Water harvesting techniques for small communities in arid areas

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Abstract Limited water resources exist in numerous remote indigenous settlements around Australia. Indigenous people in these communities are still living in rudimentary conditions while their urban counterparts have full amenities, large scale water supplies and behavioral practices which may not be appropriate for an arid continent but are supported by extensive infrastructure in higher rainfall coastal areas. As remote indigenous communities continue to develop, their water use will increase, and in some cases, costly solutions may have to be implemented to augment supplies.

Water harvesting techniques have been applied in settlements on a small scale for domestic and municipal purposes, and in the large, broadacre farm setting for productive use of the water. The techniques discussed include swales, infiltration basins, infiltration trenches and "sand dam" basins.

This paper reviews the applications of water harvesting relevant to small communities for land rehabilitation, landscaping and flood control. Landscaping is important in these communities as it provides shelter from the sun and wind, reduces soil erosion and hence reduced airborne dust, and in some cases provides food and nutrition. Case studies of water harvesting systems applied in the Pilbara Region, Western Australia for landscaping around single dwellings in Jigalong and Cheeditha, in a permaculture garden in Wittenoon and at a college and carpark in Karratha are described.

Keywords Arid areas; flood control; landscaping; water harvesting

Introduction

Small Aboriginal communities in arid areas in Australia have limited water supplies that contribute to a higher incidence of health related problems compared to the non-Aboriginal population. Water harvesting provides a means to supply non-potable water for reuse without putting additional strain on existing sources. This paper discusses various techniques for water harvesting that are suitable for small communities in arid areas. Four communities will be used as case studies in water harvesting for irrigation and flood control purposes.

Water resources

Australia has the lowest precipitation of any inhabited continent on earth. Despite this, the majority of Australians enjoy good quality water (Federal Race Discrimination Commissioner,1994, p12). While this is a comforting thought for those of us living in the cities with centralised water supply schemes, an estimated 54,000 Aboriginal people are served by water supply schemes supplying fewer than 1,000 people. In Western Australia 10% of such schemes supplying fewer than 1,000 people cannot meet peak day water needs. In addition, the 1997 Environmental Health Survey of Aboriginal communities in Western Australia (Environmental Health Needs Coordinating Committee, 1997, p22) indicated that 7.5% of Aboriginal people living in Western Australia had an inadequate water source in terms of quantity. Water in these small communities is sourced primarily from groundwater, although some is from rainwater tanks and some is carted in on trucks.

In terms of quality, none of the small communities (population less than 20) in the Environmental Health Survey had water that is disinfected and only 10% test their water at

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least monthly in Western Australia (Environmental Health Needs Coordinating Committee,1997, p22). Other problems with water quality in arid communities are the high, naturally occurring, mineral salts common in artesian water which solidify on water fixtures and pipes leading to increased leakage and poor performance (Pholeros *et al.*, 1990, p90).

This lack of clean water contributes to a significantly poorer health status in these remote communities. Aboriginal people have a life expectancy between fifteen to twenty years less than non-aboriginal Australians. They have a higher incidence of many diseases including diarrhoeal disease, acute resipiratory infection, skin infection, Hepatitis B and eye infections as a direct result of poor sanitation and water supply (Pholeros *et al.*, 1990). Water harvesting provides a sustainable way of improving the living environment in these communities which is a critical factor in reducing health problems.

Stormwater harvesting

Water harvesting can be defined as the collection of water as a product of intended or planned action. Artificial harvesting can be interpreted to be the collection by humans using some artificial means and not relying simply on natural processes. In the context of artificial harvesting, it can be inferred that following collection, water is stored and subsequently used for some purpose, from potable supply to less obvious uses such as abatement of flooding. Traditionally, stormwater has been the main source of water for reuse but increasingly treated effluent is providing a valuable source of water. The term "water harvesting" can also be used to define techniques used to decrease the amount of runoff from a site. This is required, particularly in urban areas where an increase in impervious surfaces has increased both total and peak flows downstream with detrimental impacts on downstream flooding and ecology.

