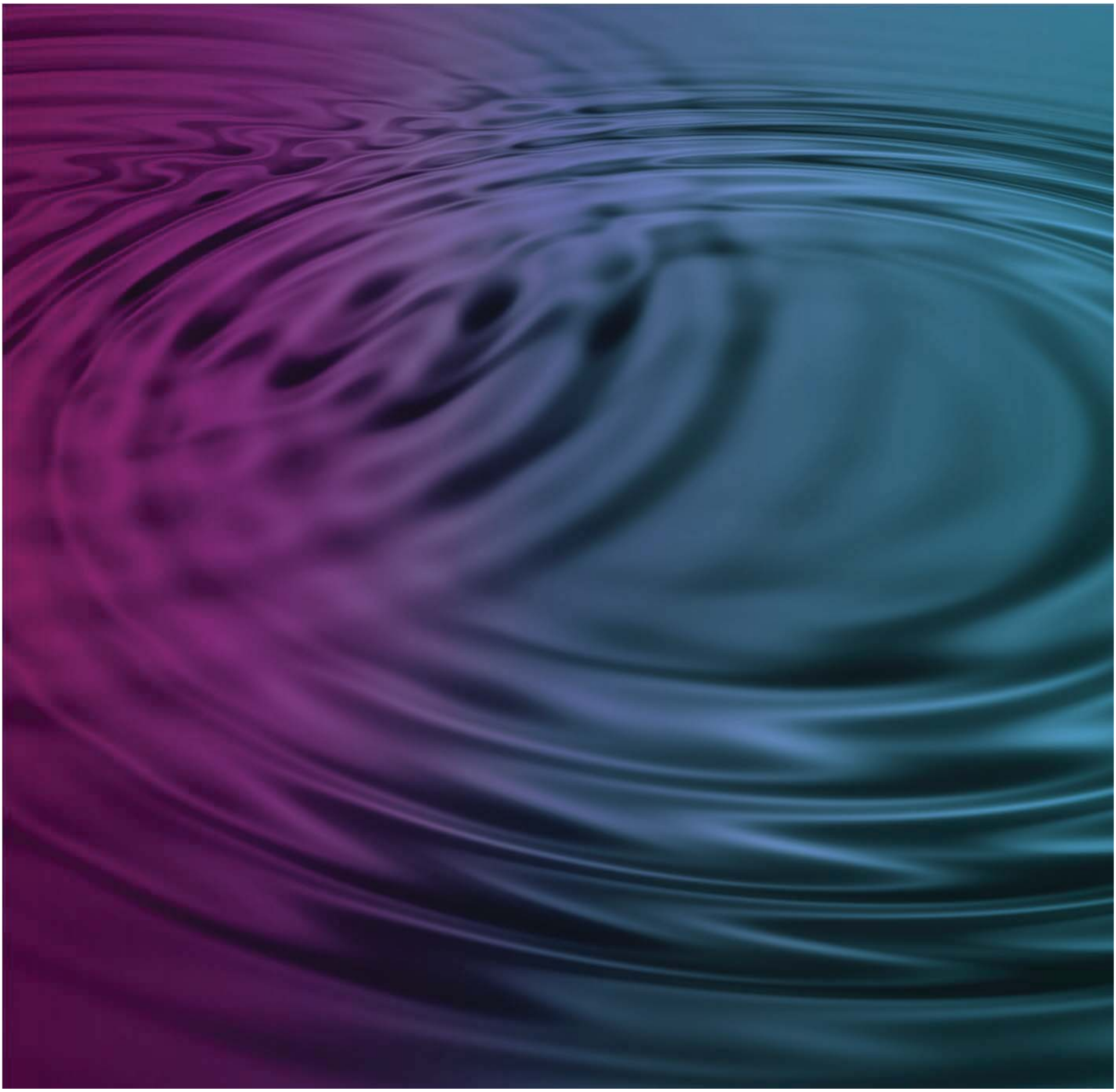
Appendix K

Discussion Papers

Non Potable Water Master Plan
ACT Procurement Solutions
12 April 2011

An Outline of the Hierarchy of Use for Non-potable Water Sources

Discussion Paper 1



An Outline of the Hierarchy of Use for Non-potable Water Sources

Discussion Paper 1

Prepared for

ACT Procurement Solutions

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Abstract

The drivers to reduce potable water demands include human needs (water shortages) and environmental needs (flow disruption from extraction and storages). Many water demands do not require water of potable standard and opportunities exist to use alternative sources of water such as treated wastewater, treated stormwater or rainwater (collected roof runoff). In order from lowest to highest risk to public health, the preferred alternative non-potable water sources are: 1. Rainwater; 2. Treated stormwater; 3. Treated wastewater.

The non-potable water demands include hot water - laundry - toilet flushing - irrigation (for private spaces, public spaces, agriculture). Different water demands require water of different qualities, *i.e.* the water should be "fit-for-purpose". The following hierarchies of use are recommended for each water source, based on a range of issues, including minimising potential for human exposure to pathogens:

- Treated wastewater - 1. Toilet flushing; 2. Forestry irrigation; 3. Agriculture irrigation; 4. Irrigation of passive use open spaces; 5. Irrigation and active use open space and private open spaces.
- Treated stormwater – 1. Irrigation of passive use open space, active use open space or private use open space; 2. Toilet flushing; 3. Agriculture or forestry irrigation.
- Rainwater – 1. Domestic hot water; 2. Domestic laundry; 3. Toilet flushing; 4. Irrigation of private open space.

If all water sources are available, the optimal use of water may be:

- Treated wastewater to toilet flushing, remainder to irrigation of agriculture/forestry or passive use open space;
- Treated stormwater to irrigation of active use open space, remainder to irrigation of other open spaces; and
- Rainwater to domestic uses such as hot water and laundry, and irrigation of private open space

In order of maximising benefits to the receiving environment the following hierarchy is recommended:

1. Wastewater; 2. Stormwater; 3. Rainwater.

The actual solution for any particular potable replacement exercise will depend on availability of the alternative sources (and storage opportunities for stormwater), cost and environmental benefits.

The overall benefits to the potable water supply catchment and dam storages (supply security) are realised through an offset in extraction of potable supplies through the maximum reuse of alternative water supplies from any source.

1.0 Introduction

This discussion paper has been prepared in conjunction with the current ACT Non-Potable Water Master Plan (NPWMP) and is intended to provide some background and context to the decision making processes which are integral to this wider project. The NPWMP has established a master plan for the provision of alternative non-potable water sources for the whole of the ACT based on identified and prioritised irrigation demands and likely urban growth areas. The master plan has been informed by an overarching modelling tool which applies quantitative assessment of economic and volumetric measures to develop a territory wide network of infrastructure to support the reuse of harvested stormwater and treated waste water. The NPWMP model is intended as a decision support tool. As such it does not incorporate the qualitative criteria which need to be considered in the ultimate selection of a preferred master plan. Drivers such as the environmental protection of waterways, management of open water bodies and potential public health considerations with the various options are not explicitly included in the modelling parameters. Rather, the modelling tool, and ensuing master plan, have been developed with the implicit consideration of these issues by the user and stakeholders. The NPWMP model does however quantify the proximity of sources and demands and costs of linking these. It is therefore important to outline the rationale behind the assessment process as they relate to the specifics of the provision of alternative water sources for the ACT. The following discussion is to support a consistent approach when considering the appropriate use of harvested stormwater and treated wastewater when both sources are available. As outlined in the following sections, there are a range of considerations beyond the lifecycle cost of securing these alternative water sources.

The objective of this discussion paper is to present the bases for the evaluation of alternative non-potable water sources based on the following criteria:

- Potable water demand reduction
- Public health protection
- Environmental protection (of both the donor and receiving environments).

These bases follow a logical structure with regards to the optimal use of water resources, but in some instances deviate from common practices or convention. The discussion presented is intended to assist in future decision making, and is not intended to describe a definitive position with regards to the use of alternative water sources for non-potable demands. There is a second discussion paper that should be read subsequent to this paper. The second paper is titled “**Draft Discussion Paper 2. Infrastructure requirements for water recycling and reuse**” (AECOM 2011).

2.0 Potable water demand reduction

The drivers to reduce potable water demands arise from human and environmental needs. Human settlements are affected as water shortages are widespread and water demands threaten to exceed supply in many regions. The environment is affected by the extraction of water. Extraction has the following negative impacts on donor environments:

- The construction of water storages disrupts the timing of environmental flows to the receiving environment; and
- The large volumes extracted cause a reduction in downstream flows that can irreparably damage many aquatic environments.

Many water demands do not require water of potable standard for their end-use e.g. open space irrigation (both public and private) or toilet flushing. Therefore opportunities exist to provide alternative sources of water for these end-users. The alternative sources of water suitable to meet non-potable demands are:

- Wastewater (treated whole wastewater, i.e. treated blackwater and grey water);
- Stormwater (harvested and treated urban run-off); and
- Rainwater (collected roof runoff).

In the absence of opportunities to reuse these water sources, the discharge of these waters to the environment is linked to several important and detrimental environmental impacts:

- Treated wastewater discharges – can deliver large pollutant loads to aquatic receiving environments and generally result in a significant disruption to downstream hydrology in terms of near constant base flows which are largely independent of natural rainfall.
- Stormwater discharges - also deliver large pollutant loads to aquatic receiving environments, and deliver large volumes of water at unnaturally high flow rates to receiving environments. These flows create hydrologic disturbances that can cause severe stream erosion and significant changes to the natural wetting and drying hydrology of wetlands and flow patterns of streams. Catchment attenuation can reduce the peak discharge to an extent but research has shown that the ensuing prolonged discharge of retarded event flows has a significant impact of freshwater biota which rely on a flow regime which is aligned with catchment rainfall.

The use of alternative water sources for non-potable demands has the benefits of alleviating the impacts described above. Additionally, since less water is required from traditional potable supplies:

- there is the potential to extract less water from the donor environment, and thus to alleviate the impacts associated with extraction
- water security may be increased with an additional ‘buffer’ retained within the catchment dams for periods of drought
- the cost and energy requirements for the treatment and distribution of potable quality water can potentially be reduced
- the need to augment infrastructure for potable water treatment and delivery to meet increased demands may be deferred.

3.0 Potential alternative water sources

- Treated Wastewater - The wastewater stream may be further split into grey water (laundry and bathroom) and Blackwater (toilet and kitchen). The local re-use of grey water may be advantageous in particular situations where the wastewater treatment plant is too far from the site for reuse to be considered feasible. However, for the purposes of this discussion paper, the separation of the grey water stream is not considered.
- Stormwater - Urban run-off is separated into two categories:
  - Rainwater (roof runoff) - this has lower pollutant loads and loads treatment requirements for reuse
  - Stormwater (non-roof runoff) - this has higher pollutant loads and higher treatment requirements for reuse.

Each of these water sources has an associated reuse risk profile, related to the concentration of pollutants likely to be associated with the source. In order from lowest to highest risk to public health, the preferred alternative non-potable water sources are:

1) Rainwater
2) Stormwater
3) Treated wastewater (the quality of treated wastewater is highly dependent on the treatment system, for the purposes of this paper it is assumed to be tertiary treated sewage as provided by the Lower Molonglo Water Quality Control Centre (LMWQCC)).

The general characteristics of each source are as follows:

- Rainwater - rainwater is mostly low in pollutants such as sediments, nutrients (with the exception of nitrogen), heavy metals (from modern roofs), toxic chemicals, petrochemicals and pathogens (although roofs do also represent a potential source of pathogens). Rainwater requires very little treatment (beyond tank storage) prior to reuse for many applications, and mostly has water quality within the Australian Drinking Water Guidelines (ARQ 2006, Chapter 6).
- Stormwater - pollutant concentrations and stormwater are often highly variable, and may contain high concentrations or loads of sediments, nutrients, heavy metals, chemicals, petrochemicals and pathogens. Even if the concentrations of these pollutants are often not very high, the large volumes associated with urban run-off deliver large loads of these pollutants to receiving environments. This water requires treatment prior to reuse for many applications
- Wastewater - treated wastewater may be low in sediments but often contains elevated concentrations of nutrients, pathogens, chemicals and salts. Waste water can be further treated to remove these components, but at a high cost and with high energy requirements.

Table 1 provides a summary of typical water quality values for untreated stormwater/rainwater and treated sewage from the current LMWQCC.

