TEACHER RESOURCE

WATER

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CSIRO
CSIRO EDUCATION AND OUTREACH

Introduction to the guide

This Student Learning Resource is designed to assist high school teachers engage students in Years 7 to 10 in the study of water and related issues. It is supported by the use of the CSIRO text *Water: Science and Solutions for Australia* and links to the Australian Curriculum with a flexible matrix of activities based on the Five Es model.

The resource explores elements of Years 7 to 10 science and geography curriculums, covering the cross-curriculum priorities of Sustainability and Aboriginal and Torres Strait Islander Histories and Cultures. For science, it more specifically covers the areas of: science understanding, science as a human endeavour, and science enquiry skills. For geography, it covers the area of geographical knowledge and understanding, and geographical inquiry and skills.

How to use the guide

The notes in this study guide offer both variety and flexibility of use for the differentiated classroom. You and your students can choose to use all or any of the five sections – although it is recommended to use them in sequence, along with all or a few of the activities within each section.

The 'Five Es' model

This resource employs the 'Five Es' instructional model designed by Biological Sciences Curriculum Study, an educational research group in Colorado. It has been found to be extremely effective in engaging students in learning science and technology. It follows a constructivist or inquiry-based approach to learning, in which students build new ideas on top of the information they have acquired through previous experience.

ABOUT

Its components are:

Engage

Students are asked to make connections between past and present learning experiences and become fully engaged in the topic to be learned.

Explore

Students actively explore the concept or topic being taught. It is an informal process where the students should have fun manipulating ideas or equipment and discovering things about the topic.

Explain

This is a more formal phase where the theory behind the concept is taught. Terms are defined and explanations are given about the models and theories.

Elaborate

Students have the opportunity to develop a deeper understanding of sections of the topic.

Evaluate

Both the teacher and the students evaluate what they have learned in each section.

WARNING: Aboriginal and Torres Strait Islander people are warned that this document may contain images of deceased persons.

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INTRODUCTION

This resource is based on content from the CSIRO book *Water: Science and Solutions for Australia*. The main concepts it covers include:

- Water availability and use
- Water values
- Water and climate
- Groundwater
- Water quality
- Urban water sustainability
- Future water
- Irrigation
- Water for the environment

See Chapter 1: Current water availability and use for background information.

To help you prepare your lessons, the table below shows which pages of the CSIRO book *Water: Science and Solutions for Australia* have been used as reference material for student activities.

Section and Activity	**Pages**
Engage	
Would you drink it?	63–65 69–70
Explore	
Who uses the most water?	3
Who has the most water?	3
Water filtration	98
Bottled water	25, and access to entire Book
Algal blooms	65 + 123
Recharging groundwater	50–52
Explain	
Article 1 – Water values	17–26
Article 2 – Water and Climate	29–45
Article 3 – Future Water	89–104

Managing water

CSIRO GROUNDWATER HYDROLOGIST DR DON McFARLANE TACKLES WATER ISSUES.

Everyday water is needed for households and industries such as farming and mining. Dr McFarlane studies water as a resource to predict how much we'll need in the future, and to ensure we have access to enough and use it wisely.

"The main water problems hydrologists deal with are too much, not enough and too dirty," explains Dr McFarlane, who leads a team focusing on water management for Western Australia.

Too much groundwater is a problem for miners and mining companies spend millions of dollars pumping water out of flooded mine sites. The longer it takes, the greater the loss.

"We often have too much groundwater over winter, so we look for ways to store it," Dr McFarlane says. For 20 years, groundwater has been the most important water source in WA.

Underground beds of rock or sand known as aquifers are used store excess water. These need to be porous – providing space for water storage – and permeable – so water can be pumped in

and out. Underground storage avoids water loss by evaporation – a major problem with above-ground reservoirs.

Most of the water problems in WA are associated with the drying climate, especially in the south-west. The backyard bore was introduced in Perth to access shallow groundwater under the house during a drought in the late 1970s. Now a third of Perth households use one.

Groundwater is becoming even more important due to increasing demand from population growth, and climate change causing increasing dryness and decreasing rainfall. Global climate models all project a drier future for south-west WA.

"People have become dependent on water sources that are drying up," Dr McFarlane explains. "If we don't get those wet years anymore, our dams and aquifers won't get filled up."

He believes that managed aquifer recharge – combining surface and groundwater – is the key to managing water supply in the future. Stormwater run-off, desalinated seawater and recycled wastewater could all be diverted into aquifers.

Currently about 40% of the purest water in Perth is used where less clean water is sufficient, such as for irrigation and flushing the toilet. We can conserve our resources by limiting the use of the purest water for drinking and cooking.

"We need to find alternative water supplies and find ways to store the water before it runs out," Dr McFarlane says.

Teacher information

Background information on water quality can be found in Chapter 5 of the CSIRO book *Water: Science and Solutions for Australia*.

For this activity three samples of water are required.

- Tap water
- Pond water: If you do not have access to pond water it can be bought commercially from educational suppliers.
- Salt water: Add enough sodium chloride to tap water to make a solution, but not so much that the solution is saturated. Use seawater if you have access to it.

Test	Equipment
Appearance	Water samples
pH	Water samples, droppers, universal indicator paper and colour matching chart
Microscopy	Light microscopes, microscope slides and cover slips, droppers
Salinity (optional)	Water samples, salinity meter (electrical conductivity meter)

Would you drink it?

Analysing water samples

Safety: DO NOT DRINK OR TASTE THE WATER SAMPLES.

It is essential that the water we drink is clean because polluted water can cause illness and even death. But just how clean does it have to be? In this activity, you will examine three water samples and determine whether they are safe to drink.

Photo: Bill van Aken, CSIRO

What to do:

You have been provided with three water samples labelled A, B and C. Carry out the following tests to decide which water sample you would drink.

Appearance

Describe the appearance of each water sample.

Water sample	**Appearance**
A	
B	
C	

pH

1. Add a few drops of sample A onto a piece of universal indicator paper.
2. Record the colour it turns in the table provided.
3. Compare the colour of your universal indicator paper to the colours of the chart (supplied with the universal indicator paper) and record the corresponding pH in the table.
4. Is the water sample acidic (pH 0-6), neutral (pH 7) or alkaline (pH 8-14)?
5. Repeat the steps above with samples B and C.

Water sample	Colour	pH	Acid, alkali or neutral
A			
B			
C			

Microscopy (using a microscope)

1. Place a drop of water sample A onto a microscope slide and cover with a cover slip.
2. Place the slide onto the stage of the microscope and view on the lowest magnification. Adjust your focus and try moving the slide around to improve your field of view (what you can see).
3. Draw your field of view in the circle below.
4. Repeat for samples B and C.

Field of view sample A

Field of view sample B

Field of view sample C

Read pp69–70 of Chapter 5 of the CSIRO book *Water: Science and Solutions for Australia* (Water Quality, Pathogens).

Optional: Salinity (dissolved salt content)

Water that contains salt is able to conduct electricity. The more salt it contains, the easier it is for the electric current to flow. Following the instructions supplied with your salinity meter (electrical conductivity meter) measure the salinity of each water sample. Your units may vary depending on the meter you are using. Record your results in the table.

Water sample	**Salinity**
A	
B	
C	

Read pp63–65 of the book CSIRO *Water: Science and Solutions for Australia*, Chapter 5, Water Quality, Salinity. How does the salinity of your water samples compare to those in Table 5.1?

For class discussion

Which water samples (if any) would you use for the following purposes?

- Watering the garden
- Flushing toilets
- Showering or bathing
- Drinking

Use your results and the information you obtained from pp63–65 of the book to justify your decisions.

Teacher information

The aim of the Explore section is for students to begin investigating concepts within the broad topic of water.

Some or all of the workstations can be set up, depending on the size and interests of the class. It is intended that students work independently as they move around the different workstations.

The table below lists the equipment and preparation required for each of the workstations. Stations can be completed in any order.

