Alternative water resources for Australia

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Summary

Every day on average we receive almost a million litres per day per person. Even in the drought we received almost half a million litres - far in excess of our requirements. Our water shortages are not caused by a lack of rain but a failure to implement technologies appropriate for a dry and arid country.

Here I aim to analyse why we capture such a small proportion of the rain that falls and describe the technologies more appropriate to our climate. Essentially much water is lost by evaporation before it even reaches our dams. We need to harvest and store more of the rain then protect it from evaporation. There are number of ways, anticipatory irrigation, wicking beds and the local harvesting and storing in the soil or shallow aquifers.

This is not just a simple change in technology; it presents a paradigm shift in water management for arid climates. It needs a change in organisational structure and mind set from managing a few large mega projects to multiple small local projects,

I analyses the limitations of current approaches, in which we essentially only harvest large rains which cause run off (alpha rains). These alpha rains are unreliable and only form a small proportion of the total rainfall; we need to harvest the much larger volume of smaller rains (beta and gamma rains).

I then describes the technologies to do this and proposes organisational ways in which they can be adopted. The final recommendation is setting up a task force to transform these technologies from fringe to mainstream status.

Part 1 Defining the problem

Introduction

All Governments but particularly the Queensland Government face serious challenges in providing an adequate water supply with the ever increasing population and the predicted effects of global warming. The challenge is to design a water supply system to cope with an increase in evaporation, a reduction in rainfall and an increase in the magnitude of the classic flood and drought cycle.

These present such severe challenges that new approaches will be required. Dams are an essential part of a long term water strategy. However they must become part of an integrated holistic approach to water management.

The first step in developing this holistic approach is to clearly define the challenge we face.

Our climate and global warming

S.E Queensland lies in the arid belt between the tropical rains of the north and the winter rains of the south. The climatic features are a consistently high evaporation which far exceeds rainfall, with occasional large freak rains from the North in summer and from the South in winter. It also receives a regular and reliable rainfall from coastal showers.

This high evaporation causes a dry crust to form on the surface of all vegetated land, including catchments. This crust insulates water deeper in the ground from further evaporation and is an essential requirement for any form of vegetation to survive.

A small rain of typically less than 10 mm will simply wet out this virtually dead crust and evaporate within hours of the rain falling. It is virtually useless. (However these small rains can have significant value when they fall on an impervious surface such as a roof top or road surface.)

A heavier rain will penetrate this crust and water will percolate down to the root zone. But there will be no surface run off or penetration of the water beyond the root zone. While this rain maintains plant life (and so has significant environmental benefit) it is of little value in providing water for human use, at least in the way we currently harvest water.

A larger rain will generate a combination of direct run off, (eg it is available to fill a dam) or it may soak deep into the ground beyond the roots zone. The chances are that it will reappear as a soak or even form a creek which may provide useful water. This water will not be lost but its path to dams and streams depends on the local hydrology.

The minimum size of a rain to provide either runoff or a deep soak is the threshold value and is a critical concept in developing a water system which can cope with the effects of droughts or global warming.

The actual value of this threshold depends on many factors, the soil type, the intensity of the rain but, most importantly, the moisture content of this insulating crust. In the dry S.E Queensland a minimum value may be 50 mm of rain. However, in the recent dry period I have measured 115 mm before any run off occurs.

The major threat of global warming is the increase in this threshold value eg it requires bigger rainfalls before there is any run off. The term ‘alpha’ rains can be conveniently used to describe these large rains which generate run off. The effective size of an alpha rain is the excess over this threshold.

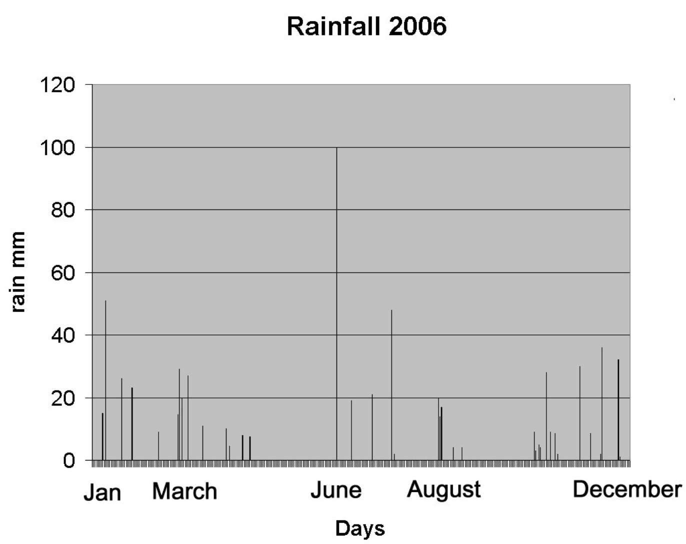
Beta rains are those that penetrate through the insulating crust and provide water to the roots systems while gamma rains are those very small rains which fail to penetrate the crust.