Table 1 **Water quality values for untreated stormwater and secondary sewage**

Variable (mg/L)	Roof Runoff	Untreated Urban Runoff	Secondary Sewage	Current water quality for lower Molonglo Water Quality Control Centre (50%ile – 90%ile)
Suspended solids	1 - 204	13 – 1620	25	2-4
Total Phosphorus		0.2 - 1.2	8	.2-.3
Total Nitrogen		0.39 – 4.9	35	26-32
Faecal coliforms (mpn orgs/100ml)	10^2	10^4	10^5	
Thermotolerant coliforms (cfu/100ml)				2-10
Salt (as dissolved solids)	8.1 - 34			483-540

4.0 Non-potable water demands and water quality that is “fit-for-purpose”

The non-potable water demands that may potentially be met by these water sources include:

- Hot water - Hot water requires water of a high quality because of its use in the kitchen and bathroom, and the potential for ingestion. The heating of water above 65° provides disinfection and reduces the risk of exposure to pathogens. At the request of ACTPLA, the use of alternative sources for hot water usage has not been included in the development of the master plan.
- Laundry - Laundry uses require water of a high quality due to the potential for human exposure to this water within domestic dwellings. At the request of ACTPLA, the use of alternative sources for laundry usage has not been included in the development of the master plan.
- Toilet - water of a lower standard is acceptable for toilet flushing, due to the reduced potential for human exposure. The use of alternative water sources for toilet flushing has only been considered for proposed new growth areas planed for residential development. The costs associated with retrofitting dedicated non-potable water reticulation in existing residential suburbs are considered prohibitive.
- Irrigation - four categories of irrigation areas are used, because each carries a different health risk profile due to the likelihood of human exposure to water.
    - Private space irrigation - water of a lower standard is acceptable for use due to the low likelihood of ingestion. However, since exposure is uncontrolled in domestic areas, water should be treated for pathogens. Treated wastewater may be high in total dissolved salts (TDS), and its use for irrigation may not be appropriate to soil types that are high in clay and low in calcium or magnesium. Irrigation with salty water can result in soil dispersion and the loss of soil structure and may inhibit the growth of certain plants. The use of alternative water sources for private space irrigation has only been considered for proposed new growth areas planed for residential development. The costs associated with retrofitting dedicated non-potable water reticulation in existing residential suburbs are considered prohibitive.
    - Public space irrigation - active use areas. Water of a lower standard is acceptable for use due to the low likelihood of ingestion. However, due to the intensive nature of the use of these areas for active recreation pursuits, the likelihood of exposure is increased through the likelihood of activity occurring soon after irrigation, or exposure through direct contact to the ground and, an increased risk of exposure through cuts and abrasions. Therefore, water used for the irrigation of active recreation areas needs to be treated for pathogens. The irrigation of salty water onto these areas may not be problematic if there is a use-specific designed soil profile that is typically free draining with under drainage to prevent waterlogging. Salts in the water are less likely to impact on a free draining soil structure, and the use of moderately salty water may be acceptable.

- Public space irrigation - passive uses. Water of a lower standard is acceptable for use due to the low likelihood of ingestion. The likelihood of human exposure to waterborne pathogens is lowest to the users of these environments due to the low intensity use these spaces, and the passive nature of the activities undertaken. Water that is high in salts may not be appropriate for the irrigation of certain soil types or certain plants.
- Agriculture or forestry irrigation - the likelihood of human exposure to waterborne pathogens is lowest if water is reused for agriculture or forestry applications. In these circumstances, soil properties are usually well understood and irrigation can be controlled to limit exposure to humans and impacts to soils.

Different water demands therefore require water of different quality. Matching the quality of water to its intended use is to determine if that water is "fit-for-purpose" i.e. that water is of a suitable quality for the use proposed

Table 2 shows that for a specific demand, different sources of water have different suitabilities based on their risks to human and environmental health. Note the key for this table describes a range of suitabilities ranging through uses that are preferred, compatible, non-preferred, and not recommended. A use may be not recommended because it is incompatible, impractical or a valuable resource best used for other demands.

A risk assessment incorporating health, financial and ecological risks has been undertaken for the issues identified as being most relevant to this project. The risk assessment is included in Appendix A.

5.0 Hierarchy of uses for different water sources

The different suitabilities of different sources lead to a recommended hierarchy of use for each. The following hierarchies of use are recommended for each water source, based on minimising potential for human exposure to pathogens. These uses are not necessarily supported by current ACT legislation or regulation, but rather are based on a fit for purpose assessment which supports the respective uses with the inclusion of appropriate safe guards.

Treated Wastewater

1) Toilet flushing
2) Forestry irrigation
3) Agriculture Irrigation
4) Irrigation of passive use open spaces
5) Irrigation and active use open space and private open space

Stormwater

1) Irrigation of passive use open space, active use open space or private use open space
2) Toilet flushing
3) Agriculture or forestry irrigation

Rainwater (Rainwater has not been separated within the master plan development but should be pursued as part of the broader integrated water management, especially in existing residential development where reticulated non-potable water is not viable).

1) Domestic hot water
2) Domestic laundry
3) Toilet flushing.
4) Irrigation of private open space

Table 2 "Fit-for-purpose" use of alternative non-potable water sources

	Domestic			Irrigation			
Water use	Hot Water	Laundry	Toilet	Private	Public - Active	Public - Passive	Agriculture or Forestry
Water Source							
Rainwater	1	1	2	2	4	4	4
Treated Stormwater	4	4	2	1	1	1	2
Treated Wastewater	4	2	1	2	2	2	1
Key. 1. Preferred use, 2. Compatible use, 3. Non-preferred use, 4.Use not recommended							

From Table 2 assuming that all water sources are available, the following recommended uses emerge. These uses are based entirely on the fit for purpose assessment and do not consider the economic/infrastructure requirements. In development of the overall master plan, consideration will need to be given for proximity to sources, location of potential storages and overall capital costs for various network configurations:

- Waste water to toilet flushing, remainder to irrigation;
- Stormwater to irrigation of active use open space, remainder to irrigation of other open spaces; and
- Rainwater to domestic uses such as hot water and laundry, and irrigation of private open space.

In instances where two alternative sources of water are available, the hierarchy of use should guide the appropriate allocation of each water resource to derive the maximum benefit of reuse from multiple sources. There may be existing policy that potentially limits the achievement of optimal benefits from such an approach. Due to the timeframe associated with implementation of a territory wide non potable water master plan, the potential benefits should be used in support of policy review of any prohibitive regulation. Precedence should be taken from current Australian and international legislation which supports the use of alternative sources of non-potable water. The hierarchy presented above suggests that where rainwater is available, it should initially be plumbed to toilet flushing and irrigation. However, if wastewater were also available, rainwater can be plumed to a use that requires a higher quality of water e.g. domestic hot water, followed by domestic laundry.

Wastewater is of a lower quality, and reference to the hierarchy of use suggests that the priority uses should be toilet flushing and irrigation. Therefore, the connection of a dwelling to a rainwater tank and to a third pipe for treated wastewater supply is complementary as these different supplies are fit for different purposes. This could be adopted within new residential growth areas in the ACT.

6.0 Hierarchy of environmental benefits of non-potable water reuse

In assessing a hierarchy of reuse, the hierarchy of the environmental benefits of the reuse of different sources should also be considered. In order of overall benefits to the receiving environment the following hierarchy is recommended:

1) Treated wastewater reuse. The reduction of the large and constant discharges to the receiving aquatic environment with wastewater provides the most benefit to the environment. These discharges can be detrimental both in terms of pollutants (especially nutrients) and volumetric flow.
2) Treated stormwater reuse protects the receiving environment through the reduction in the highly variable pollutant loads (though these are likely to be smaller than wastewater loads) and a reduction in the hydrologic disturbance to streams and aquatic ecosystems from elevated peak discharges.
3) Rainwater reuse results in a reduction of pollutant loads (though these are likely to be smaller than for non-roof run-off) and a reduction in the hydrologic disturbance to streams and aquatic ecosystems.

The environmental damage caused by the discharge of treated wastewater and untreated stormwater is addressed in the risk assessment (Appendix A).

The overall benefits to the donor environment i.e. the environment from which water is extracted for potable water are realised through the maximum reuse of alternative water supplies. Benefits to the donor environment are directly related to the potential to reduce both the volume of extraction and the hydrologic disruptions imposed with water storages on streams. The maximum benefit is therefore derived from the substitution of potable supplies with alternative water supplies from any source which endeavour to mimic the predevelopment hydrology as much as practical.

Similarly, the security of supply for existing potable water storages is maximised if the maximum volume of non-potable demands can be supplied with alternative sources.

7.0 References

ARQ (2006). Australian Runoff Quality. A guide to Water Sensitive Urban Design. Engineers Australia. Editor in chief T. H. F. Wong.

ACTEW (2010) Canberra Sewerage Strategy 2010 – 2060: Stage 1 Options Report.

Appendix A

Risk Assessment

Likelihood - Frequency Score	0 Theoretically possible, but barely credible	1 Very unlikely, 1 in 1000 per year. 0.1% chance per year	2 Unlikely. Occurs once in your working experience 30-40 years. 1% chance per year	3 Expect to occur several times in your working experience 30-40 years. 10% chance per year	4 Occasional. Occurs once per year	5 Often. Occurs 10 times per year.	6 Frequently. Occurs Every few days

Consequence Score - Health	0 1 Complaint related to injury or health	1 1 mild sickness or 10 complaints	2 1 visit to medical practitioner, 10 mild sickness, 100 complaints	3 1 hospitalisation, 10 visits to medical practitioner, 100 mild sickness, big story in local newspaper or small story in state/national newspaper	4 1 serious permanent disability or 10 hospitalisations, 100 visits to medical practitioner,big story in state/national newspaper or equivalent in other media	5 1 fatality or 10 serious permanent disabilities or 100 hospitalisations
Consequence Score - Ecology	0 Within assimilative capacity or tolerance limits of aquatic ecosystem	1 Measurable loss of biodiversity	2 Moderate loss of biodiversity, measurable reduction in ecosystem function	3 Substantial loss of biodiversity. Moderate loss of ecosystem function	4 Biodiversity value lost. Substantial loss of ecosystem function	5 Hazard to human health requiring cleanup, narrow range of ecosystem function retained
Consequence Score - Infrastructure or Asset Impact	0 $100 repair costs	1 $1 000 repair costs	2 $10 000 repair costs	3 $100 000 repair costs	4 $1 000 000 repair costs	5 $10 000 000 repair costs