Station	Equipment
1. Who uses the most water?	CSIRO *Water: Science and Solutions for Australia* book – Figure 1.1, page 3
2. Who has the most water?	CSIRO *Water: Science and Solutions for Australia* book – Table 1.2, page 3
3. How much should a litre of water cost?	Plastic bottle filled with 1 litre of tap water (only one bottle is needed for the whole class), marker pen, paper to create a concept map or an online concept map builder According to Cool Australia, the average cost of a litre of tap water in Sydney is .001¢ www.coolaustralia.org/bottled-water-secondary/ You may want to get students to check the cost against your local water provider however costs are in gigalitres and there are usually other charges to consider.
4. Water filtration	Per group: 100ml of muddy water, four filter funnels, four pieces of gauze (see note, below), four 50ml measuring cylinders (beakers or conical flasks could be used instead), one 25ml measuring cylinder, stopwatch, filter paper, sand, small pebbles, other items to trial as a filter e.g. sponge, scraps of material. The volumes of 'filter' materials required will depend on the size of the funnel used. Note: Gauze material is to prevent the smaller filter materials – e.g. sand from falling through the filter – size of the material will depend on the size of the filters used. Muslin cloth could also be used. You may want to encourage students to use only gauze as their fourth filter. See Figure 7.9 on p98 of the CSIRO book *Water: Science and Solutions for Australia.*

5. Bottled water	Computer to access Internet *CSIRO Water: Science and Solutions for Australia book*
6. How much water do you use?	Computer to access the TasWater Interactive House website: www.taswaterinteractivehouse.com.au If this site is not working, there are alternative water calculators, e.g. www.hunterwater.com.au/Save-Water/Water-Usage-Calculator.aspx
7. Algal blooms	Computer to access the ABC Rural website www.abc.net.au/news/2016-03-08/blue-green-algae-spread/7228400 NASA News science.nasa.gov/science-news/science-at-nasa/2015/26jun_algae/ See p65 and p123 of the CSIRO book *Water: Science and Solutions for Australia.*
8. Recharging groundwater	Glass beaker or jar, pebbles of uniform size, sand, soil, dried leaves or grass, spray bottle of water. See pp50–52 of the CSIRO book *Water: Science and Solutions for Australia.*
9. Dams and weirs	Large plastic container filled with a layer of damp sand, beaker, water, spoon or similar item to dig a small trench, Items to construct a dam, e.g. small pebbles, twigs, paddle pop sticks. Read pp120–123 and see Figure 9.1 on p121 of the CSIRO book *Water: Science and Solutions for Australia.*

Station One

Who uses the most water?

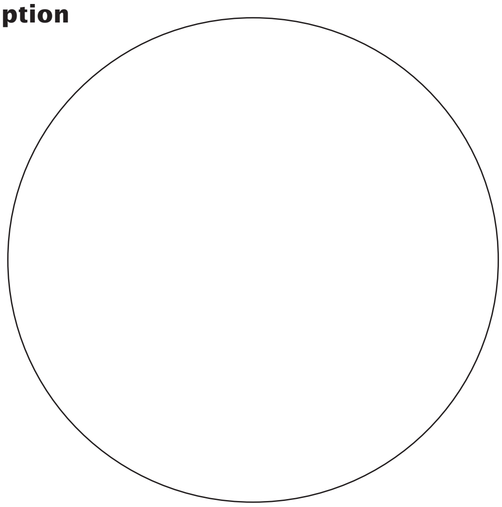
The Australian Bureau of Statistics produces reports on water use every four years. Levels of water use in 2008–09 and 2004–05 were reduced by drought across southern Australia and so the statistics for 2000–01 better reflect unrestricted demand for water. In 2000–01, of the 72,431GL (a gigalitre is 1×109 litres) that was extracted for use, 47,982GL was returned to rivers, mainly being used for hydroelectric power generation, and 24,449GL was consumed by industry, households, and agriculture.

1. Estimate the amount of water consumed (as a percentage) by different sectors of the economy, by adding each sector (below) to the pie chart provided.

Sectors

- Agriculture
- Electricity & Gas
- Forestry & Fishing
- Household
- Manufacturing & Mining
- Water supply (losses of water that occur in supplying water and providing sewerage services

Estimated water consumption



2. Which sector have you shown in the pie chart as using the most water? Explain why you thought this.

3. Which sector have you shown as using the least water? Explain why you thought this.

4. Compare your pie chart to Figure 1.1 on p3 of the CSIRO book *Water: Science and Solutions for Australia*. How do they compare?

5. In recent years, the population has increased and, while restrictions on water have eased, people are now more conscious of water conservation. How do you think these factors will affect the next set of water statistics?

Station Two

Who has the most water?

Australia has less water per unit area than any other region of the world. How does this affect the amount of water resources available to each person living in Australia (water per capita)? At this station, you will rank the regions of the world based on water per capita.

Complete the table.

1. Complete the column Predicted Region Ranking. Use your existing knowledge to rank each region based on available water per capita (ML/person/year), with 1 being the most water per capita and 11 being the least.

2. Look at Table 1.2, page 3, Water: science and solutions for Australia, CSIRO. Use the information to complete the column, Available water per capita ML/person/Year.

3. Now complete the Actual Region Ranking column.

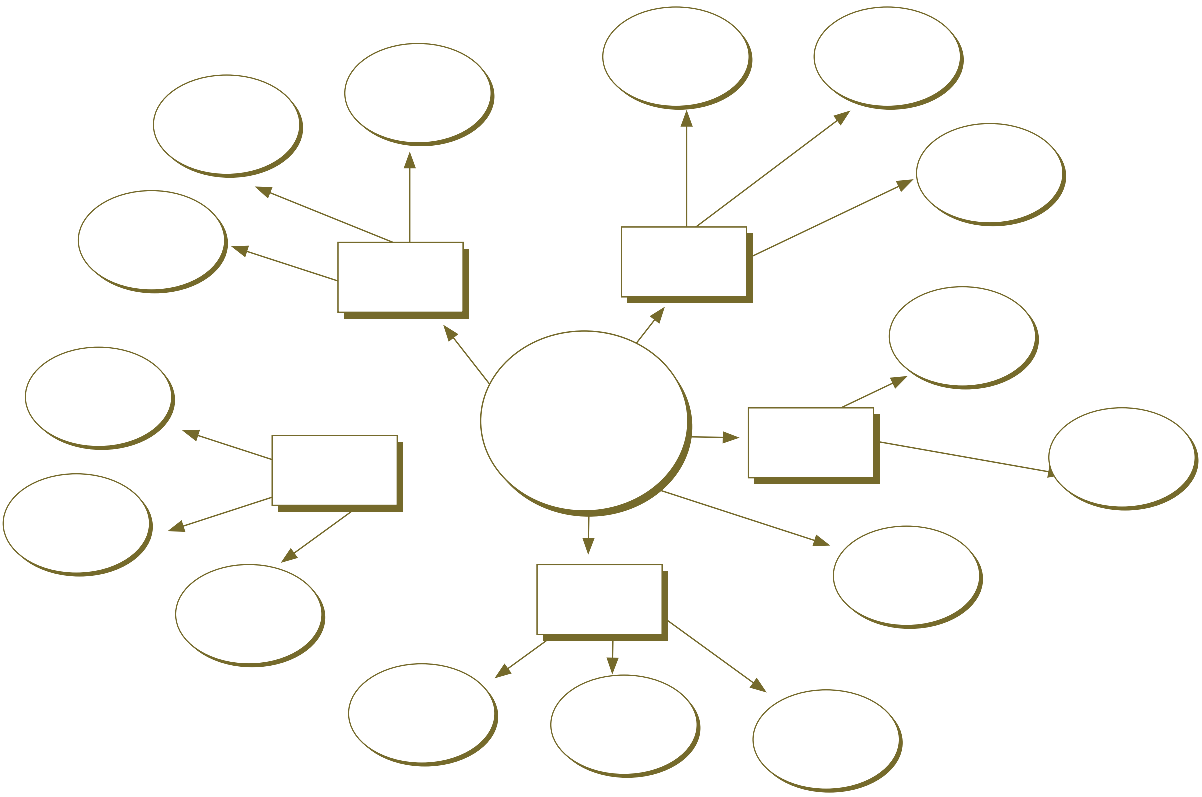
Region	Predicated Region Ranking (Most to Least)	Available water per capita ml/ person/year	Actual Region Ranking (Most to Least)
Africa			
Australia			
Central America			
Central Asia			
Eastern Europe			
Middle East			
North America			
Oceania and Pacific			
Southern America			
Southern and Eastern Asia			
Western and Central Europe			

4. Use the information on p2–4 of the CSIRO book *Water: Science and Solutions for Australia.* To explain Australia's ranking.

Station Three

How much should a litre of water cost?

In front of you is a bottle filled with one litre of clean household water. How much should this litre of tap water cost?



1. Working in a small group, create a concept map showing the costs involved in producing clean water for household use. Areas you may want to consider are water availability, water quality, and transportation.
2. As a group, decide on a dollar value for the cost of a litre of household water.
3. Write your agreed value on the bottle, together with your initials.
4. Compare your value to what the other groups have come up with.

Station Four

Water filtration

At this station, you'll compare the effectiveness of four materials used to filter muddy water.

1. Set up four filter funnels with a small piece of gauze material across the narrow stem of each funnel.
2. Place small pebbles in the first funnel, sand in the second and fluted filter paper in the third.
3. For your fourth filter funnel, choose a substance that you think will be good at filtering water.
4. Place each filter funnel into its own 50ml measuring cylinder.
5. Measure out 25ml of muddy water and pour it into filter one. Use a stopwatch to time how long it takes to collect 10ml of filtrate (the water that collects in the measuring cylinder).
6. Repeat with your other filters.
7. Observe the quality of the filtrate.
8. Rank your filters 1–4, with 1 being the best filtering method.

