Government of Western Australia
Department of Water

A resource for secondary school geography

Protecting drinking water in Western Australia

Workbook for students

Looking after all our water needs

June 2011

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Disclaimer

This publication is available at our website <www.water.wa.gov.au> or for those with special needs it can be made available in alternative formats such as audio, large print, or Braille.

Protecting drinking water

A resource for secondary school geography

Protecting drinking water will help teach students about drinking water resources in Western Australia, with a focus on the state's south-west. It will help them learn about the current pressures on our precious and limited drinking water resources, such as a drying climate and land use development, and what we all need to do to ensure they are protected to provide safe, good-quality drinking water into the future.

Western Australia's drinking water comes from both surface and groundwater sources. The Department of Water protects and manages drinking water supplies using powers provided by legislation (*Metropolitan Water Supply, Sewerage and Drainage Act 1909* and *Country Areas Water Supply Act 1947*). Public drinking water source areas (PDWSAs) are proclaimed under either Act to ensure their protection.

Our goal is to ensure that the public has access to safe, good-quality drinking water now and in the future. To achieve this we:

- work with the community, local government and water service providers to identify, assess and protect PDWSAs by preparing drinking water source protection documents for new and existing water sources
- assign priority areas and protection zones in PDWSAs, to help determine appropriate land uses and activities that will preserve water quality
- have adopted the *Australian drinking water guidelines* - 'catchment to consumer', multiple barrier, risk-based framework
- prepare and implement policies and strategies with other state government agencies (e.g. Statement of planning policy no. 2.7: *Public drinking water source policy*)
- develop water quality protection notes, codes and guidelines on best environmental practice.

Want more information?

- Visit our website www.water.wa.gov.au to find out who the Department of Water is and what we do.
- Visit http://drinkingwater.water.wa.gov.au to find out more about our program to protect drinking water sources.
- Access this and other online education resources via www.water.wa.gov.au > Tools and data > Water education tools.
- For information about the *Australian drinking water guidelines*, visit www.water.wa.gov.au > Publications > Find a publication > Series browse > Water quality protection note > Water quality protection note no. 78: *The Australian drinking water guidelines*.
- For information about priority areas and protection zones and what land uses and activities are appropriate in them, read our Water quality protection note no. 25: *Land use compatibility in public drinking water source areas* accessed via the same link described above.

- For a list of different drinking water source protection plans available around the state visit www.water.wa.gov.au > Publications > Find a publication > Series browse > Water resource protection plans.
- We have different best management practice documents available on a range of different land uses to show land owners and operators how to protect water quality. Find these at www.water.wa.gov.au > Publications > Find a publication > Series browse > Water quality protection note.
- For a short video about drinking water supplies in Western Australia visit http://www.youtube.com/watch?v=pGEHkR4Uw78 (uploaded by the Water Corporation, user name *Watercorpwa*). The full DVD is available by contacting the Water Corporation www.watercorporation.com.au.

Topic 1 – The water cycle

Reference: *Water cycle broadsheet.*

The operation of the water cycle in the south-west of Western Australia is closely linked to the climatic conditions found in this part of the state. Two distinct periods of aquifer recharge and decline occur over the year. In winter, cold fronts bring rain to the south-west. Rainfall decreases as you move north and east with the highest totals being found along the Darling Scarp to the south of Perth and in the extreme south-west corner of the state. Mild temperatures during the winter season also act to reduce evapotranspiration and therefore increase the effectiveness of the rain. Stream runoff reaches its peak during the last weeks of winter when soil moisture has been fully replenished. This combination of rainfall and stream flow means that water infiltrates into the ground and through the soil, recharging the groundwater aquifers.