Issue	Hazard	Hazardous element	Likelihood	Likelihood notes	Consequence	Notes	Risk Value	Risk Category	Mitigation	Residual Likelihood	Residual Consequence	Residual Risk	Residual Risk Category	Notes
IRRIGATION of public open space using UNTREATED STORMWATER	Exposure to water during or after irrigation results in sickness or injury to humans or pets	Pathogens	2	Assumes that UV is ineffective due to high turbidity. Allows for pathogen die-off in open storage	2	Only secondary contact is likely for humans (stormwater is not likely to be swallowed), therefore consequences are expected to be minor	4	Low	Provide treatment (wetland or bioretention) prior to irrigation use. Spatial separation - subsurface irrigation, lock gates, signage indicating that fields are closed. Temporal separation - irrigate at night.	1	2	2	Low	Treatment expected to reduce pathogen concentrations by an order of magnitude. If the full suite of mitigation measures are implemented, the residual risk is reduced to 1, the same residual risk for irrigation using treated stormwater (i.e. Stormwater treatment and spatial and temporal separation,).
		Chemicals	2	Chemicals potentially present but in low concentrations. Likelihood of 2 given because concentrations in stormwater can be highly variable depending on activity in the catchment	2	Only secondary contact is likely for humans (stormwater is not likely to be swallowed), therefore consequences are expected to be minor	4	Low	Provide treatment (wetland or bioretention) prior to use. Spatial separation - subsurface irrigation, lock gates, signage indicating that fields are closed. Temporal separation - irrigate at night	1	2	2	Low	Treatment expected to reduce chemical concentrations by an order of magnitude.
		Cyanobacteria	4	Blooms expected during hot and dry periods, and this is when irrigation is required.	3	Consequence is higher than other water parameters because humans are sensitive to external exposure to cyanobacterial toxins	12	Moderate	Stormwater runoff treatment. Re-circulation wetlands. Detention time management. Pond/storage design. Stratification management. Storage in closed tanks. Monitoring and reactive signage. Spatial separation - subsurface irrigation, lock gates, signage indicating that fields are closed. Temporal separation - irrigate at night	2	3	6	Moderate	Treatment and recirculation substantially reduces likelihood. Likelihood = 2 due to number of water bodies and potential for variability in management procedures. Consequence remains unchanged due to human sensitivity to cyanobacterial toxins.
	Stormwater has impact on plant growth and soil condition	Salt	0	Stormwater does not usually contain elevated concentrations of salts	2.5	Based on expected costs to remediate or replace a salt affected sports field.	0	Nil	None required	0	2.5	0	Nil	
	Pollutant washoff or leakage to receiving waters	Stormwater contains nutrients or other pollutants that could be detrimental to the environment	4	Expected when rain (>Q3month) follows an irrigation event. Assumes good design for irrigation scheduling. Control overspray. Control overwatering	0	Negligible or undetectable consequence because pollutants in stormwater expected to be low after storage and treatment equivalent to passing through a vegetated buffer, and then diluted by rain.	0	Nil	None required	4	0	0	Nil	
	Unacceptable asset maintenance requirements for pump and reticulation infrastructure	Sediment or biofilms could clog lines. Biofilms could foul UV filter.	5	It is expected that untreated stormwater would contain sediment, algae and aquatic plants that could clog lines. Nutrients could support biofilm growth that could clog and foul irrigation equipment	2.5	Based on expected costs to repair or replace irrigation equipment. Some treatment is expected to occur in storage i.e. During runoff events the water is more polluted but not needed for irrigation. During dry spells there has been time for settling of particles to occur and sediment is less likely to be a problem	12.5	Moderate	Provide stormwater treatment and irrigation filter systems.	3	2	6	Moderate	After mitigation, similar to maintenance required for irrigation systems that use potable water. If stormwater treatment is provided, clogging less likely to occur, and when it does it is likely to be less extensive.
IRRIGATION of public open space using TREATED STORMWATER	Exposure to water during or after irrigation results in sickness or injury to humans or pets	Pathogens	1	Assumes that UV is EFFECTIVE. Allows for pathogen die-off in open storage	2	Only secondary contact is likely for humans (stormwater is not likely to be swallowed), therefore consequences are expected to be minor	2	Low	Spatial separation - subsurface irrigation, lock gates, signage indicating that fields are closed. Temporal separation - irrigate at night.	1	1	1	Low	Water quality expected to meet ANZECC guidelines for secondary contact (not likely to be swallowed).
		Chemicals	1	Chemicals potentially present but in very low concentrations. Treatment reduces potential for high pollutant concentrations.	2	Only secondary contact is likely for humans (stormwater is not likely to be swallowed), therefore consequences are expected to be minor	2	Low	Spatial separation - subsurface irrigation, lock gates, signage indicating that fields are closed. Temporal separation - irrigate at night.	1	1	1	Low	
		Cyanobacteria	2	Blooms unlikely but could occur during hot and dry periods, and during these periods irrigation is most needed.	3	Consequence is higher than other water parameters because humans are sensitive to external exposure to cyanobacterial toxins	6	Moderate	Spatial separation - subsurface irrigation, lock gates, signage indicating that fields are closed. Temporal separation - irrigate at night. Maintenance of stormwater treatment systems.	2	3	6	Moderate	Residuals same for untreated and mitigated (treated) stormwater.
	Stormwater has impact on plant growth and soil condition	Salt	0	Stormwater does not usually contain elevated concentrations of salts	2.5	Based on expected costs to remediate or replace a salt affected sports field.	0	Nil	None required	0	2.5	0	Nil	
	Pollutant washoff or leakage to receiving waters	Nutrients or other pollutants that could be detrimental to the environment	4	Expected when rain (>Q3month) follows an irrigation event. Assumes good design for irrigation scheduling. Control overspray. Control overwatering	0	Negligible or undetectable consequence because pollutants in stormwater expected to be low after storage and treatment equivalent to passing through a vegetated buffer, and then diluted by rain.	0	Nil	None required	4	0	0	Nil	
	Unacceptable asset maintenance requirements for pump and reticulation infrastructure	Sediment or biofilms could clog lines. Biofilms could foul UV filter.	3	Occurrence equivalent to systems using potable water	2	Based on expected costs to repair or replace irrigation equipment.	6	Moderate	Regular maintenance of stormwater treatment and irrigation filter systems.	3	2	6	Moderate	Similar to maintenance required for irrigation systems that use potable water. Clogging may occur, and when it does it is likely to be less extensive if the water was treated.
IRRIGATION of public open space using TREATED WASTEWATER from a CLOSED storage	Exposure to water during or after irrigation results in sickness or injury to humans or pets	Pathogens	2	Assumes effective disinfection at WWTP and effective UV filter in irrigation system	2	Potential for pathogens due to variability in treatment plant performance. Only secondary contact is likely for humans (treated wastewater is not likely to be swallowed), therefore consequences are expected to be minor	4	Low	Spatial separation - subsurface irrigation, lock gates, signage indicating that fields are closed. Temporal separation - irrigate at night.	1	2	2	Low	
		Chemicals	2	Chemicals potentially present but in very low concentrations	2		4	Low	Spatial separation - subsurface irrigation, lock gates, signage indicating that fields are closed. Temporal separation - irrigate at night.	1	2	2	Low	
		Cyanobacteria	0	Cyanobacteria require light to grow, therefore blooms are not a credible occurrence in a closed storage.	3	Consequence is higher than other water parameters because humans are sensitive to external exposure to cyanobacterial toxins	0	Nil	None required	0	3	0	Nil	

Issue	Hazard	Hazardous element	Likelihood	Likelihood notes	Consequence	Notes	Risk Value	Risk Category	Mitigation	Residual Likelihood	Residual Consequence	Residual Risk	Residual Risk Category	Notes
	Wastewater has impact on plant growth and soil condition	Salt	3.5	Wastewater usually contains elevated concentrations of salts that may impact some soil profiles and can inhibit growth of salt sensitive species. Expected that on average one of the sports fields in the ACT could be affected each year.	2.5	Based on expected costs to remediate or replace a salt affected sports field.	8.75	Moderate	Careful planning required to determine feasibility based on plant species and chemical properties of soil. May require soil ammendments such as lime or gypsum.	2	2.5	5	Moderate	Risk to soil profile can be reduced through prior assessment and monitoring. Reliability of irrigation may be reduced by the need to limit irrigation with wastewater if approaching soil threshold. Salt tolerant grasses are available if soil structure is adequately protected.
	Pollutant washoff or leakage to receiving waters	Nutrients or other pollutants that could be detrimental to the environment	5	Wastewater nutrients could build up in soil and leach during large rain events. Pollutant release expected when rain (>Q3 month) follows an irrigation event. Assumes good design for irrigation scheduling. Control overspray. Control overwatering.	2	Volumes are small and area of impact is restricted	10	Moderate	Careful planning including MEDLI modelling to determine loading capacity of soil.	3	2	6	Moderate	
	Unacceptable asset maintenance requirements for pump and reticulation infrastructure	Biofilms could clogg lines. Biofilms could foul UV filter.	3	High concentrations of nutrients expected to support biofilm growth	2.5	Based on expected costs to repair or replace irrigation equipment. High nutrient content of wastewater is expected to promote more biofilm growth than if potable or treated stormwater were used.	7.5	Moderate	Regular maintenance of irrigation system including the use of a residual disinfectant.	3	2.5	7.5	Moderate	Residuals remain the same as regular maintenance would be expected for any irrigation system using wastewater
IRRIGATION of public open space using TREATED WASTEWATER from an OPEN storage	Exposure to water during or after irrigation results in sickness or injury to humans or pets	Cyanobacteria	4	Blooms likely and could occur during hot and dry periods when irrigation is most needed.	3	Consequence is higher than other water parameters because humans are sensitive to external exposure to cyanobacterial toxins	12	Moderate	Spatial separation - subsurface irrigation, lock gates, signage indicating that fields are closed. Temporal separation - irrigate at night.	2	3	6	Moderate	
	Unacceptable asset maintenance requirements for pump and reticulation infrastructure	Biofilms and plant/algae could clog lines. Biofilms could foul UV filter.	5	High concentrations of nutrients expected to support biofilm growth and prolific plant/algae growth in the storage	2.5	Based on expected costs to repair or replace irrigation equipment. High nutrient content of wastewater is expected to promote more biofilm growth than if potable or treated stormwater were used.	12.5	Moderate	None practicable.	5	2.5	12.5	Moderate	Storage of treated wastewater in open ponds is not recommended.
STORAGE of UNTREATED STORMWATER in OPEN water bodies	Exposure to stored water resulting in sickness or injury to humans or pets	Pathogens	2	Pathogens potentially present with each rainfall event. Exposure is only likely during fine weather, inter-event periods when recreational water quality standards are typically met for secondary contact (direct contact but little likelihood of swallowing water).	2	Sewer overflows may be an important source of pathogens if overflow discharges to water body	4	Low	Stormwater runoff treatment, Monitoring, Signage, Education, Pond edge design to inhibit access, Sewer overflow management,	1	2	2	Low	Treatment likely to reduce pathogens by an order of magnitude
		Chemicals	2	Potentially present during rainfall events but in low concentrations	2		4	Low	Stormwater runoff treatment, Monitoring, Signage, Education, Pond edge design to inhibit access, Sewer overflow management,	1	2	2	Low	Treatment likely to reduce variability in concentration of chemical compounds to a narrow, low range of concentrations.
		Cyanobacteria	3	Cyanobacteria bloom after long detention times, only some blooms are toxic. However, exposure is likely because blooms typically occur in good weather when the public are likely to be near or on the water	3	Consequence is higher than other water parameters because humans are sensitive to external exposure to cyanobacterial toxins	9	Moderate	Stormwater runoff treatment, Monitoring, and reactive signage, Pond design, detention time management, stratification managment, recirculation wetlands,	1	3	3	Low	
	Water body fails to meet expectations of the public for visual and recreational amenity	Algae and nuisance plant growth	4	Water storages will look unattractive after most rain events if water is not treated. Trapped sediments may release nutrients that support weedy plant or algal growth.	3	Repair costs for floating macrophyte harvesting for average of one lake each year.	12	Moderate	Stormwater runoff treatment, Pond design, detention time management, stratification managment, recirculation wetlands,	2	2	4	Low	Nuisance plant growth less likely and less extensive where it occurs due to reduced availability of nutrients.
STORAGE of WASTEWATER in OPEN Water Bodies	Exposure to stored water resulting in sickness or injury to humans or pets	Pathogens	2	Pathogens potentially present as a result of variations in plant performance	3	Potential greater than stormwater for a range of pathogens, including viruses at increased concentrations	6	Moderate	Plant process control, monitoring, signage, fencing	1	3	3	Low	
		Chemicals	3	Chemicals present such as heavy metals, herbicides, pesticides, endocrine disruptors, industrial waste. These are more likely to be present because wastewater treatment plants do not specifically target these pollutants.	2	Concentrations expected to be low enough not to cause substantial injury or sickness	6	Moderate	Plant process control, monitoring, signage, fencing	1	2	2	Low	
		Cyanobacteria	4	Cyanobacteria bloom after long detention times, only some blooms are toxic. However, exposure is likely because blooms typically occur in good weather when the public are likely to be near or on the water	3	Consequence is higher than other water parameters because humans are sensitive to external exposure to cyanobacterial toxins	12	Moderate	Plant process control, monitoring, signage, fencing. Detention time management, pond design	1	3	3	Low	
		Nuisance algal blooms	4	High concentrations of nutrients in water storages will support weedy plant or algal growth.	0	Nuisance plant growth not expected to lead to injury or sickness	0	Nil	Wetland treatment for detention time management, pond design, stratification managment,	2	0	0	Nil	
	Water body fails to meet expectations of the public for visual and recreational amenity	Algae and nuisance plant growth	4	High concentrations of nutrients in water storages will support weedy plant or algal growth.	4	Repair costs for floating macrophyte harvesting for average of one lake each year.	16	High	Pond design	**2**	**2**	4	Low	Nuisance plant growth less likely and less extensive where it occurs due to reduced availability of nutrients.
ECOLOGICAL IMPACTS on RECEIVING WATERS	Wastewater discharges		6	Continuous or semi-continuous discharge	3.5	Sustained pollutant release places strong pressure on environment	21	High	Demand management, Treated wastewater reuse (effectiveness depends on extent). Enhanced treatment (depends on extent of treatment) Storage??	4	2	8	Moderate	Discharge only during wet weather. Extent of mitigation depends on the quality of treatment.
	Urban Stormwater - nutrients		5	Nutrient pollutants delivered during and after rainfall	2.5	Large pollutant loads associated with rainfall. Consequence evaluated for an urban catchment > 40 % imperviousness.	12.5	Moderate	Treatment of stormwater, stormwater harvesting.	5	1	5	Moderate	

Issue	Hazard	Hazardous element	Likelihood	Likelihood notes	Consequence	Notes	Risk Value	Risk Category	Mitigation	Residual Likelihood	Residual Consequence	Residual Risk	Residual Risk Category	Notes
	Urban Stormwater - hydrology		5		4	Due to substantial in-stream erosion and increases in disturbance and flooding of wetlands. Large pollutant loads associated with rainfall. Consequence evaluated for an urban catchment > 10 % imperviousness.	20	High	Stormwater retardation, stormwater infiltration, stormwater harvesting	5	2	10	Moderate	2-3 covers the range of outcomes. Outcomes depend on context. It may be difficult to harvest sufficient volumes or provide sufficient infiltration in some cases
ECOLOGICAL IMPACTS on water HARVESTING STREAMS	Reservoir		6	permanent impact of reservoir footprint	4	Consequence refers to the footprint of the reservoir	24	High	None for existing reservoirs					
	Environmental flow disruption	Due to storage and extraction of water	6	Permanent impact to hydrologic regime	3	Functioning ecosystems remain after flow disruption but they are substantially altered.	18	High	Reduce the need for additional reservoirs by: increasing stormwater harvesting for potable replacement, increasing wastewater reuse for potable replacement through dual pipe supply water systems.					Mitigation measures are beyond the scope of the project.