Only alpha rains are of any use in filling our current system of dams.

The great danger of droughts or global warming is the increased threshold value for run off (from higher evaporation) which reduces the effective size of the highly beneficial alpha rains.

Alpha, beta and gamma rains

Rainfall data is often presented as the total volume or average rain. More important, is the rainfall distribution; - how much rains falls as alpha, beta or gamma rains. Such detailed reports are available from the Bureau of Meteorology.



The graph shows an actual rainfall distribution for the region. There is only one alpha rain for the entire year, the bulk of the rain falls as beta rains. Gamma rains are more common but are so much smaller that the accumulated rainfall is less

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Rainfall data is only part of the story, equally important is the evaporation, particularly just before and after a rainfall event.

The importance of this is readily seen in the proportion of rainfall actually captured. In the critical Coolangatta, Bundaberg, Toowoomba coastal rectangle only 0.2% of the total rainfall was captured. This compares badly with the Murray Darling Basin where 5% of the rain is captured.

The major difference is the combined effect of rainfall and evaporation.

In Queensland alpha rains tend to fall in summer when evaporation is high. Typically evaporation is over 10 mm per day so rain falls on predominately dry soil. Alpha rains can also fall in winter when they may be smaller but are more effective. Even so winter evaporation is still relatively high between 3 to 5 mm per day so soils are generally dry even when winter rains falls.

In the Southern Alps rain falls mainly in the winter when evaporation is low so there is significant capture of the rain. The rain falls when the evaporation is lowest.

Even then only 5% of the rain is captured. To make the point the Basin recently received a good rainfall of some 25 mm. This amount of rain, spread over the entire basin, delivers more rain than the entire flow of the Murray in a good year. Yet the run off into dams was negligible and the rain will have evaporated within a few weeks.

The majority of the world's population live in arid regions, but they have significant cold mountain ranges with much higher capture rates. John Pigram in his CSIRO published book 'Australia's water resources' quotes figures for the percentage run off in various countries.

South America is the highest with 57% run off; most other continents are in the 40 – 50 % bracket with Africa just missing out at 38%. Australia comes in at a woeful 12%. But this includes the run off in our tropical North and wet and cold Tasmania. The Southern Alps help maintain the Murray Darling Basin at 5% (less than one tenth of America) while SEQ only manages 0.2%. Yet the way we harvest rain in Australia makes us more dependant than any other continent on surface water.

Region	% run off
S. America	57
N. America	52
Asia	48
Europe	39
Africa	38
Australia	12
Murray Darling Basin	5
South East Queensland	0.2

S.E, Queensland stands in an extremely fickle position, it has a high and rapidly expanding population, with no serious mountains and it is dependant on fickle freak alpha rains for its water supply. It is very different to other areas of the world. Just because technologies such as dams work well overseas does not mean they are automatically the correct solution for Australia. We are very much out on our own and have to look for solutions relative to our climate.

(These points are better explained in the video '*Water and the whistle blower – an independent assessment of the effect of global warming on water*' which is available as a free download at www.waterright.com.au. Copies are also available directly form the author.)

Drought cycles and global warming

After some ten years of drought our dams now have less than two years supply of water remaining. This is a direct result of our dependence on alpha rains.

Yet the amount of rain falling as beta rains is over a hundred times our current water consumption. There is a total abundance of water largely going to waste by evaporation - water which is just waiting for us to harvest.

Even in the worst case scenario of a prolonged drought whether caused by global warming or the natural drought cycle there is no need for us to be short of water, there is more than enough.