Filter	**Time taken to filter 10ml (seconds)**	**Quality of filtrate (observation)**	**Rank**
Pebbles			
Sand			
Filter paper			
Other			

9. Which criteria did you use to decide which filter was the best? List them here.

10. Look at Figure 7.9 on p98 of the book *CSIRO Water: Science and Solutions for Australia*. This figure shows the seven barriers for water treatment in the Brisbane indirect potable reuse system, a system for purifying recycled water. Which barrier is your water filtering most similar to?

Station Five

Bottled water

How much water is used to make a bottle of drinking water? To answer a question we often use the internet, but how reliable is this?

1. Type 'how much water is used to produce a bottle of water?' into a search engine (e.g. Google).
2. Choose five websites from the first page of your search results.
3. Look at each website and find how much water its authors claim is used to produce a bottle of drinking water.
4. Record the website URLs and their claims in the table below.

Website	**Claim**

5. Do any of the websites have different values? If so, why might this be?

6. Of your five websites, which one/s do you believe and why? Your teacher may have discussed reliability with you.

7. Can you think of any ways to reduce the amount of water used to produce bottled drinking water?

8. Do you think the information in the book *CSIRO Water: Science and Solutions for Australia* is reliable? Justify your answer.

EXPLORE

Station Six

How much water do **you** use?

Use an online calculator to estimate your household and individual water usage.

1. How many litres of water do you think you use in a day? ___________________________________

2. Go to www.taswaterinteractivehouse.com.au

3. Follow the instructions for the Interactive House and Garden to estimate your water consumption.

4. What was your average daily water use calculated to be? ___________________________________

5. If possible, find out how much water you use as a household. How might your household water consumption compare with a region different to the one where you live?

Station Seven

Algal blooms

How can a natural and essential component of water systems become hazardous? Listen, watch and read the following resources on algal blooms. In the boxes below, make notes on the problems, causes and solutions mentioned.

1. Go to www.abc.net.au/news/2016-03-08/blue-green-algae-spread/7228400 (ABC Rural) and listen to the news report *Blue-green algae outbreak spreading through the Murray River*.
2. Go to science.nasa.gov/science-news/science-at-nasa/2015/26jun_algae/ (NASA News) and watch the video *The Good, The Bad and The Algae*.
3. Read p65 and p123 in the CSIRO book *Water: Science and Solutions for Australia*.

Problems

Causes

Solutions

Station Eight

Recharging groundwater

In Australia, approximately 2% of rainfall percolates through the soil to recharge or replenish groundwater. At this station, you will model how groundwater is recharged.

1. Cover the bottom of your beaker with a layer of pebbles so you cannot see the bottom.
2. Add a layer of sand approximately 3cm deep.
3. Add a layer of soil on top of the sand approximately 6cm deep.
4. Add a layer of dried leaves or grass to the top of the soil.
5. Using a spray bottle, slowly add water to your beaker.
6. Observe where the water (groundwater) collects.

Read the information on groundwater as a renewable resource on pp50–52 of the CSIRO book *Water: Science and Solutions for Australia*. Use this information and your model to answer the following questions.

1. What did the sprayed water represent?

____

____

2. Did all of the sprayed water end up as 'groundwater'? If not, what happened to it?

____

____

3. Suggest reasons why it might be difficult to measure or estimate recharge.

____

____

4. Why is it important to know the amount of recharge, not the volume of water stored, to determine how much groundwater can be sustainably removed?

____

____

Station Nine

Modelling Dams and Weirs

What happens to water flow when dams or weirs are constructed?

1. You have been given a container filled with a layer of damp sand. Dig a trench in the sand to represent a river.
2. Slowly pour water into the trench and observe what happens.
3. Empty the water and re-dig the trench.
4. Use the resources provided to construct a dam/weir at some point along the trench.
5. Slowly pour water into your trench and observe what happens.
6. How did constructing a dam/weir affect the water flow?

   ____

   ____

   ____

7. Look at Figure 9.1 on page 121 of the CSIRO book *Water: Science and Solutions for Australia*. In the 21-year period shown, how many times did the floodplains receive water?

   ____

   How many times would the floodplains have received water with natural flow?

   ____

   Read pp120–123 CSIRO book *Water: Science and Solutions for Australia*. Make a list of the ways aquatic environments are affected by a change in water flow.

   ____

   ____

   ____

   ____

   ____

Student literacy activities

Teacher instructions

In this section, we delve deeper into some of the issues associated with water and explain some of the science involved. Students read a series of articles and complete a number of linked literacy activities. These include:

- Brainstorming
- Glossary
- Comprehension and summary questions
- Questioning toolkit

Articles

1. **Water values**
   Australians value water in many different ways. Here we look at the different ways a value can be put on water and how these ideas can be conflicting. See the CSIRO book *Water: Science and Solutions for Australia* chapter 2, p17.
2. **Water and climate**
   Floods, droughts and climate change are important influences on Australia's water resources. Here we look at the vulnerability of our water resources and how seasonal forecasts of water resources can be made more accurate. See the CSIRO book *Water: Science and Solutions for Australia* chapter 3, p29.
3. **Future water**
   Australia's largest cities are forecast to need an additional 73% on top of their current supply by the year 2050. This article looks at the expanding range of ways our cities can supplement their water supplies. See the CSIRO book *Water: Science and Solutions for Australia* chapter 7, p89.

Brainstorming

How do Australians value water? Think about all the ways we use water. We can think of these uses as the ways we value water. In the table below, list your ideas under each heading (some examples have been provided).

Ways we value water				
Economic value	**Domestic value**	**Environmental value**	**Indigenous value**	**Other**
Agriculture	Clean drinking water	Biodiversity	Symbol of life	

Which value (economic, domestic, etc) do you think is the most important?
Explain why you think this.

Water values

See CSIRO book *Water: Science and Solutions for Australia* chapter 2, p17

Water has been critical in shaping Australia's history

Some experts refer to the period from early European settlement through to the first half of the 20th century as the **expansionary phase** of Australian water resources and the time since then as the **maturing phase**. During the expansionary phase, the focus was on nation building and populating rural areas with the help of irrigation. An icon of this phase was the Snowy Mountains Hydroelectric Scheme, the development of which reflected an emphasis at the time on economic values associated with water.

The maturing phase has been marked by a shift to include broader values, which at times compete with each other. These include increasing concerns over the condition of water ecosystems, where our use of water has led to environmental degradation.

At the same time, the economy has grown and diversified as settlement has concentrated in the large coastal cities, there has been a shift in values reflected in a rise in decisions based on environmental outcomes. Such decisions have included not proceeding with the damming of Tasmania's Franklin River and, more recently, moves to restore environmental flows in the Murray–Darling Basin.

Economic values

Water is used in the production of almost all goods, and water resources are critical for households and many industries. Irrigated agriculture producing food and fibre, such as cotton, is Australia's biggest user of water.

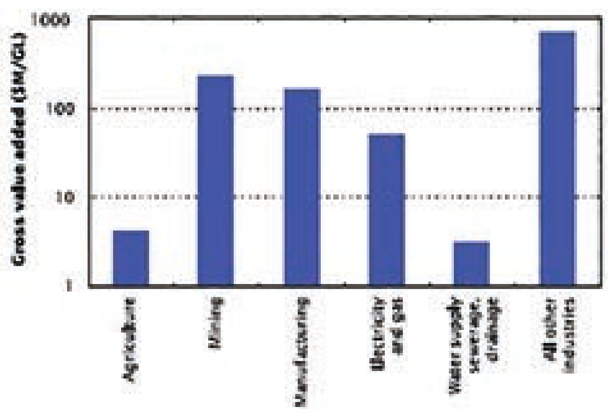


__Figure 2.1:__ Gross value added per GL of water used by various industries, 2008–2009. Mining,manufacturing, and other industries are high-value economic users of water while irrigated agriculture produces less value per GL of water used.

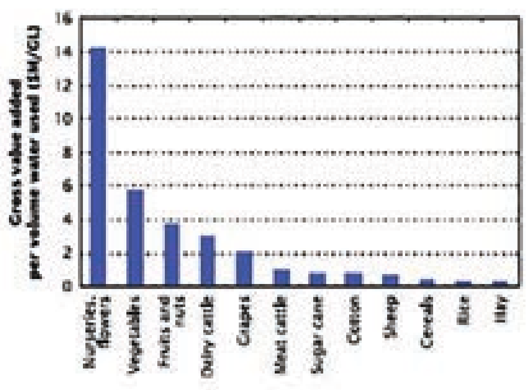


__Figure 2.2:__ Gross value added of irrigated agricultural production across Australia for 2008–09. Nurseries, vegetables, fruits, and nuts produce the highest added value from irrigation.