Harvesting techniques

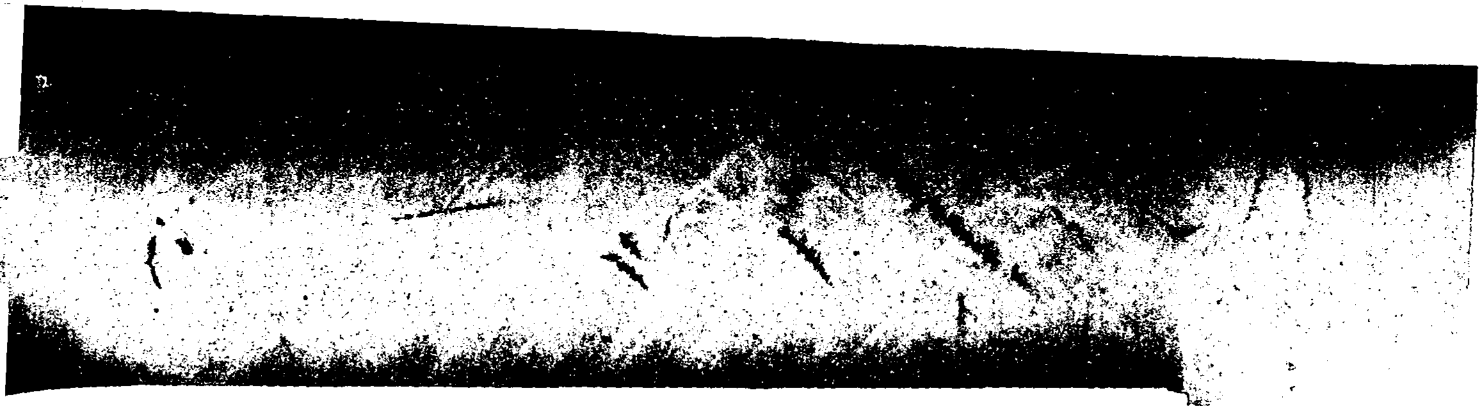
Swales (Water and Rivers Commission, 1998, p100 and Auckland Regional Council, 1992, p135–146) are open, vegetated channels that reduce runoff velocity, promote infiltration, remove sediments and can be used to increase available water to plants. Reuse occurs either by direct uptake by plants or by using groundwater recharged from the swales.

Infiltration trenches (Auckland Regional Council, 1992, p121–132) are rock-filled trenches which fill with stormwater then empty by percolation into the soil. The trenches can be planted with vegetation that transpires the water or can be used to recharge the groundwater table and be extracted later for reuse.

Infiltration basins (Water and Rivers Commission, 1998, p118) are similar to infiltration trenches, but are open excavated basins used in high permeability soils to facilitate groundwater recharge. This water can be utilised by plants or can be collected in a surface aquifer and be pumped out at a later date for reuse.

"Sand dam" basins (Orion,1996) are small clay lined basins, approximately 1 m × 2 m, filled with a layer of quartz sand and manure overlain by a layer of quartz sand, leaves, twigs, manure and 15% clay. They act to retain water and provide suitable conditions for growth of plants. Basins are interconnected with the lower basins receiving flow only in the larger rainfall events.

Harvesting rainfall from roofs (Hart, 1986, p62) can easily be achieved by not using gutters and instead, allowing the runoff to fall off the roof into garden beds, landscaped areas, stone mulch or grassed areas. Roof runoff can also be collected in gutters and directed to a rainwater tank, constructed of concrete or metal. It is advisable to incorporate a first flush diversion before flow into the storage to remove the first wash of the roof and remove the majority of contaminants.



Harvesting rainfall from carparks (Hart, 1986, p64) can be achieved by having a raised carpark surface, with runoff directed onto the surrounding garden, particularly trees, by either gaps in the kerbing or having no kerbing at all. Semi pervious carpark surfaces can also be used to increase the recharge of the groundwater and reduce surface runoff.

Runoff from a rocky outcrops (Tjitayi *et al.*, 1979) or from the construction of an impervious surface on the ground itself can also be used for harvesting rainwater. The latter can be achieved through reinforced concrete to prevent cracking. Alternatively, a large piece of plastic sheeting can be laid in a hollowed out and leveled area of ground. A drainage system will drain the water away to the reservoir or tank and a layer of coarse washed river sand or gravel is laid on the bed (Dixit and Patil, 1996).

Air wells (Hutchnison, 1982) are systems that condense water out of humid air by using a combination of cooling and increasing pressure. A wind turbine is used to draw air into an underground heat exchanger. In the exit pipe there is a flow control valve, which compresses the air slightly. The water condenses out and collects in a tank.

The technique of underground membranes uses a horizontal impervious membrane located around 60cm beneath a sandy soil. The membrane prevents the rapid percolation of water down to depths below the root zone of the crops, which are planted above (Finkel *et al.*, 1986).