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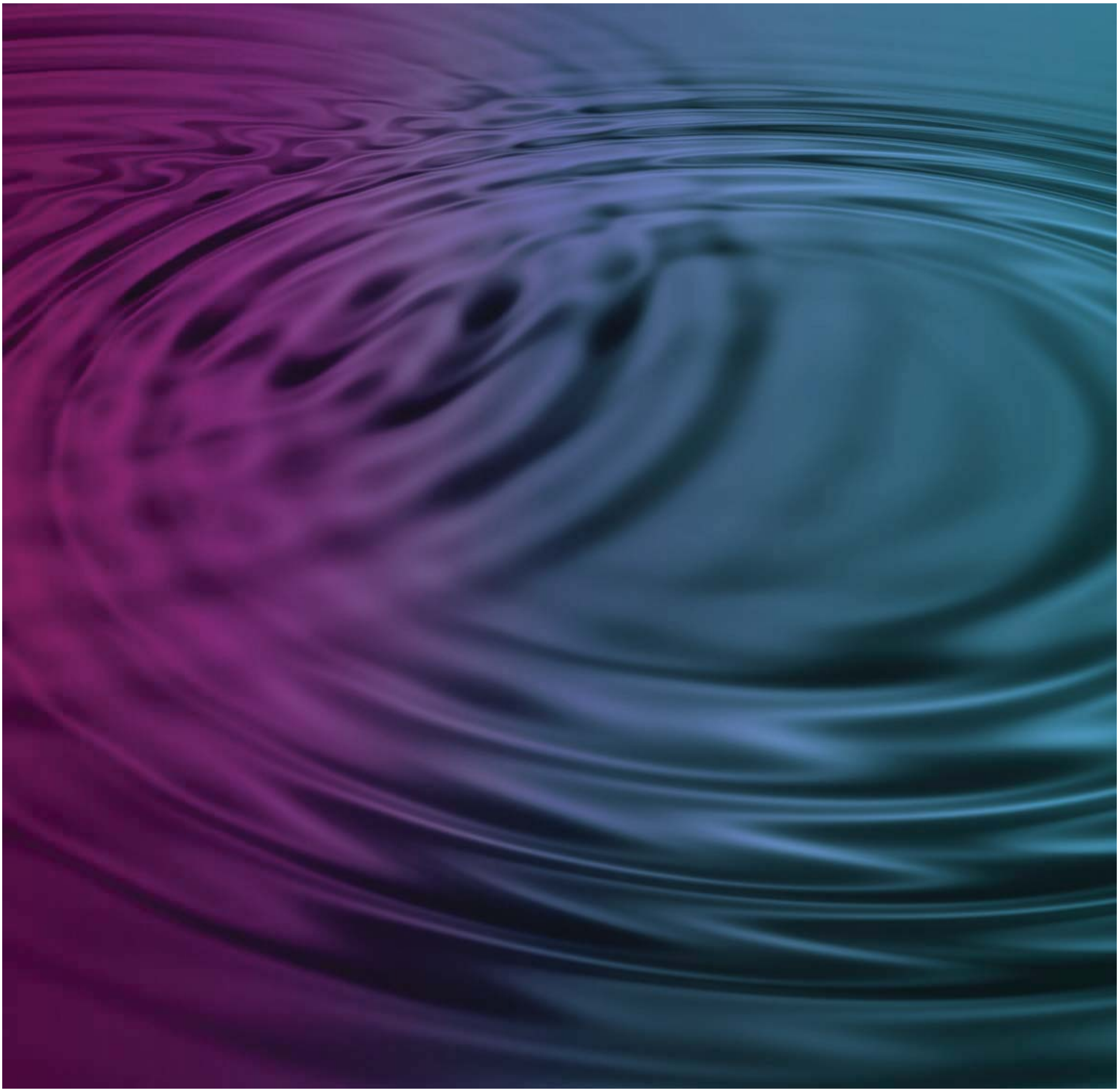
Non Potable Water Master Plan
ACT Procurement Solutions
12 April 2011

Infrastructure Requirements for Water Recycling and Reuse

Discussion Paper 2



Infrastructure Requirements for Water Recycling and Reuse

Discussion Paper 2

Prepared for

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Abstract

Infrastructure requirements for treatment, storage, and distribution are different for rainwater, stormwater and treated wastewater. The choice of water source should firstly be based on the hierarchy of use – the selection of the source that is best fit-for-purpose. Once the appropriate source has been identified, the infrastructure requirements are as follows.

Rainwater (roof runoff) is high quality water that is ideally suited for domestic uses. It requires very little treatment beyond storage in a tank. It is generally used in close proximity to the storage, requiring very little infrastructure for distribution.

Stormwater is moderate quality water that usually requires treatment with bioretention systems or constructed wetlands to make it suitable for reuse. Stormwater is ideally suited to irrigation, being usually lower in salts and pathogens than treated wastewater and is thus commonly reused in an area adjacent to the storage and usually requires little infrastructure for distribution. Typically, large storages are required for stormwater because supply and demand for rainwater and stormwater are often out of phase. The reliability of supply is therefore related to the size of storage. The use of ponds for storage of stormwater is common and requires management of the risks of cyanobacterial blooms, nuisance plant growth, and drowning hazards. Algal bloom risks can be controlled with the efficient design of the storage pond, and recirculation wetlands. Drowning hazards can be managed with batter slope and planting design. Aquifer storage may be possible and is ideal if the geology and groundwater conditions are appropriate. Treated stormwater is generally of suitable quality for aquifer storage.

Treated wastewater is generally of a poorer quality than stormwater and thus is ideal for uses such as toilet flushing. Additional treatment for reuse may be required to make it safe for some other uses. Large storages are generally not required for wastewater because the supply is constant. Since wastewater supplies are plentiful, a third pipe distribution network enables the community to take advantage of the large volumes of water available.

Reliability of supply may be an important consideration in selecting a non-potable water source. Wastewater has the most reliable supply as supply generally exceeds demand, and is suited to applications with large and constant demands such as industry and toilet flushing. Any remainder can be allocated to agricultural irrigation if an opportunity exists.

To improve reliability for domestic uses such as hot water and laundry that are supplied by rainwater, water supplies can be switched to potable water when rainwater is no longer available. Stormwater that is used for irrigation can be subjected to adaptive irrigation schedules to improve reliability. Additionally, switching to treated wastewater when stormwater is not available can ensure 100% reliability of supply. During periods of treated wastewater irrigation, additional hazard management measures may need to be taken to ensure that risks to users and soils are not increased.

1.0 Introduction

This paper should be read in conjunction with the associated discussion paper "**Draft Discussion Paper 1. An outline of the hierarchy of use for non-potable water sources**" (AECOM 2011). The objective of this discussion paper is to describe the basic treatment, storage and distribution requirements of potential alternative non-potable water sources. These requirements are combined with the hierarchy of use described in the first paper to match the likely infrastructure and management requirements with non-potable water demands and sources.

2.0 Alternative non-potable water sources

Infrastructure requirements for alternative non-potable water sources differ depending upon the source. The three potential water sources are:

- Rainwater (roof runoff);
- Treated stormwater (urban runoff); and
- Treated wastewater.

These sources have different requirements for treatment, storage, and distribution. As part of the broader Non-potable Water Master Plan (NPWMP) the capture and reuse of rainwater has not been quantified within the decision support model. Within the existing developed areas the NPWMP has only considered the use of alternative water sources for the irrigation of public open spaces (sports fields). Within the proposed new growth areas the master plan has additionally considered the provision for private irrigation and toilet flushing. As outlined within the Discussion Paper 1, the use of rainwater could be complementary in the new growth areas for other higher risk uses such as laundry and hot water.

3.0 Stormwater

Treatment: stormwater needs to be treated prior to reuse to remove suspended sediments and other particulate and dissolved contaminants. Typically stormwater will be treated by devices such as bioretention systems or constructed wetlands. The size of treatment area required varies between 2% and 7% of the impervious catchment upstream of the treatment device.

Storage: large storages are typically required for stormwater. This is due to the stochastic nature of rainfall and the temporal nature of water demands i.e. rainfall is unpredictable, and you only need to irrigate when it hasn't rained for a while or in the hottest months when evapotranspiration is highest. The size of the storage will be relative to the demands placed upon that storage and the required reliability of the storage. If the storage is small relative to the size of a catchment, the storage will fill with almost every rain event. If storage size is large relative to the catchment it may only fill after larger infrequent rain events.

Storages with high volume to catchment area ratios will tend to have longer detention times and have greater risk of experiencing nuisance algal blooms without the inclusion of adequate pre-treatment of stormwater inflows (discussed below).

Distribution: if reuse is adjacent to the storage, the distribution network may consist of only a pump and irrigation facilities. If distribution and reuse extends beyond the site, then more extensive pipe networks may be required.

4.0 Wastewater

Treatment: the level of treatment required depends on the intended end use. For example, water may be reused for toilet flushing with little additional treatment beyond tertiary treated sewage. However irrigation of public open spaces may require additional disinfection and management of total dissolved salts (TDS) loads to the soil.

Storage: storages may not be required for wastewater reuse if the demand is connected to a third pipe network. In some situations where supply may be limited by the rate of flow, for example broad acre irrigation, a buffer tank equivalent to one to two days' supply may be required. The tank can then be slowly filled in between irrigation events.

Distribution: unless the intended reuse is adjacent to the wastewater treatment plant, a third pipe network is required.

5.0 Rainwater

Treatment: roof runoff requires very little treatment beyond tank storage. Treatment may consist of a first flush diversion and a screen to block organic debris.

Storage: space considerations for rainwater tanks in dwellings generally limit tank sizes to between 2000 and 5000 litres per dwelling. Large tanks give greater reliability, however reliability also depends on the water demands connected to the tank and the roof catchment. Tank sizes will generally be approximately 10 to 20 L of storage for every square metre of roof area, and may provide a reliability of 70 to 80% of supply.

Distribution: rainwater is generally used in close proximity to the storage. Therefore, it generally requires limited plumbing and is usually restricted to the site.

6.0 Storage Risks and Management

The risks associated with the storage and management of treated and untreated stormwater and treated wastewater are assessed in the risk assessment in Appendix A of "**Draft Discussion Paper 1. An outline of the hierarchy of use for non-potable water sources**" (AECOM 2010). A summary follows:

- Stormwater - Stormwater can be stored in tanks or ponds depending upon the size of storage required. Tanks pose few storage risks. However the use of ponds for the storage of water requires the management of cyanobacterial blooms, and nuisance plant growth. Cyanobacterial blooms are of particular concern due to the toxins that they may produce that can have severe health impacts.
- Wastewater – Many reuse applications for treated wastewater do not require any storage. If a small storage/ balancing tank are required then the management and responsibilities are similar to those of rainwater tanks. The storage of treated wastewater in open storages or ponds provides a significant risk in terms of the potential for nuisance algal blooms and is generally not recommended. Depending on the treatment processes, treated wastewater still contains very high nutrient concentrations that can support rapid algal growth.
- Rainwater - The use of rainwater tanks poses very few storage risks. The responsibility for maintenance lies with the owner of the facility.