The value of water can be described using marketplace concepts. According to one measure, water used in mining and manufacturing produces much higher economic values than water for irrigated agriculture. Rivers, lakes, estuaries and wetlands support a range of economic activities without water being consumed. These include commercial fishing, tourism, and recreation. The economic value of water ecosystems can be estimated from the commercial value of markets for these activities. For example, use of south-east Queensland's Moreton Bay, which is dependent on clean freshwater inflows from adjacent rivers, annually brings in $10.5 million through tourism, $260 million from recreation and $60.1 million from commercial fishing.

Values of household water use

Good-quality water for drinking, washing, and cooking is essential to sustain human life. Domestic water values go well beyond cost and quality. This has been evident in community reactions to the option of using recycled water for household purposes. Recycling wastewater or stormwater is technically viable and cost-effective, but there is significant community resistance to some uses. The closer the use gets to direct human contact, the less acceptable it becomes. It is more acceptable, for example, for toilet flushing and open-space irrigation and less acceptable for growing fruit and vegetables, which are eaten. It is least socially acceptable as water for drinking and personal hygiene. At the heart of community concerns are emotions and perceptions of risk.

In Australia, up to half of domestic water is used for gardening. In recent years, under household water restrictions, surveys showed that people were willing to pay up to twice the price of water to secure reliable supplies for their gardens. Of course, garden watering does not require water to be clean enough for people to drink, meaning lower-quality alternative sources are an option.

Environmental water values

As well as direct economic uses, water-dependent ecosystems provide myriad services of indirect economic value, while also having intrinsic value beyond any economic consideration. Water ecosystems provide services such as processing waste and keeping water clean, or supporting biodiversity. A monetary value can be placed on such ecosystem services.

Ecosystems can also be valued purely for their own sake. Many people express interest in preserving them not just for their own benefit but for generations to come. Others have a deeply held sense of place and belonging towards water environments. The Murray River, for example, has emotional significance for many Australians. Likewise, Perth residents have a sense of attachment towards their city's many groundwater-fed lakes and wetlands and support the use of water to sustain these.

Australia has many aquatic ecosystems treasured by society because of their natural beauty, such as the Murray River at the Victorian town of Echuca. Photo: Bill Van Aken, CSIRO.

Aquatic ecosystems may be appreciated purely for their biodiversity, placing intrinsic worth on all the organisms they support. Legislation such as the Federal Environment Protection and Biodiversity Conservation Act (1999), protects species and ecosystems for their own sake, not because they have particular economic value. In a similar way, the Ramsar Convention is an international agreement that protects migratory birds and globally significant wetlands.

Metrics used to value biological diversity in marine or freshwater habitats include the number of endangered species, species richness and diversity, and the presence of indicator species. Australia has many aquatic ecosystems of high intrinsic worth that are treasured by society, including the Kakadu wetlands, Lake Eyre, Murray and Darling Rivers, Moreton Bay, Port Phillip Bay and Swan River. The degradation of rivers and estuaries in recent decades has led to public awareness of the importance of sustaining these environments. There are more than 1000 estuaries in Australia, of which 50% are in near pristine condition. There are also more than 900 wetlands listed as being of national importance, including 64 of international significance.

Water's environmental values are often expressed in monetary terms so they can be directly compared with economic water uses. For example, more than 60 studies have estimated the value of natural capital assets and ecosystem services across the Murray–Darling Basin. These reveal that the restoration of the Coorong and Lower Lakes of the Murray River could be worth $5.8 billion.

Interestingly, while attempts to put an economic price on intrinsic values of water ecosystems are fraught with uncertainty, the values identified for the Murray–Darling Basin are of the same magnitude as the $10 billion being spent by the Australian Government, with community support, to restore the Basin's environmental health.

Indigenous values

Indigenous Australians attach deep spiritual significance to water ecosystems. They believe water to be a sacred and elemental symbol of life, which has sustained watershed communities for millennia and governed Indigenous peoples' relationships to each other and country.

Indigenous perspectives and values relating to water are not widely understood and have been neglected in water-use decisions and water management, although this is changing. National water policy, for example, now recognises the need to include Indigenous people in all activities relating to water planning and management. Indigenous people express a strong desire to be involved in land and water management to be able to fulfil customary obligations to care for Country. They have identified water management as one of the most pressing environmental problems they face, alongside climate change.

Water is also of value to contemporary Indigenous livelihoods. Indigenous people have rights under common law to access cultural water sites and maintain customary use and access of places, plants and animals that depend on water. Many Indigenous people and communities rely heavily on aquatic resources to supplement their household incomes.

Some Indigenous landowners and corporate organisations also have water entitlements and wish to develop water-based enterprises. Indigenous organisations have argued that their people have a right to benefit from the economic use of water and water resource development. Water policy reform under the National Water Initiative has begun enabling recognition of some aspects of Indigenous water values, but progress towards including Indigenous values in water planning remains slow.

Collecting bush tucker, Kakadu wetlands Northern Territory. © Skyscans.

Resolving conflicts in values

Competing values for water and increasing demands often result in conflicts over access to water, and trade-offs between different groups are inevitable.

The over-arching challenge of sustainable water use is to balance consumption with the intrinsic and economic values of maintaining water environments in good condition. The resolution of conflicting values for water in Australia is being achieved through a combination of regulation, planning and markets.

Treating water as an economic commodity is not acceptable in many societies, because it is not always considered ethical to charge for such an essential and natural resource. Nevertheless, the price of the resource typically includes the provision of services such as safe, reliable, piped water. Bottled water – high-quality, refrigerated and widely available in a convenient container – is priced at a few dollars per litre. Potable, reliably supplied domestic water, piped to your home is priced at a few dollars per thousand litres. But irrigation water, provided in larger quantities and of variable quality and reliability, costs much less than a dollar per thousand litres. In an open market, the price of water reflects the balance of supply and demand for the service, and its perceived value, not just its cost.

Water plans and regulations are used to ensure protection of water environments and that licensed users have fair and reliable access. For example, an interim cap on diversions in the Murray–Darling Basin was introduced in 1995 to ensure the reliability of existing entitlements and prevent further ecological degradation. The limits on water use in the Murray–Darling Basin are being revised now, through the Murray–Darling Basin Plan, to restore and protect ecosystems.

There is now much more knowledge being generated to better inform water plans. An important first step is to catalogue broader sets of values, such as poorly appreciated Indigenous water uses, and incorporate them into decision-making. This is a current area of research.

Trade-offs between different water uses can be shown in a cost–benefit analysis and expressed in monetary terms. This can reveal whether a community's overall welfare will be improved as a result of a particular water project or policy decision. Ecosystem services can be included to broaden the scope of a cost–benefit analysis and this is another active area of international research. Where there are non-monetary values, analyses can include different social, cultural, and environmental aspirations.

Activity 1 – Glossary

Using the table provided, define some of the terms used in the article.

Term	Definition
Expansionary phase	
Maturing phase	
Irrigated agriculture	
Domestic water	
Aquatic ecosystems	
Environmental degradation	
Intrinsic worth	
Economic commodity	
Economic values	
Recycled water	
Wastewater	
Stormwater	
Water dependent ecosystem	
Metrics	
National water policy	
Water entitlements	
Indicator species	

Activity 2 – Summarising

Answer the following questions relating to the article.

1. What are the main differences between the expansionary phase of Australian water resources and the maturing phase?

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2. Water is consumed in the production of almost all goods. However, there are some economic activities where water is used but not consumed. In the table below, list the economic activities the article mentions and categorise them according to whether they consume water or not (some examples have been provided to start you off).

Economic activities

Consumes water	**Does not consume water**
Mining	Tourism

3. a) The majority of people in Australia are against using recycled wastewater or stormwater for household purposes. What do you think are their main concerns?

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b) Would you drink recycled wastewater or stormwater? Explain your answer.

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c) Would you shower in recycled wastewater or stormwater? Explain your answer.

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d) Would you water your garden with recycled wastewater or stormwater? Explain your answer.

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4. Name two agreements that are in place to protect aquatic species and ecosystems.

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5. a) Why do you think Indigenous perspectives have been neglected in water use decisions in the past?

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b) What change has been made to try and include Indigenous perspectives more in future water planning and management?

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6. a) Why is it important to have water plans and regulations in place?

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b) What do you think might happen if we didn't have water regulations?

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7. Look back at your response to the brainstorming activity. Do you still agree with the water value you chose as the most important? If not, what made you change your mind?

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Activity 3 – Questioning Toolkit

Write your ideas and opinions relating to each of the different types of questions.