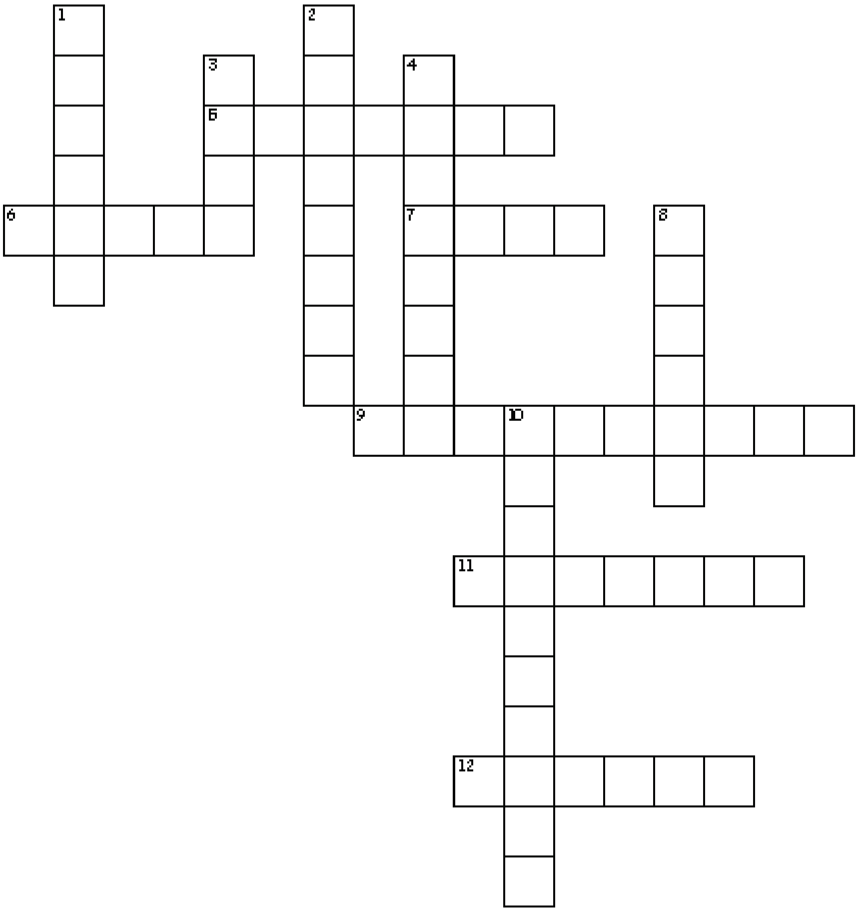
With the coming of summer, declining rainfall and rising temperatures bring the dry season. All but the largest streams cease to flow and the groundwater table falls. Higher evapotranspiration rates affect water levels in lakes and reservoirs. The native vegetation has adapted to this extended dry period and exhibits a number of special adaptations to prevent moisture loss (sclerophyllous characteristics).

Our drying climate has resulted in a 20 per cent decline in the amount of rainfall being received in the south-west over the last 40 years. With an increasing number of years having below average rainfall, the balances between precipitation, infiltration, runoff and evapotranspiration are changing. These changes in the water cycle are having a significant effect on the availability of water for agriculture, industry and drinking-water supplies. In addition, the availability of water for environmental purposes (i.e. ecosystem maintenance) is also being affected.

Activities 1 – 6 are designed to provide a detailed understanding of the operation of the water cycle in the south-west of Western Australia. They are based on the *Water cycle broadsheet.*

Activity 1

1. Complete the following crossword using the *Southern Perth topographic map* on side 1 of the *Water cycle broadsheet*.



Across
5. Land use found at GR (grid reference) 137255.
6. What structure surrounds the tailing dam near Hope Valley Road.
7. Recreational activity found about 5 km east of Orelia GR 885325.
9. Alternative name for White Lake.
11. Suburb north of Kingsley.
12. Feature found at GR 035301.

Down
1. Beach found north of Woodman Point.
2. Lake at GR 790270.
3. Hill or mount 55 m high on Garden Island.
4. Name of brook found below Canning dam.
8. Land use carried out at Lat 32 16'S Long 116 05'E.
10. Feature found at GR 838442.