Nuisance plant growth includes the prolific growth of algae such as filamentous green algae, and floating plants such as duck weeds or Azolla (Water Fern). The excessive growth of these plants can:

- Clog irrigation infrastructure;
- Impact the ecosystem of the pond, resulting in bad odours, fish kills, growth of weedy species and loss of habitat values;
- Create mosquito breeding habitat; and
- Compromise visual amenity.

The incidence of algal blooms and nuisance plant growth is related to the quality of the water being stored, the detention time of the storage, and the mixing behaviour of the storage.

Water that is stored in open ponds creates a niche for aquatic organisms that thrive in full light. If the water quality of the pond is poor and high in nutrients, cyanobacterial and algae respond with rapid growth rates. If the sediments in the pond are high in nutrients, vascular plants may respond with rapid growth. The water quality of the pond is influenced by the inflow water quality, the organic load, and water circulation patterns (i.e. stagnant zones or the propensity of the pond for stratification). If the detention time in the pond is long (> 30-40 days), resident algae in the pond have long enough time to grow and reach bloom proportions.

[Note: stratification is the creation of a distinct thermocline or chemocline in the depth profile of a lake or pond. Persistent stratification can lead to the de-oxygenation of the sediments and lower layers, leading to nutrient releases from the sediments capable of supporting blooms of cyanobacteria or algae. Decomposition processes at the bottom of the pond can lower oxygen levels, release nutrients from the sediments (internal loading), and leading to fish kills when deoxygenated water is mixed through the lake.]

The risk of algal blooms is greatest during warm periods with low rainfall. Because monthly average rainfall in the ACT is relatively even throughout the year, the period of greatest risk is related mostly to temperature, therefore the warmest months *i.e.* summer is the period of greatest risk.

7.0 Control of algal blooms

In conditions with ample light in nutrients such as stormwater ponds, the risk of algal blooms is controlled by the residence time of the water in the pond. If water stays in the pond for a long time, cyanobacteria have a longer time to grow to bloom proportions.

Residence time can be controlled through the size and shape of the storage. If the size of the pond is large relative to its catchment, the pond will only be flushed by infrequent large flows from the catchment, leading to long residence time. If the shape of the storage is hydrologically inefficient i.e. there are stagnant zones of water receiving little flow, this creates pockets where residence times are long and cyanobacteria can persist and bloom.

7.1 Recirculation wetlands for algal control

Recirculation wetlands can be used to control algal blooms and storages. Recirculation works by filtering the “stagnant” water of the storage pond through a wetland macrophyte zone. The macrophyte zone controls floating algae through several mechanisms:

- Shading - the algae are shaded long enough (approximately 5 days) that their carbohydrate resources are exhausted and they then fall from the water column and are trapped as sediment;
- Screening - algae get trapped by sticky biofilms that grow on the macrophytes; and
- Grazing – control exerted by zooplankton.

Recirculation wetlands need to be sized to provide a five day detention time for water, and to be able to fill to the volume of the storage pond within the risk period (approximately 30 to 40 days). The pump only needs to be turned on during risk periods. Such systems also typically treat runoff prior to entering the storage.

8.0 Drowning risks associated with stormwater ponds

An important risk associated with stormwater ponds is the drowning hazard created by a body of deep water. This hazard can be addressed by constructing safe littoral batter slopes and discouraging access to the water by densely vegetating the batters with spiky sedges and rushes. Where space is highly constrained, fencing may be required.

9.0 Aquifer storage and recovery

If suitable aquifers are available for the storage of treated stormwater, this affords an excellent opportunity for large storage, high reliability and low evaporative losses. For aquifer storage to be viable, geotechnical studies must be undertaken to confirm that the geology is compatible to such a use. Some parts of the ACT have fractured rock aquifers that would be capable of supporting sufficiently high injections rates to make ASR feasible

(Mahapeela *et al*. 2009). The feasibility of ASR is highly dependent on the local geology, and opportunities are therefore site specific. The CSIRO is undertaking trials to examine the suitability of injecting treated stormwater and treated effluent into aquifers for subsequent potable uses (http://www.csiro.au/science/Leederville-aquifer-storage-recovery.html, and http://www.csiro.au/resources/ASTRbottledwater.html, accessed 1 Feb 2011).

Groundwater quality must be assessed to determine its potential beneficial uses and confirm that aquifer storage would not jeopardise the beneficial uses. Water to be discharged to the aquifer must be of equivalent or better quality than the groundwater itself so as not to contaminate this resource.

In many circumstances, if stormwater is treated to best practice standards then it will be of a quality suitable for aquifer storage. To avoid impacts on infrastructure near the aquifer, the aquifer must not be close to the surface (e.g. <5m deep). Additionally, the increase in volume discharged to the aquifer must not impact upon any groundwater dependent ecosystems.

While storage may not be required for many treated wastewater reuse applications, storage of treated wastewater in aquifers may be applicable in some circumstances. Aquifer storage can also represent a significant treatment mechanism in some circumstances.

10.0 Distribution infrastructure requirements

Stormwater - Due to the nature of land planning for flood prone land, stormwater storages are often likely to be located adjacent to irrigable open spaces. Therefore, the irrigation of these areas with treated stormwater may require only a localised pipe network. In the Canberra context, a number of large ‘on-line’ ponds are already constructed which are valued by the community as an integral part of the landscape. These large ponds provide the opportunity for very large storage volumes and therefore potential reliability of supply. Current management of these large ponds is based on a limited drawdown depth. There is currently only limited harvest for non-potable reuse from these ponds. The option to optimise the value of these large storages would be dependent on constructing an extensive reticulation network with associated pumps etc. In many cases the construction of this reticulation can be more cost effective on a $/kL basis in comparison to multiple distributed smaller ponds due to the higher reliabilities and potential yields. Numerous smaller constructed ponds are also distributed across the territory. These elements have been constructed for water quality management and in some cases as part of localised stormwater reuse schemes.

Wastewater - The widespread potential for reuse of treated wastewater requires the construction of a large distribution network (a third pipe). Localised and minor reuse schemes are possible if there is a non-potable water demand close to the treatment plant. However, wastewater is normally produced in such large quantities that a large distribution network is required to take advantage of this resource. For an individual site, the extent of additional pipe infrastructure required to connect from the site to the third pipe network may influence the cost effectiveness of wastewater reuse.

Rainwater - Rainwater tanks require very little infrastructure as the demands are usually close to the source.

11.0 Supply reliability

Stormwater - The supply of stormwater for irrigation is often out of phase with demands, and water must therefore be stored for later periods when it will be required. The reliability of supply is therefore dependent on the size of storage. As for rainwater tanks, there is an asymptote of diminishing returns whereby, in order to achieve higher reliabilities, very large and costly storages are required. For many sports fields it is important that a reliable supply is maintained to support the vegetation and ensure player safety. It is therefore necessary that sports fields relying on stormwater harvesting have a top-up connection to the potable system. In some cases there may be opportunity for top-up from the recycled wastewater system to be provided preferentially and backed up with potable supply. Alternative water sources allow the volumes required from the potable water supply to be reduced. This will increase the volume of water retained in the potable supply system that can then be relied upon during dryer periods for top-up. Generally irrigated landscapes are resilient to reductions in irrigation levels. Therefore, during times of water scarcity where allocations are restricted, it may be necessary to prioritise primary sports fields to receive full allocations while lower priority users such as passive open spaces may receive reduced allocations for plant survival only. This will allow water to be retained to preserve reliability for high priority areas.

A shortfall in supply can be addressed by switching water sources when required. If the irrigable areas are in proximity to the third pipe network, it may be acceptable to irrigate with other water sources i.e. treated wastewater to increase the reliability of supply during prolonged drought periods. During periods of treated wastewater irrigation, additional hazard management measures may need to be taken to ensure that risks to users are not increased.

Wastewater – Wastewater supply usually exceeds demand. The constant supply of treated wastewater makes it ideal for uses that require constant demands, such as toilet flushing. If the successful disposal of wastewater is dependent on temporally variable demands such as irrigation, there is likely to be an excess of supply during winter (when evaporation is lowest) or during periods of wet weather.

Rainwater - The domestic demands best suited to rainwater reuse are often constant (such as toilet flushing, hot water) or out of phase with supply (such as garden watering). The size of the rainwater storage tank is used to buffer this mismatch in supply and demand. Therefore, larger tanks have greater reliability but soon begin to reach an asymptote of diminishing returns, i.e. large increases in storage provide only small benefits to reliability. A storage that provides 70 to 80% reliability generally provides the best reliability value in proportion to the cost. Any shortfall in supply can be addressed by switching over to potable water when required for essential domestic needs such as hot water. During water shortages irrigation can be reduced to supply water for plant survival rather than for optimum growth.

12.0 Matching infrastructure to demands

These following recommendations are not intended to preclude the use of other sources of water for the demands identified, rather they indicate that, if all other considerations are equal, what the most appropriate alternative source of water would be.

Irrigation - Irrigation demands for public and private open spaces should be preferentially met with stormwater when the proximity to storages which provide high reliabilities present the most cost effective option. If aquifer storage is available, this should be investigated as it overcomes many of the management issues associated with ponds. In these circumstances, limited distribution infrastructure is required. In locations where the existing treated wastewater pipelines (from either Fyshwick or LMWQCC) are in close proximity to irrigation demands these should be utilised. Options to optimise the high volumetric supply and reliabilities associated with treated wastewater should be pursued in consideration of connection to other large growth areas where high constant demands (toilet flushing) can be met.

Agricultural/forestry irrigation – Where opportunities exist to dispose of treated wastewater through agricultural/forestry irrigation, these present a beneficial use for large volumes of wastewater that may otherwise be discharged to the environment. Limited infrastructure is required in order to connect the wastewater treatment plant to the site of reuse assuming that distances are not great.

Toilet flushing – The widespread and high demands for water of a relatively poor quality for toilet flushing are ideally suited for the reuse of the large quantities of wastewater available. Such reuse requires an extensive third pipe network to meet the distributed demands but can be very cost effective when adopted within the proposed new residential growth areas.

Domestic uses - Harvested rainwater is ideal for domestic uses. Rainwater tanks can be compulsory or discretionary. They should be initially plumbed to toilet and garden watering to optimise reuse volumes. If a third pipe becomes available at a later stage, treated wastewater can be plumbed to toilet and garden and rainwater can be plumbed to a use that requires better quality water, such as hot water and laundry.

Industrial uses – Industrial reuse of treated wastewater is possible with a limited and focussed distribution network.