A fog collecting system is installed on the slopes of coastal mountains at El Tofo to provide water to Caleta Chungungo in Chile (Smithsonian Institution and UNEP, 1995). This area is arid although there is often a cover of fog known locally as Camanchaca. The system consists of large nets arrayed perpendicular to the landward flow of the fog. The fog condenses on the mesh and drips into a trough at the bottom. This is probably not appropriate for remote Aboriginal communities, as they often experience low humidity.

Wittenoom

"Sand dam" basins have been constructed in the northern mountains in the Pilbara in Wittenoom (Orion, 1996) 1,500 km north of Perth. Their climate is extreme with summer temperatures exceeding 45 degrees Celcius and winter temperatures rarely below 4 degrees Celcius. Rainfall is over 400 mm per year.

The site is the location of an arid/tropical permaculture research facility and consists of gardens, one residence and a small backpackers' accommodation. The basins were designed for a surface flow of 25 mm per hour, which occurs in the area as often as 4 times a year. Each basin is approximately 1 m x 2 m and its depth varies according to its position in the catchment and hence amount of runoff it is likely to receive. Basins at the beginning of the water harvest channel are shallow but long to act as filters for removing unwanted materials and seeds. Further along the water channel, basins are broader and deeper as they only get water from moderately heavy rainfalls. The final basin is the largest at around 5–20 square metres and 450–600 mm deep. A special rock valve is placed at the entry point that is designed to "blow out" when rainfall exceeds 100 mm per hour (Orion, 2000).

Cheeditha

Basins and swales were constructed at Cheeditha, an Aboriginal community on the outskirts of Roeburn, 30 km from Karratha. Rainfall is between 100–400 mm per year although there is a superwet every 10–11 years with very high rainfalls and extended periods of drought. Annual evaporation is at least 2.5 m with strong hot winds causing a large amount of evaporation.

In 1997, a "Greening Cheeditha Project" developed a water harvesting plan for six residential lots. This included the construction of earth banks and swales along natural topographic lines to direct yard runoff into a number of depressions which were then planted with juvenile trees, shrubs and groundcover. Species included Carobs, Albizias, fruit trees (Mangoes, Figs, Oranges, Lemons, Grapefruits, Guavas), shrubs such as Wattles, Daturas, Cotton, Saltbushes, Basil, Gooseberry and groundcover including Herbs, Grasses, Creepers (eg Lippia/Spinifex).

As many of the fruit trees are sensitive to disturbance there were problems in initial establishment. Particularly, as they were planted when the weather was possibly too warm and the plants were subject to increased traffic over the summer months as more people came to the community.

Cheeditha is a windy place with problems of soil erosion and health problems such as eye diseases resulting from the dusty environment. As such, the most pressing need was shelter from the wind and reducing airborne dust. Vegetation reduces the risk of erosion, hence dust generation, as well as providing wind breaks for the houses. Three of the houses were prone to flooding and a way of removing runoff from certain areas and maximising infiltration needed to be implemented. The swales and basins constructed are proving successful in meeting these objectives as well as providing traffic control.

It was found that the basin walls needed occasional maintenance to ensure that they didn't leak excessively. Plants in the higher basins and along drainage lines were found to survive well. However, many plants on the banks did not obtain enough water to survive and plants in the lowest basin were prone to water logging and rotting.

Plantings were undertaken with juvenile plants on bare earth that acted as pioneer species to encourage subsequent plantings. Some of the more sensitive species were lost in the first year and would have been better planted in the second year when surrounding plants were more established and would have provided some protection and resources to the more sensitive species. In addition, tree guards were not provided which lead to further losses and should be used in subsequent projects. Companion plantings of compatible species in future projects would also increase the success rate.

Further research is required in quantification of total and peak inflows as well as survival over extended periods of drought. This will assist in better sizing of basins, placement of plants and will determine if it is possible for no generation of runoff to be achieved, as required by some shires. Another area where research needs to be conducted is in ranking the hardiness of plants in terms of water requirements and where they should be planted. The range varies from plants with low water requirements and highly placed to sensitive, high water use plants, placed in the bottom of the basins and swales.

Jigalong

Swales and basins have also been constructed in the Jigalong Community located on the edge of the Western Desert Region, 110 km east of Newman. Like Cheeditha, rainfall is low with the annual average around 100–350 mm (Orion, 2000). The majority of this occurs during the summer months due to cyclonic activity. However, there is some winter rain from frontal systems that normally approach from the east.