Harvesting beta rains is a more secure alternative to projects like the Mary River Dam or diverting a river system such as the Clarence. These are totally dependant on alpha rains and can therefore not be regarded as a reliable water source. Improving our capture rate by harvesting beta and gamma rains is the solution.

We can and should continue to improve our current use of alpha rains by better water efficiency and recycling, but these gains are marginal. Desalination can certainly provide an additional source of water totally independent of rain, and can form part of an integrated water strategy providing a base line for essential requirement such as drinking and cooking. However, the amounts of water are trivial in comparison with either our total requirements or the water that falls as beta rain. They make a useful last stand.

The volume of rain falling as beta rains is some 10 times that of alpha rains. The catchments areas for alpha rains are limited essentially to rivers and their valleys which represent only a fraction of the total land area. By contrast beta rains can be captured and used locally virtually anywhere increasing the effective catchment area many fold.

This means that the total volume of useable beta rains is a couple of orders of magnitude higher than alpha rains. There is an abundant supply of these reliable beta rains.

Total rainfall per head of population across the continent approaches a million litres per person per day, some 2,000 times our needs. That is an astounding figure but somewhat inflated by the large rains in the Northern tropics. But narrowing down to the area in the Coolangatta, Bundaberg, Toowoomba rectangle shows there is still several hundreds times the amount of water we need.

Risks of relying on alpha rains

Projects like the Mary River Dam and the Clarence diversion may instil a sense of confidence that the water crisis is under control but they are totally dependant on the unreliable alpha rains and do not provide security.

Beta rains may involve adopting new technologies and organisational structures, but they do provide a much higher level of security.

Major change takes time to implement; we are not just running out of water, we are running out of time.

In a cold climate where the land is generally wet, building a dam in a deep mountain valley is by far the cheapest and most convenient way of capturing water. Even better; - this can be readily distributed under gravity without external power.

Dams, when they work, are extremely effective and economic. But in S.E Queensland, which has some of the worst conditions for capture, they do not provide water security.

We have seen the effect of a drought; the recent rains do not mean it is all over, global warming is an unknown but ever increasing threat. Relying on random alpha rains to fill our dams is a high risk approach. Harvesting beta rains provides security.

Summary

In SEQ dry and arid climate soils in the catchment dry out. Dams are only filled by large alpha rains which are unreliable. Total rainfall in the current drought is below average but the real change is the reduction in alpha rains. The amount of rain that falls as beta and gamma rains is much more stable.

The volume of water in these beta rains far exceeds requirements. The emphasis should be on how to capture more of these abundant and reliable Beta rains.

Part 2 Capturing beta rains - organisation and technology

There are many different ways of beta harvesting but they are all best used as a component in an integrated water system. Before having a look at the many technologies I want to demonstrate what is meant by a hybrid system using one of the simplest forms of beta harvesting, the household water tank.

Integrating dams with beta harvesting

Beta rain harvesting is not a stand alone option, we can not wait until the dams are empty then change to Beta rain harvesting. It must be integrated in with dams. Beta rain harvesting should be used to substitute for dam water allowing the dams to fill in rainy periods when it is easy to harvest rain.

It is clearly tempting when the dams are filling and rain is plentiful to use the cheap and readily available dam water. Historically we have failed to resist this temptation; we have made use of the dam water when it would have been very easy to make widespread use of beta rains to allow the dams to fill further. If we started beta harvesting five years ago our dams would still be relatively full.

We should learn and be ready for the next drought when the water is really needed.

We need to encourage widespread use of beta rains to take the demand load of our dams in periods of rain when beta rains are readily harvested allowing the dams to fill ready for the next drought.

Probability theory is not the most exciting of subjects but is at the essence of hybrid water schemes. Water tanks are a simple example. Country people are used to water tanks but there is a much resistance to water tanks in urban area. This is largely because it is perceived that urban water tanks have to be large, like rural water tanks.

Urban water tanks do not have to be large to provide all water needs. All they have to do is substitute for **some** dam water. They can be small but still effective.

Let us take a very simplified model where the chance of rain is 1 in 20. Over a long period of time we will receive, on average a rain every twenty days. We can use probability theory to calculate how much water we can catch and use. We will still use the same amount of water - we are just substituting dam water with rain water.

Let us look what happens as we gradually increase the size of the storage tank.