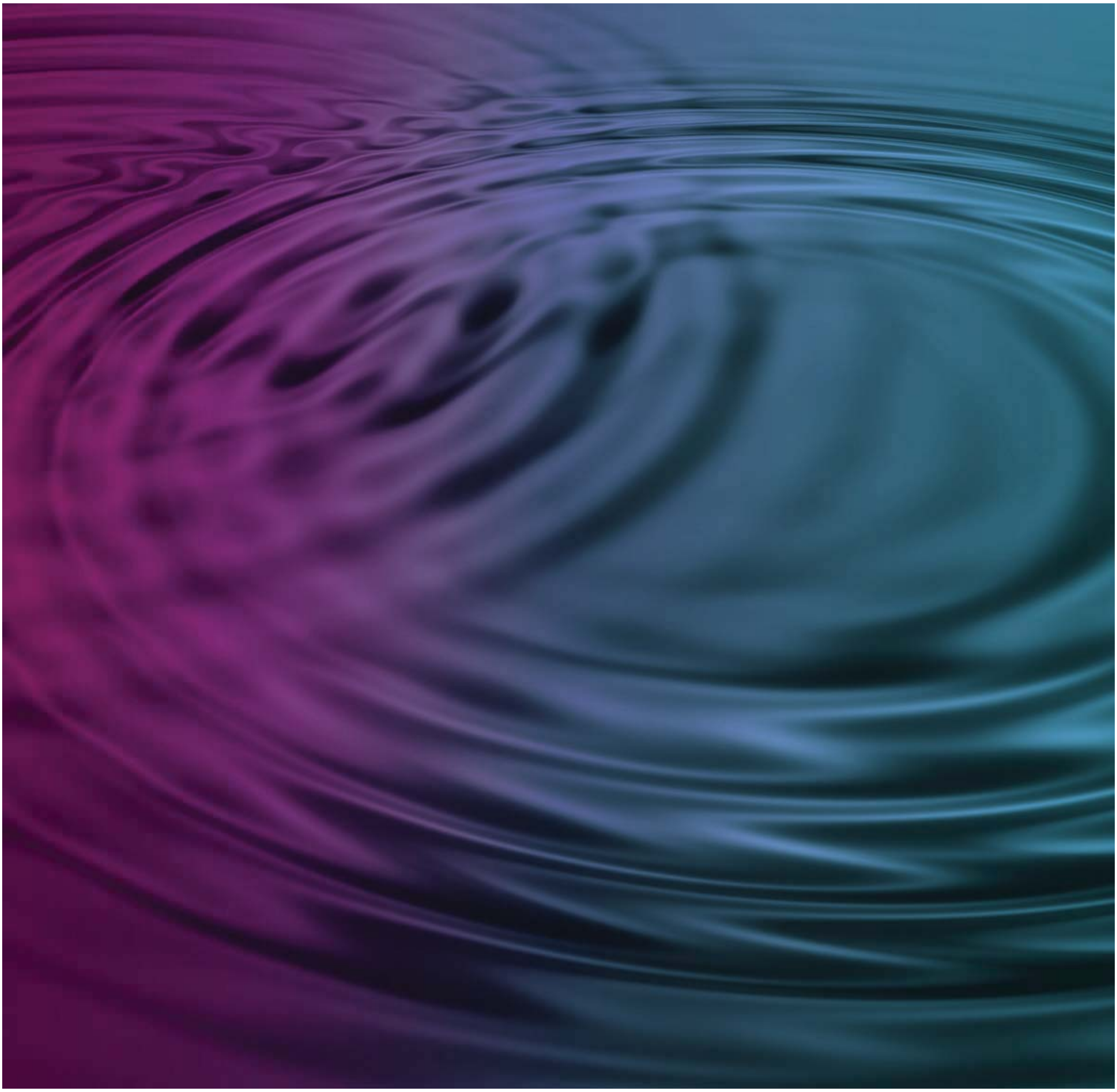
13.0 References

Maheepala, S. et al., 2009. Canberra Integrated Waterways: Feasibility Study. Report for Territory and Municipal Services, ACT, CSIRO: Water for a Healthy Country National Research Flagship, Black Mountain, Canberra, Australia.

Non Potable Water Master Plan
ACT Procurement Solutions
12 April 2011

Residential Dual Reticulation in the ACT

Discussion Paper 3



Residential Dual Reticulation in the ACT

Discussion Paper 3

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Risk Assessment B

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1.0 Introduction

This discussion paper provides an overview of the benefits and challenges associated with implementation of dual reticulation schemes in the Australian Capital Territory (ACT). A dual reticulation scheme involves the supply of recycled water (treated wastewater) from a centralised treatment plant to residential dwellings for non-potable end uses. The dual reticulation network can also be used to supply recycled water to public open spaces and commercial premises.

The aim of this discussion paper is to outline the context for implementing dual reticulation in the ACT and highlight some of the benefits, practical issues and risks. The discussion paper covers the following areas:

- The water management context
- An overview of the general benefits and constraints of dual reticulation
- Suitable end uses for recycled water
- The key health and environmental risks, identified through a high level risk assessment
- The potential cost implications of dual reticulation infrastructure
- Further investigations required to determine the feasibility of dual reticulation schemes in the ACT.

2.0 Water Management Context

Potable water supplied to the ACT's urban areas is sourced from the Cotter, Molonglo and Murrumbidgee Rivers. The average volume of water extracted for supply to Canberra and Queanbeyan has averaged around 55 GL/yr over the last ten years. Restrictions have been in force during the recent dry periods, and potable consumption is expected to increase to around 65 GL/year once restrictions are eased (ACTEW, 2011).

After water is supplied to customers, a large proportion of it enters Canberra's sewerage network and is treated at the Lower Molonglo Water Quality Control Centre (LMWQCC). The volume of treated effluent produced at the LMWQCC averages around 31 GL/year.

Approximately 8% of the treated effluent is recycled within Canberra, predominately for irrigation. The rest of the treated effluent is released from the LMWQCC to the Murrumbidgee River, becoming available for downstream uses. These releases contribute to flow that is used for environmental flows and agricultural irrigation, including the Murrumbidgee Irrigation Area.

2.1 Murray Darling Basin Cap and the Basin Plan

In October 2011, the Murray Darling Basin Authority (MDBA) released the *Guide to the Proposed Murray Darling Basin Plan*. The aim of the Basin Plan is to set enforceable limits on the quantities of water that can be extracted from the basin to protect long-term ecological health of the river system. The Basin Plan is currently subject to a parliamentary inquiry and is expected to be released sometime in 2011.

The Basin Plan will replace the Murray Darling Basin Cap limit that currently applies in the ACT. The Cap allows 40 GL/year (adjusted each year for population) net diversions, taking into account the treated effluent that is discharged back into the river system. The Cap is subject to a credit system, meaning that the ACT can exceed the Cap in any one year, as long as the long term average net extraction is below the Cap limit. The ACT's current long term average net extraction is 25 GL/year (ACTEW, 2011).

Whilst the final details of the Basin Plan and the timeframe for implementation are uncertain, the Guide to the Basin Plan indicated that the ACT would see a significant drop in allowable net diversions to somewhere between 21 and 26 GL/year.

Dual reticulation schemes will result in reduced surface water extractions, but will also reduce discharge from the LMWQCC to the Murrumbidgee by the same amount, resulting in no net change in the volume of water available for downstream uses.

2.2 Think Water, Act Water

In 2004 the ACT Government developed *Think water, act water,* which is a long term strategy for water resource management in the ACT. *Think water, act water* sets a plan for achieving the goal of the *Water ACT, a draft policy for sustainable water resource management,* namely:

The ACT Government is committed to the sustainable use and management of ACT water resources, and will implement best practice water resource management strategies

In terms of water recycling, *Think water, act water* commits the ACT Government to increasing water reuse from 5 per cent to 20 per cent of 2004 volumes by 2013 (ACT Government, 2004).

Think water, act water is currently under review.

2.3 Water Recycling in the ACT

The ACT has a long history of water recycling, with ACTEW providing recycled water to sports grounds for over 30 years. Recycled water from the Fyshwick Sewage Treatment Plant (STP) was first supplied to sports grounds at Duntroon Military College back in 1972 and after a reverse osmosis unit was added to the treatment process, the scheme was expanded to other sports grounds. This scheme, now known as the North Canberra Water Reuse Scheme (NCWRS), currently supplies 190 ML/year to sports grounds. In addition to the NCWRS, recycled water is also supplied from the LMWQCC to a nearby vineyard and golf course. Until recently, a sewer mining was used at Southwell Park for open space irrigation. The sewer mining treatment plant has recently been decommissioned.

Despite a strong focus on water recycling, and the ACT Government's commitment to increasing use of recycled water to 20 per cent by 2013 (ACT Government, 2004), no dual reticulation schemes have been implemented in the ACT.

2.4 Water Security Program

In October 2007, the ACT Government announced a range of new water supply projects, which aim to secure the long term security of the ACT's water supply to cater for population growth and potential climate change impacts. The ACT's water security program consists of the following projects, which are currently underway:

- Enlarging the Cotter Dam from 4 GL to 78 GL (due for completion late 2011)
- A 12 km pipeline to transfer water from the Murrumbidgee River to Burra Creek, allowing it to flow into the Googong Reservoir (under construction)
- Tantangara Transfer, which involves transferring water from the Murrumbidgee River in NSW to the ACT.

3.0 Benefits and Costs of Dual Reticulation

There are a range of benefits and costs associated with the implementation of dual reticulation schemes in the ACT that need to be taken into consideration. The benefits and costs need to be weighed up through a decision making framework that balances the environmental, social and financial implications of each opportunity. This section provides an overview of some of the key benefits and costs specific to the ACT.

Some of the benefits of dual reticulation include:

- Reduces raw water extraction – dual reticulation schemes will reduce the need to extract raw water from surface waters in the ACT, instead utilising recycled water from LMWQCC. It is recognised that this also reduces discharge to the Murrumbidgee from LMWQCC by the same amount, resulting in no overall net change in volume of water downstream. However, it means that the water stays in the natural river system, contributing to river ecosystem health.
- Beneficial use of nutrients – when used sustainably, irrigation with recycled water can beneficially use the nutrients present in wastewater for plant growth and prevent those nutrients being discharged to receiving waters (sustainable application of recycled water is discussed further in Section 7.1). This can also reduce fertilizer requirements for irrigators. There is currently a move towards more stringent discharge licence conditions in many parts of Australia. Increased water recycling can reduce the nutrient load on receiving waters and assist utilities in meeting their licence conditions.

- Increased resilience to drought – recycled water provides a constant supply of water even during dry times, improving security of supply though source diversification. However, this benefit needs to be considered in the specific context, taking into consideration that increased use of recycled water can decrease discharges from LMWQCC and water available for downstream uses.
- Community benefits – dual reticulation schemes can have community benefits by making an alternative water supply available for irrigation of public open spaces and sporting facilities that wouldn't otherwise have a water supply. It should be noted that supplying recycled water for irrigation of spaces not normally irrigated does not achieve any potable water substitution and results in a reduction in water returned to the Murrumbidgee. This requires consideration of how that will impact the ACT's performance under the Cap.

The key costs and constraints associated with dual reticulation in the ACT include:

- Cost – dual reticulation schemes require significant infrastructure to treat, pump and reticulate the recycled water back into houses. The cost of this infrastructure needs to be assessed for each specific opportunity to determine if dual reticulation provides a cost effective solution on a triple bottom line basis. This is discussed further in Section 6.0.
- Greenhouse gas emissions – recycled water supplied through dual reticulation schemes has to be highly treated to ensure protection of public health and the environment. The water also needs to be reticulated back to houses, requiring pumping. In this case, recycled water would need to be pumped from LMWQCC, the low point in the sewerage system. Depending on the location of the dual reticulation scheme, the ongoing operation can be energy intensive and have a significant greenhouse gas footprint.
- Operational requirements – the implementation of dual reticulation infrastructure requires ongoing operational commitment from the water utility. This includes additional, suitably trained, staff to operate the system, increased chemical use in the treatment process and additional requirements to dispose of waste products produced through the treatment process.
- Health and environment – if not managed properly, the use of recycled water through dual reticulation schemes can pose threats to both public health and the environment. The management of these risks is discussed further in Section 4.0.

4.0 End uses for recycled water

4.1 Guidelines and policies that apply to dual reticulation

4.1.1 Australian Guidelines for Water Recycling (AGWR)

The *Australian Guidelines for Water Recycling: Managing Health and Environmental Risks* (Phase 1) (NRMMC-EPHC-AHMC 2006) (AGWR) was published in 2006 in response to a need for a nationally consistent approach to the management of water recycling schemes. Prior to release of the AGWR, the different levels of government in the states and territories had developed a variety of frameworks and policies for assessing the growing number of recycled water schemes being proposed.

The AGWR advocates a risk management based approach and is designed to be suitable on a wide range of scales, from small on-site schemes through to large utility run schemes. The risk management framework outlined in the AGWR is based on the *Australian Drinking Water Guidelines* (NHMRC -NRMMC 2004) and *World Health Organisation's Guidelines for Drinking-water Quality* (WHO 2004). Whilst not mandatory, the AGWR was designed to be used by any government or private entity involved in the supply, use or regulation of recycled water.

The approach advocated in the AGWR utilises microbial risk assessment to calculate the risks to human health associated with a recycled water scheme. Performance targets for the treatment processes are determined in terms of log reduction for each pathogen group to achieve a residual risk that is considered tolerable. The tolerable risk level is defined as 10^{-6} disability adjusted life years (DALYs) per person per year. The required log reductions are calculated as a function of the concentration of the hazardous microorganisms in the source water, the exposure pathway and the exposure frequency.

In terms of environmental protection, the AGWR also advocates a risk assessment based approach focusing on the chemical hazards of recycled water use (the microbial risks are largely dealt with by the measures to protect human health).