In Jigalong, earth banks, swales and basins have been constructed alongside roads, which were then planted with mature trees already available in the community (Orion, 2000). The majority of species available were not appropriate for the area as some required considerable care, particularly in the early stages, and some were relatively high water usage plants. Jigalong is an area of severely limited water resources for drinking and washing, let alone for irrigation of high water use plants. As such, water for irrigation purposes should be sourced from supplies unsuitable for potable use. In many Aboriginal communities, cultural factors can result in plants being left unattended for significant periods of time, during which they may die. As such the more hardy and low water use plants were selected. Species included Palms, Eucalyptus, Bamboo, Hibiscus, Grevillea, Figs, Jacaranda, Kings Park Bottlebrush, Bougainvillaea, Liquid Amber, Illawarra Flame trees and Poinceiana. It is interesting to note that the Aboriginal community members expressed a strong preference for brightly coloured trees, particularly for the colour red. Unfortunately, many of these brightly coloured plants are exotic species and less adapted to the local conditions.

Street plantings were implemented in three locations, with one site using swales only, and two sites using a series of basins for stormwater retention. Basins were constructed besides the Training Centre covering an area approximately 15 m × 6 m. Swales were also constructed in an open space area near the store approximately 30 m × 40 m in size. At the Mechanics Workshop, basins were filled with rubble and river sand and the entire area covered approximately 20 m × 5 m.

Flooding was a high priority at the site located near the Mechanics Workshop where the constructed basins provided an area for stormwater collection. All three sites benefited from shade and partial shelter from the wind.

Some problems were encountered, particularly due to the plant species available in the community. The figs were transplanted from another garden and had difficulties surviving, probably due to damage during transportation. Another issue identified is establishment of the pioneer species and first plantings before other, more sensitive plants can become established. For example, a common practice in the community is to rake the ground to remove the prickly groundcover, which act as pioneer species. However, this also prevents other more desirable species from becoming established and causes erosion. Community awareness and involvement is required to alter the practice of raking and allow the development of the plants in the early stages.

The above projects were conducted adjacent to roads and in front of a few houses. Water harvesting would prove effective in other areas within the community, such as directly adjacent to the buildings. One of the problems surrounding the buildings is erosion of the soil following wash down off the verandahs and undercutting of the concrete. Gravel trenches planted with trees would reduce the erosive potential and utilise a precious resource providing shade, wind shelter and food.

A follow-up study is yet to be conducted to investigate which plants survived, particularly after recent regional flooding. In particular, there is the danger that some of the trees may have toppled over due to water logged soil and lack of support for the plants.

Karratha

About 60% of the weekly rainfall in Karratha is insufficient to stimulate plant growth. As such, useful rain needed to be increased by water harvesting techniques to increase the period of effective rains.

A successful water harvesting project has been developed at Karratha College (Nicholson, 2000). The college buildings have been aligned along the contours with buildings terraced up the hill. All buildings have large verandahs, no gutters, and roof runoff directed onto the surrounding landscaped gardens located between the buildings. The water harvested in this area considerably increased the amount of useful rainfall. In these gardens, tropical species including Palms and Bougainvilleas were planted and thrived. Any overflow from these gardens was directed down the hill to an ethnobotanical garden planted with indigenous edible foods and beneficial plants. The seed stock for this garden was collected by Aboriginal women from Roebourne, who also assisted in the documentation of the plant information. This included the history of the plants, associated mythology and traditional uses. Runoff from the front of the site was directed into swales and an open landscaped area, planted with indigenous, low water use plants.

Other developments in Karratha include swales that were constructed adjacent the road in a roadside parking area and planted with trees. In addition to shelter, these provide an attractive area for passing motorists to rest. There were some problems in the early establishment stages following a heavy rainfall that drowned the trees before they could become established. The swales were replanted and are now mature.

Conclusions

Water harvesting is an ancient method of collecting water that is yet to be utilised to its full potential. Work in Jigalong, Cheeditha Wittenoom and Karratha shows that it provides valuable irrigation water in harsh climatic and environmental conditions. Although care needs to be taken in the early establishment stages, many of the plantings proved effective in providing protection from the sun and wind, flood control, aesthetic amenity, and in the case of fruit trees, they provided a nutritious food supply. Water harvesting is an environmentally sustainable, relatively low maintenance, irrigation method that improves the living environment of Aboriginal communities in arid areas.

Further research is needed in the areas of quantifying variations in inflows into basins and survival of plants over periods of extended drought. Follow-up studies are essential to investigate plant selection and placement within the harvesting system. In addition, research into management of the system in terms of planting seasons and follow-up maintenance needs to be conducted.

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