With just one day's storage 5% of the water will be replaced. Hardly worth the bother! A 2 day supply again only replaces 9.8% of dam water – no big deal. 5 days gives us 23% water replacement, beginning to be useful. But at 14 days supply we have replaced 50% of dam water.

Let us put this in plain English. If every user of water were able to store enough water to last them for just 2 weeks it would be the equivalent of doubling our supply of dam water. That is a powerful statement.

Now let us look at what is needed to get high levels of water security. Storing a 100 days supply gives us a 99.4% security - good but not really secure, we have to go to 180 storage capacity to 99.99% secure.

Water storage in days	% mains water replaced
1	5
2	9.8
5	22.6
7	30.2
10	40.1
14	51.2
20	64
50	95
100	99.4
180	99.99

The results are very clear. With an integrated system we only need to store a relatively small amount of water (14 days) to achieve very significant savings.

Large deep dams can hold water with acceptable evaporation losses for many years. The key to water security is to use beta rains wherever possible, keeping the dams full as long as possible.

Integrated systems at the home

If we use water tanks as part of an integrated system even small tanks are highly effective. Let us take a system where a house has say a thousand litre tanks on each corner, (4 tanks) these are connected by a pump and filter to a further thousand litre tank in the roof. Highly efficient revered osmosis filters are available if needed but generally tank water is of a higher standard than most water supplies.

This tank in the roof is connected to the mains water so that when all tanks are empty the system automatically diverts to mains water. Using actual rainfall data we can see that for some 80% of the time the household would be using tank water and only 20% of the time would mains water be needed.

In water crisis they would be no need for water restrictions. At the extreme, mains water would simply not be available after adequate rain but would be turned on after a period without rain. People would very soon get used to the idea that they had to make do with the water in the tank until either the mains water was turned on again or it rained.

They can use the water however they like; it is their problem to ensure they do not run out of tank water before the water is turned on again. If they want extra water they just put in a bigger tank.

Economics of tank production

There is a good reason for selecting a small tank. Currently most water tanks are made by rotational casting, a slow process where the mould has to be heated and cooled which limits the production rate. It is an expensive and limited production system but is good for making large tanks.

Mass production of water tanks needs a high volume production process like blow moulding. This is the process used for making drink bottles and can produce literally thousand of bottles per day.

One blow moulding machine could produce some 1,500 small tanks per day at a cost of about $60 each. There are a number of manufacturers with the potential capability; the barrier is the high capital cost (about a million dollars for tooling and the large machine).

Companies would be willing to invest if the market were assured by Government policy.

Roads, beta and gamma rains

Our road surfaces naturally harvest very large quantities of beta and gamma rains. Unfortunately it is usually highly contaminated and full of rubbish. However using the concept of micro dams and percolation holes this water can be captured and stored in the ground. These are more fully described on the web site www.waterright.com.au

Alpha rains may be beyond the flow rates of percolation holes, so like tanks they has to be overflows when water is wasted.

Part 3 A glance into beta harvesting technology

Capturing beta and gamma rains from impervious surfaces is not difficult. But most rain falls on dry soil requiring more sophisticated approaches.

This cannot be a detailed description on beta rain harvesting. The aim is to show that capturing beta and gamma rains is both viable and economic. It is not a detailed presentation on the technologies but aims to give a basic appreciation of the technologies.

A simple demo

Take two deep clear containers; fill both with soil and a plant in one. Fill with water and watch the evaporation by looking at the water level. A dry crust will quickly form in both pots, may be within hours, a most a day. The dark soil heats up so its evaporation is faster than pan evaporation.

Over a few days the water level in both pots will drop to about 50 mm. Thereafter the rate at which the level in the pot without a plant will exponentially slow down and by the time the level has dropped to about 300 mm it will have virtually stopped. The level in the pot with a plant will drop faster until it has dropped below the root zone when the plant will die and the level again will virtually stop.

If the pot is deep enough there will still be a lot of water in the base of the pot virtually protected from evaporation.

Why do this simple demo? Because it shows one of the basic features of beta harvesting, get the water deep in the ground, below the root level where it will remain protected until needed. (It also helps us separate evaporation from plant transpiration.)

Storage of water in aquifers is an established practise, but we can store water in most soils. The use of deep aquifers is well established, many overseas counties rely heavily on aquifers. Less so in Australia where it is far more appropriate. However here we are talking about using shallow aquifers just under the surface.