4.1.2 ACT Wastewater Reuse for Irrigation – Environmental Protection Policy 1999

The key document governing water recycling in the ACT is the *Wastewater Reuse for Irrigation - Environment Protection Policy (EPP)* (Environment ACT 1999). The aim of the EPP is to assist in the application of the *Environment Protection Act 1997,* and associated regulations, as they apply to recycled water, to ensure adequate protection of public health and the environment.

The EPP specifies final water quality required for different end uses to ensure the water is fit-for-purpose and suggests treatment processes that should achieve the required quality. Alternative treatment processes are acceptable as long as the proponent can demonstrate that the scheme meets the required water quality parameters. The EPP primarily relates to water recycling for irrigation, however it also provides final water quality requirements for residential garden watering and toilet flushing.

The EPP was developed with advice from the Health Protection Service, ACT Department of Health and Community Care, and it refers to the *Guidelines for Sewerage Systems – Use of Reclaimed Water* (ARMCANZ-ANZECC-NHMRC 2000).

The EPP does not apply to stormwater recycling.

4.1.3 Environmental Protection Act 1997

Under the *Environmental Protection Act 1997*, a water recycling scheme will either require an environmental authorisation (schemes producing or supplying **more** than three megalitres per year) or a protection agreement (schemes producing or supplying **less** than three megalitres per year) from the Environmental Protection Authority.

4.1.4 Public Health Act 1997

There are no specific powers in the *Public Health Act 1997* to address water recycling schemes. However, there are powers in the Act relating to significant public health risks. The policy process under the *Environmental Protection Act 1997* is used to address risks if necessary.

4.1.5 The ACT and the AGWR

At the time of the AGWR release, the ACT Environment Protection Authority (EPA) reviewed the EPP against the AGWR and felt that the EPP was at least, if not more, stringent than the AGWR (NWC, 2010). The ACT EPA concluded that the EPP remained appropriate for the types of schemes in the ACT especially given that most schemes are small and require potable top up to meet demand. The ACT EPA indicated that if the EPP did not cover an important parameter associated with a future scheme, then it would refer to the AGWR in that case.

4.2 Suitable end uses in dual reticulation schemes

Suitable end uses of recycled water are determined by the principle of “fit for purpose”. The aim of the AGWR and the EPP is to ensure that the quality of recycled water used in the ACT is fit for its intended end use, or fit for purpose. This means that recycled water must be treated to a quality that ensures adequate protection of human health and the environment, taking into consideration what the water will be used for (end use) and how the water will be used (management controls).

For example, the quality of recycled water used for irrigating a public open space will be different if there is unrestricted public access during irrigation, compared to restricted access or subsurface irrigation, which reduces the potential for contact.

The AGWR includes the following intended residential end uses that could form part of a dual reticulation scheme:

- Garden irrigation
- Toilet flushing
- Washing machine use.

The EPP only covers garden irrigation and toilet flushing and does not cover washing machine use. However, it is assumed here that if a scheme is proposed in the ACT that includes washing machine use, the AGWR could be referred to for guidance. The potential to use recycled water in washing machines in the ACT is discussed further in Section 4.5.

4.3 Exposure risks

With respect to human health impacts, the exposure pathways for each end use of recycled water and the required log reductions documented in the AGWR are shown in Table 1.

Table 1 Exposure pathways and log reductions for dual reticulation end uses (NRMMC-EPHC-AHMC 2006)

	Exposure pathway			Required log reductions		
Intended end use	Ingestion of sprays	Ingestion of recycled water	Ingestion of produce	Crypto-sporidium	Rotavirus	Campylo-bacter
Garden irrigation	✓	✓		4.4	5.8	4.6
Garden food crops			✓	4.0	5.3	4.2
Toilet flushing	✓			3.1	4.5	3.3
Washing machine	✓			2.1	3.5	2.3
Cross connection		✓		4.7	6.1	4.8
Total (garden + internal)				4.9	6.3	5.1

From Table 1 it can be seen that cross connections represent a significant proportion of the exposure risk associated with dual reticulation schemes. Decreasing the likelihood of cross connections by implementing stringent control measures decreases the exposure risk and would therefore decrease the log reduction required via treatment. Standard measures to prevent cross connections include double check valves on potable water systems and pressure differential between the recycled water and potable water networks, to ensure, that in the event of a cross connection, potable water flows into the recycled water network rather than vice versa.

4.4 Treatment requirements

For dual reticulation schemes with garden and internal end uses, the AWGR suggests the following advanced treatment processes to achieve the required log reductions:

- Secondary treatment, coagulation, filtration and disinfection, or
- Secondary treatment, membrane filtration and UV disinfection

Similarly, the ACT EPP suggests secondary treatment, filtration and pathogen reduction as the level of treatment required.

Whilst both guidelines suggest possible treatment trains for different end uses, it is up to the proponent to demonstrate that the treatment and control measures will provide adequate protection of human health and the environment. As such, alternative treatment processes can be implemented if their effectiveness can be demonstrated.

4.5 Using recycled water in washing machines

The ACT EPP does not provide guidance on the use of recycled water for washing machines. Whilst the management and regulation of a scheme in the ACT with washing machine use could be dealt with using the framework outlined in the AGWR, some other considerations, including the treatment process requirements for aesthetic parameters and the community acceptance challenges, have been discussed in the following sections.

4.5.1 Treatment requirements

The required log reductions listed in Table 1 demonstrate that supplying recycled water for use in washing machines does not pose any greater risk to human health than other dual reticulation end uses. In fact, use in washing machines poses a lower risk than either garden irrigation or toilet flushing for each of the hazardous microorganisms listed.

Aesthetic considerations are also important for washing machine use, particularly colour and odour. Without adequate colour removal in the treatment process, clothes can discolour and it can lead to consumer reluctance to use recycled water for this purpose. Aesthetic considerations are covered in the AGWR and selection of the treatment process for a scheme that includes washing machines will have to achieve acceptable colour levels.

A review of the current treatment processes at the STPs in the ACT would need to be undertaken to determine the treatment process upgrades required.

4.5.2 Community acceptance

Whilst the treatment requirements can be met using available technologies, the greater challenge may be associated with community acceptance of using recycled water for clothes washing. It may be a particular challenge in the ACT where consumers are not familiar with dual reticulation schemes and have not previously used recycled water for residential purposes.

By example, residents of Mawson Lakes, a residential development in South Australia that is supplied with recycled water for garden irrigation and toilet flushing, were surveyed to establish their attitudes to recycled water. Four surveys were conducted; two before the supply of recycled water commenced and two after. A trend of declining acceptance for using recycled water in washing machines was observed in the first three surveys, with only 23% of respondents in favour and 62% not in favour of clothes washing in the third survey in 2005.

However, the fourth survey in 2007 revealed a significant increase in support, with 74% in favour of using recycled water for clothes washing. This could indicate that after two years of recycled water use for toilet flushing and gardens, the community became increasingly confident that recycled water is safe and clean for washing machines (Hurlimann, 2008).

A similar trend could be experienced in the ACT, with low support for use of recycled water for washing machines, until some confidence is established in the safety of using recycled water for residential purposes. Proactive community education and engagement could be used to expedite acceptance.

4.5.3 Case studies

Two dual reticulation schemes in western Sydney, the Rouse Hill Recycled Water Area and the Water Reclamation and Management Scheme (WRAMS) at Olympic Park and Newington, both allow the use of recycled water in washing machines.

The Rouse Hill scheme is operated by Sydney Water and is Australia's largest residential water recycling project. It is located in Sydney's north-west and provides recycled water for non-potable uses to over 19,000 properties in a number of suburbs. The households in Rouse Hill use up to 40% less drinking water than other households in greater Sydney. The scheme started in 2001and will eventually serve over 36,000 homes. (http://www.sydneywater.com.au/Water4Life/RecyclingandReuse/RecyclingAndReuseInAction/RouseHill.cfm)

WRAMS was built as part of the 2000 Olympic Games and is owned by the Sydney Olympic Park Authority and operated by United KG. It provides recycled water for irrigation and fountains in Olympic Park, as well as for residential uses in the suburb of Newington. The scheme is capable of providing recycled water to up to 20,000 people. (Chapman, 2005)

Both of these recycled water schemes allowed the use of recycled water for washing machines after the scheme had been in operation for some years. It is standard Sydney Water practice to design both the drinking water and recycled water supply networks for washing machine supply.

5.0 Risk assessment

In May 2010, GHD completed a risk assessment for ACT Procurement Solutions, which considered the risks associated with using non-potable water for irrigation. The risk assessment considered the use of both stormwater and recycled water for irrigation of public open spaces, but only looked at risks associated with using stormwater for irrigation of privately owned open space.

As part of this discussion paper, the risk assessment undertaken by GHD has been used as a basis for completing a high level risk assessment for dual reticulation schemes. The methodology used by GHD has been adopted.

5.1 Risk assessment approach

The approach to risk assessment adopted by GHD is consistent with the Australian and New Zealand Standard for Risk Management, AS/NZ 4360:2004, which consists of four phases:

- Identify risks – understand causes and drivers for risk

- Analyse risks – review current management and regulations already in place to deal with each risk, assessing the consequences and likelihood of each identified risk
- Evaluate risks – rank risks in terms of their severity
- Treat the risks – identify relevant options to manage or adapt to the risks and their consequences.

The analysis of risks is undertaken by considering the likelihood and consequence of each risk. The likelihood and consequence matrices developed by GHD (Appendix A) have been used here to rank assess risks.

5.2 Key risks

Using the process described above, the risks associated with dual reticulation schemes in the ACT were identified, covering the following areas:

- Human health impacts resulting from contact with recycled water
- Environmental impacts associated with release of recycled water into the environment
- Organisational impacts such as cost implications.

The likelihood and consequence associated with each identified risk were considered before and after the likely mitigation measures were implemented to provide an understanding of the residual risk. The results of the risk assessment are provided in Appendix B.

The risks that were assessed to pose a High and Medium risk prior to adding mitigation measures are shown in Table 2.

Table 2 High and Medium risks prior to mitigation measures and residual risk

Risk	Rank before mitigation	Mitigation measure	Rank after mitigation
Ingestion of recycled water from a cross connection between the recycled water and potable water systems	High	Pressure differential between systems Appropriate treatment according to guidelines Plumber training and inspections	Low
Ingestion of recycled water intended for use in the garden	High	Consumer awareness through education Appropriate treatment according to guidelines Signage and purple pipes and fittings	Very Low
Ingestion of recycled water by operations and maintenance staff	High	Appropriate treatment according to guidelines Employee education	Very Low
Consumers choose not to use recycled water - economic impact to proponent	High	Community consultation during project planning Community awareness through education	Low
Ingestion of food crops that have been irrigated with recycled water	Medium	Consumer awareness through education Appropriate treatment according to guidelines Signage and purple pipes and fittings	Very Low
Ingestion of recycled water aerosols intended for use in the garden	Medium	Appropriate treatment according to guidelines	Low
Ingestion of recycled water aerosols by operations and maintenance staff	Medium	Appropriate treatment according to guidelines	Very Low
Build-up of nutrients and/or salts in the environment impacting soils and plants	Medium	Appropriate treatment according to guidelines	Very Low
Nutrients and/or salts leaching to receiving waters (ground and surface water)	Medium	Appropriate treatment according to guidelines	Very Low
System fails to meet demand	Medium	Potable water back up Agency monitoring of supply availability	Very Low

After the mitigation measures were considered, all identified risks ranked either Low or Very Low. The residual risk could be further lowered with more stringent mitigation measures. The mitigation measures included in this risk assessment were measures that are considered to be standard practice for dual reticulation schemes and included:

- Appropriate level of treatment for the intended end use
- Signage and purple pipes and fittings to differentiate the recycled water supply from the drinking water supply
- Program to educate plumbers and monitor their work to ensure the recycled water pipes and fittings are installed correctly
- Maintaining a higher pressure in the drinking water system than in the recycled water system to ensure, that in the event of an accidental cross connection, recycled water does not flow into the drinking water system
- Community education programs to raise awareness of the safe use of recycled water. This would include formal procedures for notifying new home owners and occupiers of the recycled water supply and the safe uses

The risk assessment shows that the risks associated with dual reticulation schemes can be managed with appropriate treatment and controls.