[Inspired by Jamie McKenzie's Questioning Toolkit. Further reading on questioning toolkits: McKenzie, Jamie (2000) Beyond Technology, FNO Press, Bellingham, Washington, USA. www.fno.org/nov97/toolkit.html]

Type of question	**Your ideas and opinions**
Essential questions *These are the most important and central questions. They probe the deepest issues that confront us and can be difficult to answer.* Questions Why do people value water in different ways? Are the monetary values currently placed on water accurate?	
Subsidiary questions *These questions help us to manage our information by finding the most relevant details.* Questions How does the end use of water reflect its price? Are our expectations too high? Should we be using the same quality water for all household needs?	
Hypothetical questions *Questions designed to explore the possibilities, the 'what ifs?' They are useful when we want to test our hunches.* Questions Instead of water regulations, what if water was costed on a supply and demand basis? (i.e. when demand is high, the cost goes up; if you can't afford it, you have to use less.) Would we be concerned with the different uses of water if water was an unlimited resource?	
Provocative questions *Questions to challenge convention.* Questions Should we be protecting our water environments? Are our agricultural needs more important than migratory birds? Should all water rights be returned to Indigenous people?	

Brainstorming

You have been given a one-off superpower. You can stop either floods or droughts in Australia, but you cannot stop both. Which one would you stop and why?

Water and climate

See CSIRO book *Water: Science and Solutions for Australia* chapter 3, p29

The primary influences on Australia's water resources are weather and climate

Floods, drought, and climate change are all driven by processes in the atmosphere and oceans. These include circulation patterns in the Pacific Ocean that create El Niño conditions across eastern and northern Australia, which are drier than normal, and La Niña conditions, which are wetter than normal.

In a similar way, the Indian Ocean Dipole (a feature of the Indian Ocean) can bring drought to south-west and south-east Australia, and the Southern Annular Mode (a feature of the Southern Ocean) can affect weather and climate in southern Australia.

Drought in southern Australia

From 1997 to 2009, large areas of southern Australia – particularly the southern Murray-Darling Basin, Victoria, south-west Australia, and South East Queensland – experienced a prolonged drought that is often referred to as the 'millennium drought'.

In the southern Murray-Darling, this long drought was unprecedented in the 110 years that reliable rainfall records had been kept. It resulted in declining storage levels in reservoirs and years of severe water restrictions in cities, as well as low water allocations to irrigators in the southern part of the Basin and elsewhere in Victoria.

The drought had major environmental impacts. For example, the Lower Lakes of the Murray River fell more than 1m below previously record low levels. This exposed potentially toxic acidic sediments and increased salinity in the lakes. Across the Murray-Darling Basin, there was extensive death and stress to river red gums on floodplains, and low river flows led to the isolation of fish communities and a decline in fish breeding.

Water use for irrigation fell by 64% – the first time that drought had caused a major fall in use for an extended period. Because most of Australia's water use is in southern Australia, the drought had substantial economic, environmental and social impacts.

There had been earlier multi-year droughts in the southern Murray-Darling Basin – such as the Federation drought of 1895 to 1903, and the depression drought of the late 1930s and early 1940s – but none was as severe in terms of reduced run-off as the millennium drought.

Floods

At the opposite end of the range of climate variability are floods, such as those experienced in 2010 and 2011 across eastern Australia.

These were associated with one of the strongest La Niña events on record, opposite to the El Niño conditions associated with the millennium drought. During La Niña conditions, the eastern Pacific Ocean is cooled due to the upwelling of deep ocean water, which strengthens the easterly trade winds coming to Australia from the western Pacific Ocean. This brings warm moist air over eastern Australia, causing widespread above-average rainfall.

Floods are Australia's most costly natural disasters. The average direct annual cost of flooding between 1967 and 1999 has been estimated at $314 million. Costs can vary widely between individual flood events, depending on flood volumes and the infrastructure affected. For example, the 1974 Brisbane floods caused $700 million in damage at the time, while damage from the 2011 floods is likely to be in the vicinity of $10 billion in current values.

Moderate floods can have benefits – they fill reservoirs, recharge groundwater and replenish natural environments.

Climate modelling shows that extreme rainfall events such as cyclones are likely to become more intense, although less frequent, resulting in bigger floods and greater costs from flooding.

Flood warnings

The Bureau of Meteorology (BOM) issues flood warnings based on continuous monitoring and reporting of rainfall and river levels, rainfall forecasts, and modelling of the hydrological (water) cycle. Floods on small rivers generally have warning periods of several hours to a couple of days. Large regional floods on lowland rivers have warning periods of days or weeks, because they flow gradually downstream from run-off in tributaries.

Most unpredictable is local flash flooding in creeks and small rivers. This type of flooding is caused by intense local storms that can make a creek rise to a major torrent in less than an hour. Flash flooding in Toowoomba and the Lockyer Valley in January 2011 had tragic consequences, killing at least 24 people.

Forecasting river flow

A paradox of Australia's highly variable rainfall and run-off is that it can be predicted months in advance from signals of global circulation such as El Niño and La Niña. Information on soil moisture in the catchment can also be used to forecast river flows months ahead.

Seasonal rainfall and run-off forecasts can help water-users, such as irrigators, plan. The BOM has been issuing seasonal weather outlooks since the 1990s, and in 2010 launched a new service on seasonal river flow forecasting. This is based on models developed by CSIRO that give probabilistic forecasts of river flow several months ahead, particularly for flows to major water storages, such as the Hume and Dartmouth Dams in the upper Murray. The BOM is also responsible for issuing flood warnings.

Impacts of climate change on river flows

Global temperatures of both the atmosphere and oceans have been rising since the 1950s, and at a more rapid rate than has been recorded in the geological past. Many studies have linked such global warming to increasing greenhouse gas emissions.

There is less certainty, however, as to whether human-induced temperature increases are the cause of the decline in rainfall in south-west Australia since the 1970s, and the historically unprecedented conditions of the millennium drought. This is because the huge natural variability in rainfall from year to year makes it difficult to detect an overall trend. Rainfall is also controlled by regional weather and climate patterns, which have a complex relationship with global temperatures.

Climate modelling indicates, however, that the persistent dry conditions in the far south-west and the millennium drought are at least in part a result of climate change. The dry conditions are associated with a shift of storm tracks towards the southern ocean. According to climate modelling, such changes are likely to intensify and become more persistent, so the dry conditions experienced are consistent with the trajectories of future climate for those regions.

Extended droughts and decades of wetter conditions are also a natural feature of southern Australia's climate. With only just over a century of measurements, it is hard to establish patterns that span several decades. Records from tree rings, corals, and caves are therefore used to describe longer term climate patterns. These are correlated for recent times with historical measurements of the oceans and atmosphere, and then used to extend those records further back in time.

At shorter time scales, we know that El Niño and La Niña influence rainfall and run-off. Now additional longer decade cycles are being found of increased frequency of El Niño events followed by decades of increased frequency of La Niña events. Decades of high frequency of El Niño events are associated with extended periods of drier-than-average conditions in eastern Australia, such as in the last few decades, and vice versa for wetter than average conditions, such as in the 1950s and 1970s.

It is possible that the millennium drought was a combination of natural variability and climate change. It is only through continued observations in coming years that any long-term trend in rainfall can be confirmed or not, and then, if the connection is evident, be attributed unequivocally to human-induced climate change.

Regardless of the cause, a decade or more of drier conditions is enough to put water users, including ecosystems, under considerable stress and has tested whether Australia's water management is well-adapted to such harsh conditions.

Activity 1 – Glossary

Using the table provided, define some of the terms used in the article.

Term	Definition
Drought	
Climate change	
Millennium drought	
Unprecedented	
Flood	
El Niño	
La Niña	
Climate modelling	
Water allocations	
Trade winds	
Run-off	
Tributaries	
Natural variability	

Activity 2 – Summarising

Answer the following questions relating to the article.

1. Processes in the atmosphere and oceans affect weather and climate. Complete the table below to show the areas affected and the conditions each process brings.

Process in the atmosphere or oceans	**Areas affected**	**Conditions**
Circulation pattern in the Pacific Ocean, El Niño		
Circulation pattern in the Pacific Ocean, La Niña		
Indian Ocean Dipole		
Southern Annular Mode		

2. From 1997 to 2009, large areas of southern Australia experienced a prolonged drought that is often referred to as the 'millennium drought'.

a) Name two earlier multi-year droughts.

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b) List the problems associated with the 'millennium drought'.

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c) In your opinion, which problem is the most significant? Explain your reasoning.

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3. Floods are Australia's most costly natural disaster.

a) According to the article, what is the average direct annual cost of flooding?

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b) Why do you think the economic cost of flooding is greater than the economic cost of drought?

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c) Why is local flash flooding more unpredictable than floods on small rivers and large regional floods?

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d) Why is flash flooding more dangerous to people?