2. List three different ways in which relief is shown on the topographic map.
3. Calculate the surface area in hectares of the Canning and the Wungong reservoirs.
   NOTE: There are 100 ha to 1 km^2.
4. Calculate the average gradient of the Wungong Brook from GR 211261 to GR 160319.
   NOTE: Find the height at the start and finish points and calculate the difference. Find the distance in metres along the brook. Divide the difference in height into the distance to find the gradient and express this as a ratio of 1 in x.
5. Identify two different types of surface water features produced by people (cultural water features) and provide map evidence to support your conclusion.
6. Annual rainfall across the Churchman Brook drinking water catchment is approximately 900 mm per year. Assuming 10 per cent of this runs off while the rest evaporates, is used by plants or infiltrates into the ground; calculate the amount of water that will enter the Churchman Brook reservoir each year. To do this activity, complete the following steps:
   - Use the scale shown on the *Southern Perth water resources* map to find the area of the catchment in hectares. This can also be done by plotting the catchment on the *Southern Perth topographic map*.
   - As there are 1 000 L of water to 1 m^3, a total of 10 000 000 L will fall on each hectare of land.
   - Runoff of 10 per cent will produce 1 000 000 L/ha.
   - Provide your answer in kilolitres (1 kL is 1 000 L).

Activity 2

The Canning Dam Catchment Area is found on the western edge of the Darling Plateau. It is a region of igneous granite outcrops and lateritic capstone. Being close to the edge of the plateau it has deep v-shaped valleys, which provide ideal dam sites. The Canning dam is one of a number of hills dams that supply drinking water to the Perth metropolitan area.

The majority of the catchment is covered by dry sclerophyllous forest and open woodland. Dominant species include jarrah in the higher rainfall areas to the west and wandoo in the eastern areas of the catchment.

The combined area of the catchments contributing to the Canning reservoir is approximately 804 km^2. The catchment extends 55 km in a south-easterly direction from the dam. The catchment is up to 16 km wide, with the Helena River Catchment Area forming a boundary on its north-eastern side and the Wungong and Serpentine Catchment Areas forming the southern boundary.

Elevation in the catchment is 200 m above sea level (ASL) at the surface of the reservoir, rising to 582 m ASL at Mt Cooke on the southern boundary of the catchment. Elevation at the catchment boundary is generally about 400 m ASL. Water inflow to the reservoir is mostly generated by lateral flow through the upper soil layer over the winter months. However, there is deeper subsurface flow yearround due to the slow release of groundwater recharged by winter rainfall infiltrating the gravelly soils. The average monthly flow in the winter months is significantly greater than in the summer months, with the greatest inflow of water occurring from late winter to early spring.

The area has a Mediterranean-type climate, characterised by warm, dry summers with cool, wet winters. The long-term average annual rainfall for the catchment is approximately 900 mm and most of this falls between May and September. There is considerable variation in rainfall across the catchment from approximately 1300 mm in the west through to 700 mm in the east. Since 1975, the average annual rainfall at Canning dam has decreased by almost 20 per cent from the long-term average. This drop in rainfall is associated with a significant reduction in stream flow from 1975 to the present. From 1948 to 1974 the average annual inflow of water into the Canning reservoir was 54 GL (a gigalitre equals 1 000 000 000 L), however, from 1975 to 2004 the average annual stream flow into the reservoir via the Canning River was only 22 GL. This decrease in average stream flow of approximately 60 per cent since the 1970s has mainly been due to reduced rainfall.

1. Using the information provided for the Canning dam as well as the map found on side 1 of the *Water cycle broadsheet*, write a detailed description of the *site* and *situation* of the Canning catchment. Include details of natural and cultural features.
2. With reference to topography, geology, climate, vegetation and cultural factors, account for the location of the Canning dam.
3. Explain why there is a decrease in rainfall as you move from west to east across the Canning catchment.
4. Identify one significant change that has occurred in the Canning catchment after the dam construction and briefly discuss how it impacts on the catchment and Perth's drinking water resources.
5. Compare and contrast the drainage patterns and water features shown to the east and west of the South Western Highway on the topographic map. Include the names and locations of different features as well as a description of their general distribution patterns.
6. Using the *Groundwater – infiltration* diagram on side 2 of the broadsheet as well as the *Southern Perth topographic map*, compare and contrast the infiltration and groundwater resources on the Darling Scarp and the Swan Coastal Plain. Explain why there is greater infiltration on the plain compared to the scarp.