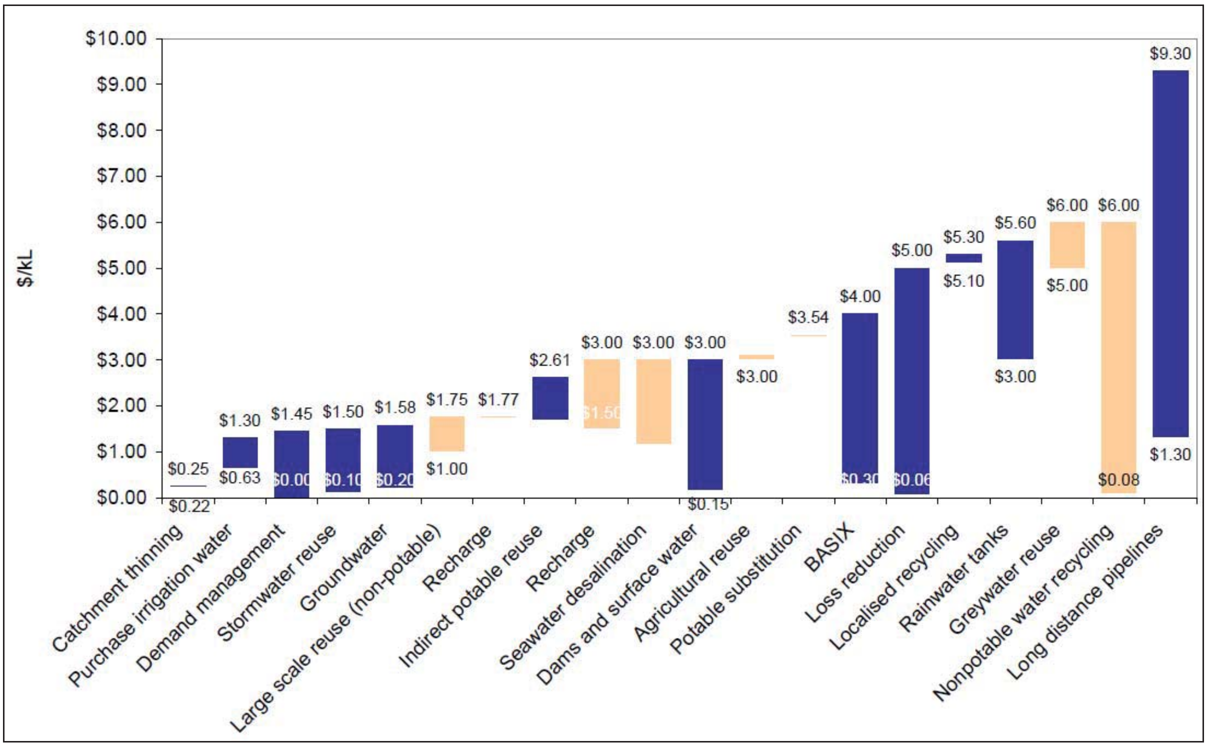
6.0 Cost assessment

Dual reticulation schemes can require a significant amount of infrastructure to deliver recycled water to residential dwellings, including a dedicated water supply pipe network, in addition to the network that supplies drinking water. The cost of dual reticulation schemes are influenced by a number of factors including:

- Type of development – dual reticulation schemes are difficult to implement in established residential areas as houses need to retrofitted to separate the drinking water and recycled water supply systems. For this reason, dual reticulation is generally only considered for new, Greenfield developments
- Distance and elevation between the treatment plant and the residential area and the infrastructure required to transfer recycled water can have a significant impact on cost
- Treatment requirements can be substantial depending on the existing treatment processes and the quality of water required
- The density of the development impacts on the costs of distributing the water to customers.

Whilst costs can be high, it is important to note that research suggests that the costs also vary significantly, depending on individual circumstances. This variation in cost, for recycled water and other supply and demand options, is shown in Figure 1 (dual reticulation is labelled as non-potable water recycling). This demonstrates the need to examine supply and demand management options on a situation by situation basis.

Figure 1 Direct Costs of Water Supply / Demand Options



(Source: Marsden Jacob, 2008)

The work undertaken by Marsden Jacobs (2008) also reported on the known costs of different recycling schemes around Australia. The costs reported by Marsden Jacobs for residential schemes are shown in Table 3.

Table 3 Cost of recycled water by scheme

Recycling scheme	End use	Cost estimate ($/kL)
Western Sydney Recycled Water Initiative, NSW	Environmental flow replacement, residential and agricultural	$5.80
Rouse Hill, NSW	Residential	$3.00 - $4.00
Olympic Park, NSW	Residential	$1.60+ (operating costs only)

Recycling scheme	End use	Cost estimate ($/kL)
Redcliffe City, QLD	Irrigation and residential	$2.50
Springfield, QLD	Residential	$1.45

The information presented in Table 3 again demonstrates that the cost of dual reticulation schemes can vary significantly, but shows that dual reticulation schemes have been implemented that fall at the lower end of the cost scale.

The cost assessment shows that the economics of implementing dual reticulation schemes should be considered on a situation by situation basis. Given the right circumstances, a dual reticulation scheme may provide a cost effective alternative water source. It is also important to consider other non-financial benefits and costs associated with recycling options, such as reduction in surface water extraction, reduction in nutrient discharges to the environment and the community benefits that can result from recycling schemes.

7.0 Further investigation

7.1 Irrigation sustainability

A recycled water sustainability assessment could be undertaken to further investigate the feasibility of implementing dual reticulation schemes in the ACT. The purpose of the sustainability assessment would be to identify areas where irrigating with recycled water would be cost effective (triple bottom line), beneficial and sustainable.

Recycled water typically contains nutrients and salts and, while both occur naturally in soils in Australia, it is possible that the application of recycled water could cause adverse impacts to groundwater, surface water and soils over the long term. The likelihood of adverse impacts will be influenced by a number of factors including the quality of recycled water, the vegetation type, the method irrigation, the proximity to groundwater and the depth and soil type.

It is recommended that a sustainability assessment consistent with the AGWR, and a water and nutrient balance on a daily time step be undertaken. A software program such as MEDLI (Model for Effluent Disposal to Land Irrigation) could be used. MEDLI is a daily time-step model that simulates a water and nutrient balance for a site based on the historic climate data for the last 50 years (including rainfall, evaporation, solar radiation and maximum and minimum temperature). The model also considers the type of irrigation, irrigation frequency, the plants/grass irrigated, and the site’s geology.

Initially the sustainability assessment could be undertaken at an ACT-wide scale, using broad-scale soil mapping. It may also be possible that the assessment incorporated other factors such as any environmentally protected areas, slope or potential adverse impacts from salinity. The purpose of the sustainability assessment would be to identify broad areas with good potential for irrigation as part of a dual reticulation scheme or for open space. This methodology is consistent with other sustainability assessments for recycled water and greywater completed elsewhere in Australia.

It is recommended that a more detailed sustainability assessment based on site-specific soil testing be undertaken prior to selection of a preferred option.

The sustainability assessment could be used to identify the threshold recycled water quality for different areas in Canberra to avoid adverse impacts to receiving water or soils. If the required quality is higher than what is currently produced at the STPs, a review of current treatment processes could be undertaken to determine the required process upgrades to enable the broader application of recycled water.

7.2 Multi criteria assessment

As discussed in Section 6.0, the cost to implement dual reticulation schemes can vary significantly depending on the site specific constraints and opportunities. A triple bottom line cost assessment should be undertaken on specific Greenfield sites in the ACT to identify cost effective opportunities for dual reticulation schemes.

In addition, other non-financial factors should be assessed using a triple bottom line (TBL) approach. A TBL approach will allow social and environmental benefits and impacts to form part of the decision making process, as well as the financial considerations. The TBL approach will allow options to be considered on their “overall value to society”, as well as direct costs to other stakeholders.

Factors that are important to stakeholders and the community need to be considered in the TBL and may include, reducing discharges to the environment, reducing extraction from the environment, improvements to amenity and the benefits to supply security in diversifying supply.

8.0 References

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Appendix A

Risk assessment matrices

Appendix A Risk assessment matrices

Table A1: Risk Assessment Consequence Matrix

Consequence	Minimal	Minor	Moderate	Major	Severe
Ecological					
Spatial	Immediate work area	Site & immediate surrounds	Neighbourhood	Suburb	Canberra
Flora/Fauna	Indirect effect on native species	Direct effect to local species	Direct effect to threatened species	Loss of threatened species or habitat	Extinction of species
Values	Modified site area	Modified parkland, or landscaped area	Loss of native flora/fauna	Conservation Area/Nature Reserve	Nationally threatened species
Sensitivity	No recovery required	Will recover completely	Moderate change to ecosystem	Major change to ecosystem	Will not recover
Frequency	One-off	Once per year	Once per month	Once per week	Once per day
Social					
Number of people	Individual	Few people	Hundreds	Thousands	Tens of thousands
Spatial	Within work site	one dwelling / small workplace	Number of workplaces / residential neighbourhood	Suburb	Canberra
Personal Effect	Indirect effect	Direct effect	Injury	Serious injury	Lethal Impact
Frequency	One-off	Once per year	Once per month	Once per week	Once per day
Economic					
Community Costs	Minimal cost	Thousands	Hundreds of thousands	Millions	Tens of millions
Duration	Single event	Short term	Medium term	Long term	Permanent
Frequency	One-off	Once per year	Once per month	Once per week	Once per day

Table A2: Risk Assessment Likelihood Matrix

Likelihood	Occurrence
Remote	May occur, but only in exceptional circumstances
Unlikely	Not expected to occur in most circumstances
Possible	May Occur
Likely	Probably will occur
Almost Certain	Expected to occur

Table A3: Risk Assessment Risk Ranking

Likelihood	Consequence				
	Minimal	Minor	Moderate	Major	Severe
Remote	Negligible	Negligible	Very Low	Low	Medium
Unlikely	Negligible	Very Low	Low	Medium	High
Possible	Very Low	Low	Medium	High	Very High
Likely	Low	Medium	High	Very High	Significant
Almost Certain	Medium	High	Very High	Significant	Significant

Appendix B

Risk Assessment

Category	Potential impact	Risk assessment (before mitigation)			Mitigation measures	Risk assessment (after mitigation)		
		Likelihood	Consequenc	Risk		Likelihood	Consequenc	Risk
Human health	Ingestion of recycled water from a cross connection between the recycled water and potable water systems	Likely	Moderate	**High**	Pressure differential between systems Appropriate treatment according to guidelines Plumber training and inspections	Unlikely	Moderate	**Low**
Human health	Ingestion of food crops that have been irrigated with recycled water	Possible	Moderate	**Medium**	Consumer awareness through education Appropriate treatment according to guidelines Signage and purple pipes and fittings	Unlikely	Minor	**Very low**
Human health	Ingestion of recycled water intended for use in the garden	Possible	Major	**High**	Consumer awareness through education Appropriate treatment according to guidelines Signage and purple pipes and fittings	Unlikely	Minor	**Very low**
Human health	Ingestion of recycled water aerosols intended for use in the garden	Possible	Moderate	**Medium**	Appropriate treatment according to guidelines	Possible	Minor	**Low**
Human health	Ingestion of recycled water aerosols from toilet flushing	Unlikely	Moderate	**Low**	Appropriate treatment according to guidelines	Unlikely	Minor	**Very low**
Human health	Ingestion of recycled water aerosols from washing machines	Unlikely	Moderate	**Low**	Appropriate treatment according to guidelines	Unlikely	Minor	**Very low**
Human health	Ingestion of recycled water by operations and maintenance staff	Possible	Major	**High**	Appropriate treatment according to guidelines Employee education	Unlikely	Minor	**Very low**
Human health	Ingestion of recycled water aerosols by operations and maintenance staff	Possible	Moderate	**Medium**	Appropriate treatment according to guidelines Employee education	Unlikely	Minor	**Very low**
Environment	Build up of nutrients and/or salts in the environment impacting soils and plants	Possible	Moderate	**Medium**	Appropriate treatment according to guidelines Investigation studies to identify suitable soils Community awareness through education Monitoring	Unlikely	Minor	**Very low**
Environment	Nutrients and/or salts leaching to receiving waters (ground and surface water)	Possible	Moderate	**Medium**	Appropriate treatment according to guidelines Investigation studies to identify suitable soils Community awareness through education Monitoring	Unlikely	Minor	**Very low**
Organisational	Consumers choose not to use recycled water - economic impact to proponent	Possible	Major	**High**	Community consultation during project planning Community awareness through education	Unlikely	Moderate	**Low**
Organisational	System fails to meet demand	Possible	Moderate	**Medium**	Potable water back up Agency monitoring of supply availability	Unlikely	Minor	**Very low**