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4. According to the article, why is it difficult to know for sure that human induced temperature increases are the cause of decreased rainfall in south-west Australia?

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Activity 3 – Questioning Toolkit

Write your ideas and opinions relating to each of the different types of questions.

[Inspired by Jamie McKenzie's Questioning Toolkit. Further reading on questioning toolkits: McKenzie, Jamie (2000) Beyond Technology, FNO Press, Bellingham, Washington, USA. www.fno.org/nov97/toolkit.html]

Type of question	Your ideas and opinions
Essential questions *These are the most important and central questions. They probe the deepest issues that confront us and can be difficult to answer.* Questions How does climate affect rainfall in Australia?	
Subsidiary questions *These questions help us to manage our information by finding the most relevant details.* Questions What processes, both natural and or derived from human activity, contribute to drought and flooding in Australia? Has climate change increased the frequency of drought events in Australia? Will it affect drought in the future? Is climate modelling accurate in predicting rainfall?	
Hypothetical questions *Questions designed to explore the possibilities, the 'what ifs?' They are useful when we want to test our hunches.* Questions Should we be trying to modify the natural environment to suit our own needs, or do we need to learn to adapt, like Australia's native organisms? What if we could use technology to increase rainfall over the southern half of Australia, but this led to an increase in floods and droughts in Northern Australia – should we use this technology?	
Provocative questions *Questions to challenge convention.* Questions Drought and flooding events are more common in some areas of Australia than others. Should the rest of Australia support people who choose to live in drought or flood-prone areas?	

Brainstorming

Many people in Australia are against the idea of using recycled water. Imagine you come from Ethiopia, where an estimated 8 million people are at immediate risk due to drought. How do you think you would feel about using recycled water? What would you think if someone told you Australians wouldn't use recycled water? Write your thoughts in the space below.

Future water

See CSIRO book *Water: Science and Solutions for Australia* chapter 7, p89, and watch the video *Australian National Outlook – Water and Environment* at www.youtube.com/watch?v=DgCjBhXY6M0

Australian cities have an expanding range of options to supplement their water supplies

Desalination

Australia's six largest coastal cities all have desalination plants either already in place or under construction. All use a technology known as reverse osmosis. This involves saltwater being forced under pressure through a semi-permeable membrane in a process that traps salt ions, large molecules and disease-causing pathogens on one side while pure water passes through to the other side. One shortcoming of reverse osmosis is that it can let through chemicals such as pesticides and herbicides. Another drawback is that it removes all the naturally occurring salts, producing water that is deficient in calcium and other essential minerals. These salts then need to be added back in for drinking purposes.

Reverse osmosis is relatively inefficient. All the input water must first be chemically pre-treated and filtered. The technology also uses significant amounts of electricity to pressurise the input water. The Perth plant, for example, uses power equivalent to that for 27,000 homes.

It is expected that the trend to use reverse osmosis for urban and industrial water desalination will continue. Research is therefore underway to make the process more efficient and reduce the amount of energy needed.

Rainwater tanks

Rainwater tanks have traditionally been used in rural areas without a reticulated water supply, but the use of tanks has proliferated in cities in response to government policies aimed at reducing demand on centralised water supplies. From 1994 to 2010, the number of capital city households using rainwater tanks more than doubled from 407,000 to 1,030,000. Urban rainwater tanks are mainly used for garden watering and toilet flushing.

One benefit of tanks is that capturing and using rainwater controls peak stormwater run-off in urban areas, helping to reduce the discharge of nutrients to rivers and estuaries. It is expected that the number of urban rainwater tanks will continue to increase, because most jurisdictions now require installation of water-saving features for new buildings and tanks are a relatively easy way of meeting such requirements.

Using tank water usually requires a pump, and this raises questions about their energy efficiency. Energy use is reported to range widely, from 0.6 to 11.6 kWh/kL, and can exceed the energy used per kilolitre to produce water by desalination.

The potential for improvements in energy and water use makes a case for providing professional services, supported by automated control systems, to improve and maintain the performance of rainwater tanks.

Recycled water

Water is mostly used once and then discarded. However, significant efforts are now underway to recycle wastewater. Most water recycling systems are designed to enable the re-use of water for non-potable purposes, such as for the irrigation of crops, gardens and sporting fields.

Recent urban water shortages have raised the prospect of indirect potable reuse. This involves treating sewage to a level that meets drinking water standards, and storing it in an existing reservoir from where it can be extracted for later use. Key international examples are in place in Singapore, where about 2.5% of total daily water consumption is re-used water, and Orange County in the United States.

Indirect potable reuse has been quietly happening for decades along some Australian rivers. For example, Canberra's wastewater is treated and disposed of in the Murrumbidgee River, and towns downstream, including Wagga Wagga and Adelaide, then extract and treat the river water for potable supplies. This is similar to the situation in virtually every European river city.

Re-use systems contain advanced water treatment systems to ensure almost complete removal of all traces of biological and chemical contaminants. Despite this, regulators require that potable recycling is done in an indirect manner using some form of natural reservoir, to store the water between the advanced water treatment and drinking water treatment plant. For example, the Western Australian Government plans to use aquifers – natural underground layers of permeable rock, sediment, or soil – for storage. These natural environments also remove or reduce any pathogens or organic chemicals present and provide an additional control point through dilution and prolonged storage.

Despite all the measures to make potable recycling safe, community resistance to recycled water remains strong.

Stormwater capture

Stormwater is a large resource that could be collected from urban run-off to substitute existing water supplies. Many municipal councils already capture stormwater for non-potable use. For example, new stormwater harvesting projects proposed for Adelaide will increase the city's

Canberra suburban lake used for stormwater capture and re-use. Photo: Greg Heath, CSIRO.

total stormwater harvesting capacity from 6GL per year to about 20GL per year by 2013 and up to 60GL per year by 2050.

In most capital cities, the limitations for urban stormwater harvesting include finding suitable storage sites for the water, and the high costs of treating it. Urban stormwater often contains pollutants that are a human health risk, including heavy metals, hydrocarbons, organic chemicals and disease-causing organisms. Advanced treatment systems already used for wastewater are not economically practical for treating stormwater because stormwater is dispersed across urban areas rather than being collected centrally in pipes. Alternative treatment processes such as filtering it through wetlands or aquifers need to be used to allow cost-effective treatment.

Storage is also a barrier to using harvested stormwater. Appropriate storage places are urban lakes and wetlands. But stormwater recycling, using aquifers to store water from where it is later pumped is being used increasingly where there are suitable aquifers.

An example is Adelaide's Mawson Lakes scheme, which uses reclaimed wastewater from the Bolivar Wastewater Treatment Plant, blends it with harvested urban stormwater, and then injects it into an aquifer. When needed, up to 0.8GL per year of water is withdrawn from the aquifer and reticulated to 4000 homes for non-potable reuse.

Australia's first large-scale, potable stormwater harvesting project, in the NSW city of Orange, also uses a local aquifer for storage and additional treatment.

Reducing reservoir evaporation

Reservoirs are still the main source of water for cities, but they lose large volumes of water through evaporation. In dry periods, reservoir levels decline over a period of several years, and the loss of water to evaporation can be as large as the water supplied to the city. For example, Brisbane's three water supply reservoirs can lose 248GL per year through evaporation, which is about the same as their supply rate of 240GL per year.

A range of evaporation reduction techniques has been considered for small dams, but the only likely technique for large dams is using a monolayer on the water surface. Monolayers are artificially synthesised long-chain alcohol films that are one molecule thick (2 millionths of a millimetre), and they inhibit evaporation when applied to a water surface. Evaporation reductions of up to 30% have been recorded in small trials, but new polymers have the potential to double that.

Monolayers have not yet been applied to large reservoirs because of cost limitations, potential effects on water quality and break-up by winds. Before monolayers could be applied to potable water reservoirs, the potential impact on water ecology and recreational use would need to be fully tested.

Activity 1 – Glossary

Using the table provided, define some of the scientific terms used in the article.

Term	Definition
Desalination	
Reverse osmosis	
Recycled water	
Stormwater	
Stormwater harvesting	
Evaporation	
Aquifer	
Reservoir	
Monolayer	
Synthesised	
Semi-permeable	
Potable	
Reticulated	
Gigalitre (GL)	

Activity 2 – Summarising

Answer the following questions relating to the article.

1. Australia's six largest coastal cities all have desalination plants either already in place or under construction. All use a technology known as reverse osmosis.

a) Explain the process involved in reverse osmosis.

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b) What problems are associated with reverse osmosis?

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2. Rainwater tanks have traditionally been used in rural areas, but in recent years their use has increased in cities. Suggest reasons for the increased use of rainwater tanks in cities.

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3. The article discusses the problems associated with wastewater recycling. In the table below, list those problems mentioned and any others you can think of. For each problem, suggest a possible solution.