How desert plant survive

Desert plants survive, even when rainfall may by only 100 mm and evaporation over 2 metres. Superficially this may be attributed to the specially developed plant physiology such as leaf and root structure and water storing adaptations.

These are of course important but without the appropriate local hydrology they would not survive.

There are many areas where the hydrology is wrong and nothing grows, there are other areas with the hydrology is right and many plants, even plants we would not classify as true desert plant survive. The local hydrology is the crucial element.

The key principles are amplification, transport and storage (in the soil).

After a rain many seeds will germinate and put down roots. Most die and the roots rot or are eaten by termites forming holes in the ground which act as percolation holes. Deserts are full of dead trees and plants which did not make it, but they are sacrificial allowing the few that do survive to flourish.

This area of dead vegetation is a catchment area. If the surface is smooth it would be a very inefficient catchment and no plants would survive but a rough surface may allow water to reach the ex roots of the dead trees.

During the next rain water percolates down these ex root holes and if the hydrology is right water may well flow underground, combine with other flows and form a subsurface pool which will feed those plants lucky enough to be immediately above the pool.

This is a natural process of amplification. Isolated plants will survive in the middle of what appears to be a barren plain by receiving water from a larger area. If this catchment area is ten times the plant area the 100 mm of rain has been amplified to 1,000 mm of rain.

This is a natural process which has been going on for million of years. All we have to do is imitate this natural process.

Traditional desert farmers use this technique by ridging their fields to deflect water to the roots of their plant. Dates have been grown this way in the Middle East for centuries. We are just looking at modern versions of these ancient technologies.

Beta rains are most easily exploited for growing plants, from commercial agriculture to urban gardening. It can also capture utility water which could be used of a variety of household and industrial usage. Further treatment is needed to produce potable water.

Beta harvesting in dry land horticulture

The modern version is to work an area of land to divert any flow under the ground, where it is protected from evaporation. In horticulture or agriculture the collection area may be close to the crops, row crops are a natural target as water will then move though the ground and feed plants directly.

Inter row areas can be sloped and channelled to direct the flow into percolation holes which take the water directly to the root zone.

Beta rains in irrigation

The easiest way to harvest beta rains is in irrigation. Again this is a process of replacing alpha water from dams with beta rains collected locally. Of course this happens automatically for rain that falls on the plants but it is simple to work the ground to imitate the natural process of desert plant survival.

Anticipatory irrigation, wicking beds and micro dams with percolation holes are all ways of capturing, amplifying and storing water in the soil.

Anticipatory irrigation

Anticipatory irrigation is the simplest and most cost effective method of beta harvesting. It is a method of irrigation scheduling combined with weather forecast. Typically irrigation is applied **just after** a rain, when the soil is already wet so the irrigation water penetrates deep into the ground without wasting water wetting the surface.

It is necessary to know how much water to apply; this is best done using software which analyses the irrigation history (typically using soil moisture sensors) to 'learn' the irrigation characteristics of the soil. This then automatically predicts how much water to apply so the water just reaches the base of the root zone without any wastage past the roots. The video on anticipatory irrigation provides more detail (www.waterright.com.au).

Wicking beds

Wicking beds are a simple and proven way of capturing and storing water and are already being widely adopted by dedicated growers. They can just as easily be used on a wide scale by commercial growers.

In essence they are an underground water trough, usually filled with a combination of soil and organic matter. Water wicks up to the root zone. In its simplest form it provides a very efficient and inexpensive form of subsurface irrigation but the real benefits come from the increased water holding capacity which increases the time between irrigations (filling of the water trough). Just as with a household water tank this increases the probability of a rain falling and so substitutes for external sources of water.

Wicking beds can incorporate 'wings' which direct rain water into the underground tank or they can be fed with water which may be collected externally.

Technical details are on the website www.waterright.com.au and in the various videos.

Leaky micro dams and percolation holes.

Leaky dams may sound bizarre. They are not intended to permanently store water but simply to catch and hold water while it soaks down a percolation hole into the subsoil. With the appropriate hydrology this water can then be harvested in the conventional sense.

If the micro dams are positioned at a higher level the water may well percolate to a lower level and appear as a soak, a conventional dam can then be constructed to harvest this water. Very large volume of water can be held in the soil so the lower catchment dam need not be large; it is more a way of accessing the water.