Problem	Solution

4. Most capital cities face problems and limitations associated with stormwater harvesting.

a) Identify these problems or limitations.

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b) Name those cities that are already addressing the limitations associated with stormwater harvesting and describe what they are doing.

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5. In small scale trials, monolayers have reduced water loss by up to 30%. Why have monolayers not yet been applied to large reservoirs?

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Activity 3 – Questioning Toolkit

Write your ideas and opinions relating to each of the different types of questions.

[Inspired by Jamie McKenzie's Questioning Toolkit. Further reading on questioning toolkits: McKenzie, Jamie (2000) Beyond Technology, FNO Press, Bellingham, Washington, USA. www.fno.org/nov97/toolkit.html]

Type of question	Your ideas and opinions
Essential questions *These are the most important and central questions. They probe the deepest issues that confront us and can be difficult to answer.* Questions How can we increase the amount of water available for human use? Will we always have enough water for our needs?	
Subsidiary questions *These questions help us to manage our information by finding the most relevant details.* Questions How can we store water that would normally be discharged as waste? How can future technologies help us conserve water?	
Hypothetical questions *Questions designed to explore the possibilities, the 'what ifs?' They are useful when we want to test our hunches.* Questions To encourage people to use recycled water in their homes, should recycled water cost less than non-recycled water? Should we be using aquifers for the storage of water across the whole of Australia?	
Provocative questions *Questions to challenge convention.* Questions If the population of Australia is set to increase to a level where we can't meet the demand for water, should we put policies in place to reduce population growth? Rather than using recycled water, should we increase the number of desalination plants in Australia? In times of drought, should the export of agricultural products be banned?	

Questioning Toolkit

Bringing it all together

1. Create a mind map to show the main topics the three articles address, and how these are related.

2. List five things that you have learned from reading the articles.

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3. List five questions you have after reading these articles.

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About the Science Matrix

What is the Water Learning Matrix?

A Learning Matrix is a flexible classroom tool designed to meet the needs of a variety of different learning styles across different levels of capabilities. Students learn in many different ways: some are suited to hands-on activities, others are strong visual learners, some enjoy intellectually challenging and independent hands-off activities, while others need more guidance. The Matrix provides a smorgasbord of science learning activities from which teachers and/or students can choose.

Each activity is linked to a chapter of the CSIRO book *Water: Science and Solutions for Australia*, which should be read by students to enhance their learning experience.

Can I use the Matrix for one or two lessons, or a whole unit of study?

Either! The Matrix is designed to be time flexible as well educationally flexible. Choose to complete one activity, or as many as you like.

Is there room for student negotiation?

Yes! Students can be given a copy of the Matrix and choose their own activities, or design their own activities in consultation with their classroom teacher.

Developing	**Extending**
Designed to enhance student comprehension of information by including research (other people's knowledge and ideas) into their activities.	Gives the student the opportunity to apply or transfer their learning into a new format where they have to create using their own design or evaluate using their own criteria.

What do the row headings mean?

First-hand investigations	Hands-on activities that follow scientific method. Includes experiments and surveys. Great for kinaesthetic and logical learners, as well as budding scientists.
Maker space activities	Hands-on building, troubleshooting and reviewing a design of their own.
Ethical thinking	Students learn to recognise and explore ethical concepts. They examine reasons supporting ethical decisions, consider consequences of ethical decisions and reflect on ethical actions. Students examine values, rights, responsibilities and points of view.
ICT	Students use searches to locate, access and generate digital data and information. Students generate ideas, plans and processes, and communicate these via ICT. They select and use software, manage data, understand social and ethical protocols, and understand the impacts of ICT.
Personal and social capabilities	Students recognise emotions, personal qualities and achievements in themselves and diverse perspectives and relationships with and between others. They learn self-management through working independently and learning how to express emotions appropriately. Students work collaboratively, make decisions, negotiate, resolve conflict and develop leadership skills.
Creative and critical thinking	Models the inquiry process. Students question, identify, clarify organise and process information. They generate ideas, possibilities and actions, connect ideas, consider alternatives and seek solutions. Students also reflect on thinking (metacognition) and processes, apply logic and reasoning, draw conclusions, and evaluate procedures. Knowledge is transferred into new contexts.
Time travel	Here students consider scientific and technological development as a linear process by travelling back in time or creatively into the future.

Water Learning Matrix		
	Developing	**Extending**
First-hand investigations	**Chapter 7. Future urban water supplies** Does surface area affect the evaporation rate of water? See Linked Activity 1.	**Chapter 5. Water quality** Fertiliser run-off and aquatic plant growth. Investigate the effect of fertiliser on the growth of Duckweed, *Lemna minor*. See Linked Activity 2.
Maker space activities	**Chapter 7. Future urban water supplies** Make a simple water filter out of a plastic bottle and a selection of resources (e.g. coffee filter, cotton balls, fabric, sand, charcoal, gravel, small pebbles, soil). Could your filter help in the recycling of wastewater or the capture of stormwater?	**Chapter 8. Irrigation** Design and build an irrigation system that minimises water usage and/or promotes the return of water to the environment.
Ethical thinking	**Chapter 2, Water values and Chapter 9. Water for the environment** Create a poster showing the importance of water ecosystems, the reasons they are under threat and the measures that can be taken to protect them.	**Chapter 9. Water for the environment** ***Aboriginal water values and management in northern Australia* at www.youtube.com/watch?v=XMKYybtUJ-o** Debate the statement 'That people's water needs should come before the environment'. Make a list of points you could make if you were on the 'affirmative' team, and another list for the 'negative' team.
ICT	**Chapter 7. Future urban water supplies** Use Windows Movie Maker, iMovie or similar software to create a 30-second TV commercial promoting the use of recycled water.	**Chapter 6. Urban water sustainability** Pool to Pond. Build a website promoting improved garden design, including the turning of backyard swimming pools into freshwater pools. Easy-to-use and free web development platforms include: www.wix.com

Water Learning Matrix		
	Developing	**Extending**
Personal and social capabilities	**Chapter 6. Urban water sustainability** What can you do in your own home to reduce the amount of water you use and the amount of wastewater you produce? Create a list of goals, e.g. "only spend 3 minutes in the shower". See if you can stick to it for a whole week.	**Chapter 6. Urban water sustainability** Write a letter that could be sent to your local government (council), outlining ways water consumption and wastewater production could be reduced in your local area.
Creative and critical thinking	**Chapter 2. Water values** How can we ensure that everyone uses water in a sustainable way? Create your own 'fair' water usage regulations. Look at the water restrictions or regulations already in place for ideas.	**Chapter 8. Irrigation** Grant funding. Work in groups of four to apply for three-year grant funding to research agricultural irrigation in your chosen area. See Linked Activity 3.
Time travel	**Chapter 7. Future urban water supplies** How might water supply change in the future? Write a letter from your future self, living in 2050, describing how water supply and usage has changed.	**Chapter 7. Future urban water supplies** Write a 1–2 page report evaluating the 'best' method to provide adequate urban water supplies in the future.

Linked Activity 1

Does surface area affect the evaporation rate of water?

Aim

To investigate the effect of surface area on the evaporation of water.

Introduction

Most water for cities is stored in reservoirs, but large volumes of water are lost through evaporation. For example, Brisbane's three water supply reservoirs can lose 248GL per year through evaporation. But why is this? In this investigation, you will look at the effect water surface area has on evaporation rates.

Hypothesis

(Circle your choice) A larger/smaller surface area will increase/decrease the evaporation rate of water.

Variables

Independent variable (the variable you are changing):

The surface area of the water

Dependent variable (the variable you are measuring):

The volume of water lost to evaporation

Controlled/constant variables (list the variables you are keeping the same):

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Materials

- Beaker to hold 100ml of water
- Round dish to hold 100ml of water
- Measuring cylinder
- A warm area (e.g. a sun-lit windowsill)
- Marker pen or glass marker pencil

Method

1. Using a measuring cylinder, add 100ml of water to a beaker and 100ml of water to a round dish.
2. Use a marker pen or glass marker pencil to mark the height of the water.
3. Place both containers in a warm area for a set period of time (your teacher will decide this).
4. Observe your samples. If it looks as though the volume of water has decreased, use a measuring cylinder to measure the volume of water remaining in each container. If no change in water volume is observed, move the containers to a warmer area and leave for longer.
5. Record your results in the table below.

Results

Give your table a title. Make sure it includes the independent and dependent variable.

Title

____

Container	Volume of water at start of investigation (ml)	Volume of water at end of investigation (ml)	Volume of water lost to evaporation (ml)
Beaker	100		
Dish	100		

Extension task

Use the equation Area=∏r^2 to calculate the surface area of the water in both containers.

Beaker surface area ____

Dish surface area ____

ELABORATE

Discussion

1. a) Which container lost the greatest volume of water to evaporation?

____

____

b) In which container did the water have the greatest surface area?

____

____

c) Did your results support your hypothesis?

____

2. Can you think of a way to further extend this investigation? Write a list of your ideas below. One has been added for you.

____

____

3. Read reducing reservoir evaporation on pp101–102 of CSIRO book *Water: Science and Solutions for Australia*.

a) What evaporation reduction technique is being considered for use in large reservoirs?

____

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b) Can you think of any other ideas to reduce evaporation in reservoirs? Describe your ideas below. A diagram may help.

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Conclusion

Write a concluding sentence that relates to your aim.

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Linked Activity 2

Fertiliser run-off and aquatic plant growth

Aim

To investigate the effect of fertiliser on the growth of duckweed, *Lemna minor.*

Introduction

Aquatic plants such as duckweed are a natural and essential component of water ecosystems. They provide habitat for many organisms, reduce evaporation and prevent fluctuations in water temperature. However, as a result of agriculture and urban discharges, many water ecosystems become rich in nitrogen and phosphorus. This increase in nutrients causes aquatic plants to grow vigorously to a point where they become a nuisance.

Hypothesis

How do you think the addition of fertiliser will affect the growth of duckweed?

____

____

Variables

Independent variable (the variable you are changing):

____

Dependent variable (the variable you are measuring):

____

Controlled/constant variables (list the variables you are keeping the same):

____

____

____

Materials

Below is a list of the minimum equipment you will need. Add further information about your equipment (e.g. volumes/amounts) and list any other equipment that you use.

- Duckweed *Lemna minor* (Can be purchased, or you may find it growing naturally in local ponds. If found locally, ask for permission before removing it.)
- Water
- Fertiliser
- Containers

Method

1. Fill two containers with equal volumes of water.
2. Add fertiliser to one of the containers (make sure you follow the instructions provided with the fertiliser).
3. Add equal amounts of duckweed to each container, ensuring that less than a quarter of water surface is covered.
4. Place the containers in the same area.
5. Observe your containers every few days for approximately two weeks.
   Record any growth (see Note).

Modifications to method

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Note: One way to measure the amount of duckweed is to estimate the surface cover. You could take photos to compare your results.

Risk Analysis

List any risks and the precautions that can be taken to reduce these during the experiment.

Risk	Precaution	Consequence

Results

1. Design a table to record your results.

2. Draw a graph of your results.

3. Write a sentence or two summarising the results shown in the graph.

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____

____

Discussion

1. (a) Did the results support your hypothesis? ______________________

(b) If the results did not support your hypothesis, then explain why not.

____

____

2. Were there any variables that were difficult to control?

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____

____

3. How could this investigation be improved?

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4. How does this investigation relate to the problems discussed in Chapter 5, Water quality?

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5. Can you think of any ways to further extend this investigation? Write a list of your ideas.

____

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Conclusion

Write a concluding sentence that relates to your Aim.

____

____

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Linked Activity 3

Grant funding

In countries with a dry and variable climate, irrigation from rivers or groundwater enables more productive agriculture than is possible from rainfall alone. Irrigation in Australia is concentrated in the Murray–Darling Basin where, in future, less water could be available for use because of some water being returned to the river to restore environmental values, and because of lower river flows as a result of climate change, bushfires and changing land use.

There are calls to expand irrigation elsewhere, but first scientists need to research how successful it would be. Scientific research can be expensive, so scientists need to apply for a grant to pay for it. There is a lot of competition for grant funding so scientists put a lot of effort into writing a grant application.

In this activity, you will work in groups of four to apply for three-year grant funding to research agricultural irrigation in your chosen area.

1. Decide who will be the Chief Investigator and who will be the Principal Investigators. You will have equal amounts of work to do, but the Chief Investigator will be responsible for ensuring all areas of the grant application are completed and submitted on time.
2. As a group, decide on a suitable area of Australia that would benefit from irrigation for agriculture. You need flat land with suitable soils that will not be subject to salinity, and to which water can be easily supplied. Agriculture also requires associated processing industries, transport infrastructure and markets.
3. Read through the grant application form and decide who will be responsible for researching each area. A good place to start your research is by reading Chapter 8 of the CSIRO book *Water: Science and Solutions for Australia.*
4. Time management. Make sure you plan appropriate times to discuss your research as a group and allow enough time to write the application. If you have the opportunity, you may want to swap your application with another group for peer feedback.

Application closing date: (Your teacher will decide this) ________________________________

Title

The title is the reviewers' first impression of a grant application. It should summarise your whole proposal, so make sure you include the most important information such as what you're investigating, the area you have chosen and what you want to achieve. It should be creative but still sound scientific and be no more than 300 characters long.

____

____

____

Chief Investigator

____

Principal Investigators

____

____

____

Project summary

You might want to write this bit last as it's a summary of your whole project proposal. It should still include the science, but must be understandable by the general public. Your summary should be no more than 150 words.

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____

Outline of project

This is your introduction section. Explain the importance of your project and the supporting science.

____

____

____

Project aims

What do you hope to achieve with your project? As well as the immediate aim, think about the long-term goals for the geographic area you have chosen.

____

____

____

Social/economic benefits

List the social and economic benefits of your research.

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____

Environmental impact

You must consider other water users and the environment. Here you can describe ways to minimise the environmental impact of your research.

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____

____

Project method

Write a scientific method showing what you are planning to do.

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Timeline

How long will your project take? A good way of showing this is with a timeline. Consider how long it will take to set up your research and how long it takes to grow your chosen crop. You will also have to consider the time of year you plant your crops and how many times you will be able to repeat your research. Remember the funding is for three years.

Costing

How much money are you applying for and how will you spend this money? Consider the cost of purchasing land, the cost of equipment and the salaries of anyone you may need to employ. Drawing a table is a good way to display your costs.

Two experts in the field who can review your application

Before handing out money, the funding body will ask a panel of anonymous experts to assess your project ideas. Here you have the opportunity to suggest two scientists who could review your proposal. Choose two scientists from CSIRO's *Water: Science and Solutions for Australia*. You may want to do an internet search to find more information on them. Give their names, where they work and their area of expertise – you don't need to contact them, just prepare your proposal as though you were going to submit it.

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Your application is now ready for submission. Well done!

Activities to allow students to show what they now know about water and to evaluate their learning.

Provide a series of Review Activities such as:

- Create a quiz
- Class debate
- Write a book review
- Personal review of unit

Water DIY quiz

1. Ask each student to call out a word or term that relates to water (e.g. reverse osmosis). Record these on the board.
2. Each student chooses five terms from the board and writes a corresponding question for each one.
3. Students then give their questions to another student to answer.

Class debate

1. Choose one of the following statements as the topic for a class debate:

   a) Clean water is a human right.
   b) Australia should be the first country to ban plastic water bottles.
   c) Australia should be recycling all of its waste water by 2030.

2. Divide the class into two groups. Group 1 will debate the affirmative stance and Group 2 will debate the opposing view.
3. Appoint an adjudicator, or an adjudicating team to decide which debating team presented the most compelling argument.

Write a book review

Ask students to write a review of the CSIRO book *Water: Science and Solutions for Australia*. The review should be from their own perspective and include statements explaining what they have learned and how they learnt it. As students may have only used sections of the book, this could be modified to be a chapter review.

Personal review of unit	
Personal summary	**Where to now?**
Make a dot point summary, or a mind map, of all the things you learned during this unit of work. Highlight the things you found most interesting.	Write five questions that have come up while you have been studying this unit of work, which you would like to know the answers to.
Something philosophical	**Something political**
Think of two ethical issues that came up during this unit of work, and propose some ideas about how these issues might be addressed.	If you were a leader in Australia today, what changes would you make to ensure our country's water supplies were protected for the future?

NOTES

NOTES

WATER

Australians have always had a strong sense of living in a dry continent, so they value their water resources highly. Water is essential to support the economy, the natural environment, and our way of life, but tensions between the differing uses of water are often at the heart of potential conflicts over maintaining sustainable levels of water use.

Australia faces challenges of a growing urbanised population, of a growing demand for food, and of managing threatened aquatic ecosystems, all of which will require more water. Meanwhile, climate change in southern Australia threatens to reduce water availability, while the extreme floods and droughts of the last decade or so have revealed deep vulnerabilities of Australia's water resources and the ecosystems that depend upon them. It is no surprise therefore that our society is increasingly seeking knowledge about how best to use our finite water resources.

Water: Science and Solutions for Australia draws upon the scientific literature to provide a clear picture of the water challenges and prospects facing Australia. The book covers the status of Australia's water resources and their future prospects, the many values we hold for water, and the potential for using water more effectively to meet the growing demands of cities, farmers, industries, and the environment.

CSIRO