As water is extracted from the dam additional water will percolate into the dam so it is continuously topped up. It may take some significant time for the water to percolate through the soil which improves the quality of the water making it immediately useful as a source of utility water.

Part 4 Implementing beta harvesting

Beta harvesting may appear to be a very simple process that any person or local group could implement. But to achieve any worthwhile scale many such small schemes must be integrated into a system together with conventional dams.

Alpha water stored in dams and beta water stored in the soil are complimentary. Dam water is a centralised system where water is concentrated into a large dam and distributed over a large area by a complex reticulation system. It is generally managed and controlled by large, typically public entities.

Beta harvesting projects are small and local and would tend to be managed by individuals or local communities.

The challenge is to develop a technical and management system which exploits the advantages of both sources of water with a combination of centralised and decentralised management.

The politics of implementation

Beta schemes are best implemented at the local level, but there needs to be some incentive, in terms of either financial support or in a higher level of water security.

But there are logistical problems to overcome; there is a general shortage of expertise on beta schemes. People have to be trained, and various services such as hydrological, design and operational expertise need to be provided.

Information on the local hydrology is perhaps one of the most critical issues. Technologies such as electro magnetic mapping would appear to be a critical.

Governments have already demonstrated a willingness to invest money into water projects, but money by itself is not enough. There must be a system of rewards and a provision of services, particularly eduction and coordination, which realistically only Governments can provide.

Traditionally Governments have accepted the responsibility of providing water for the community. The reality is that Governments can no longer guarantee to supply water. Water security can only be provided by a combination of the existing large scale projects controlled by the Governments and smaller scale projects which involve significant involvement from the community and local organisations.

Making it happen

Despite the frustration in gaining acceptance of these ideas there are many people on the Government payroll who accept that logic but are prevented from taking action because of the highly fragmented and often internally competitive environment. It is fair to say that most seem to appreciate the logic of the arguments and agree that it should be done, but it is not their departments' role.

But there are solutions which are well established in private industry - what is called colloquially the skunk works. The most shining example is the ubiquitous PC. When IBM senior management realised that a desk top PC was almost inevitable they were faced with the problem of how this could be developed within the massive IBM infra structure. The large and powerful groups from the mainframe division, which then dominated IBM business, would see this as a threat to their core multi billion dollar business and could easily sabotage what they may see as a threat.

IBM solution was to incubate the PC in a skunk works outside the main area of business and giving that small group a degree of independence from the traditional business. We know the success.

The situation with water is similar to those heady days of the birth of the PC. Anyone outside the system, and I think many within, are totally bemused by the myriad of Government entities dealing with water. It is not unreasonable to expect that the powerful water entities, which generate significant revenues, would feel threatened by what is essentially a community contribution to the process of water collection and could feel their traditional monopoly position is under threat.

The solution is the skunk works approach - setting up a task force to establish beta rain harvesting sites at suitable locations.

Would it work? Well it has to be said it already is. I spend my time promoting these technologies and there is the beginning of a ground swell adoption. The early adopters generally fit into the environmental grower bracket but most encouraging is the adoption by schools. This is a very effective way of getting the message out to a large number of the future generation. But kids actually do talk to their parents who are adopting the ideas by a process of osmosis.

However this is a slow process. Anyone can look at the statistics on the dams and see the way the water is dropping. It is obvious that, despite the almost daily denials, Queensland is running out of water with at best two years to go. People understand that our dams running out is just like a car running out of fuel, everything is going fine until the car splutters to a halt.

With two years to go we are running out of time, this is not something that can be left to a few enthusiastic individuals. We are approaching a regional if not a National crisis and the Government needs to act. And not just by allocating large amounts of money to traditional projects from the old paradigm but accepting the need for action on the new paradigm.

Summary

Only Governments can facilitate the adoption of beta harvesting at the rate needed to ensure water security. There appears to be widespread acceptance of the need for beta harvesting at least by individuals within the Government entities, but it is always some other departments problem.

The recommendation is that the Federal Government establishes a task force with the twin aims of establishing beta harvesting schemes as demonstration sites and preparing plans how the technology could be widely adopted considering the current complexity of the structure of entities with responsibilities for water.

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