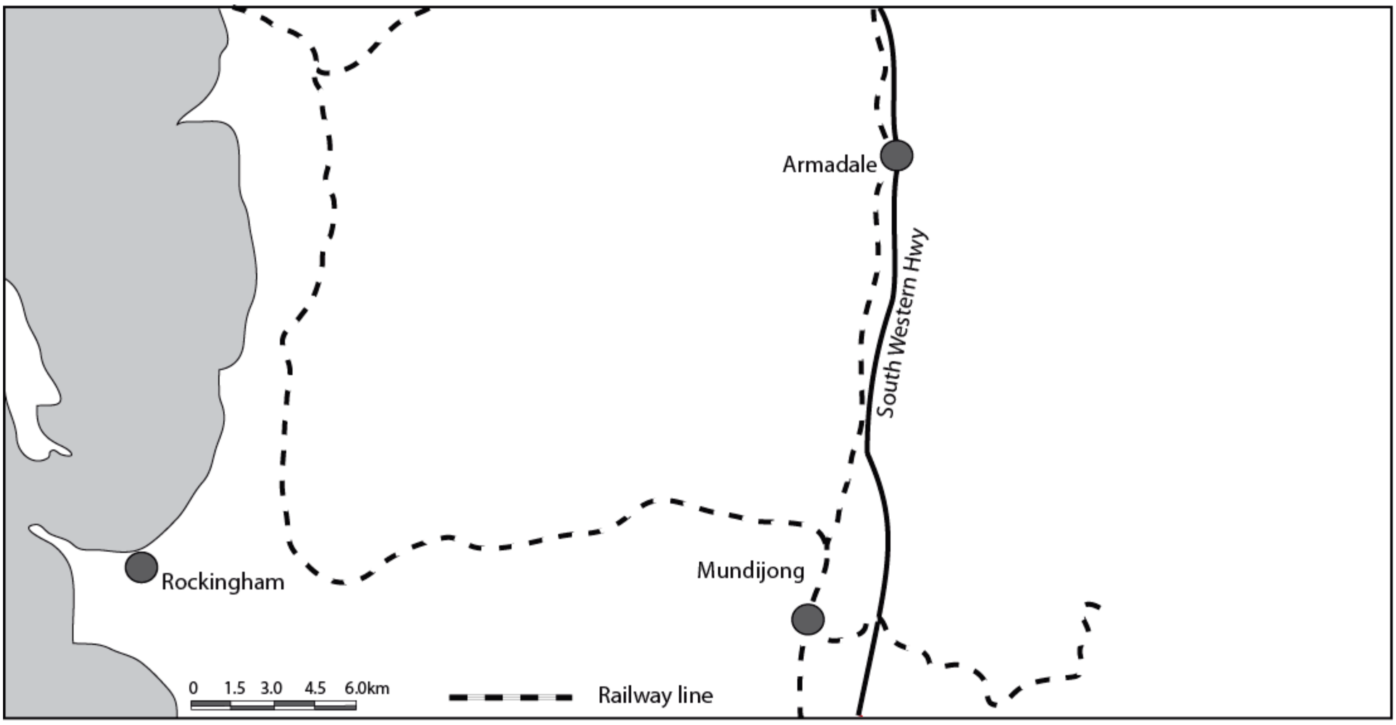
Activity 3

Topographic maps often show a number of water and drainage features. They assist us in understanding the importance of water to the biosphere and people. The following activities are provided to increase your understanding of these features.

1. Use the following outline map and the *Southern Perth topographic map* on side 1 of the *Water cycle broadsheet* to show the location of the water and drainage features listed below:
    - Jandakot Underground Water Pollution Control Area (UWPCA)
    - Yangebup, Thompsons and Forrestdale lakes

- Canning and Wungong reservoirs
- White Lake
- Bollard Bulrush Swamp
- Big Bulrush Swamp
- Wungong Brook
- Birriga drain
- Cockburn Sound
- Safety Bay.

Outline map



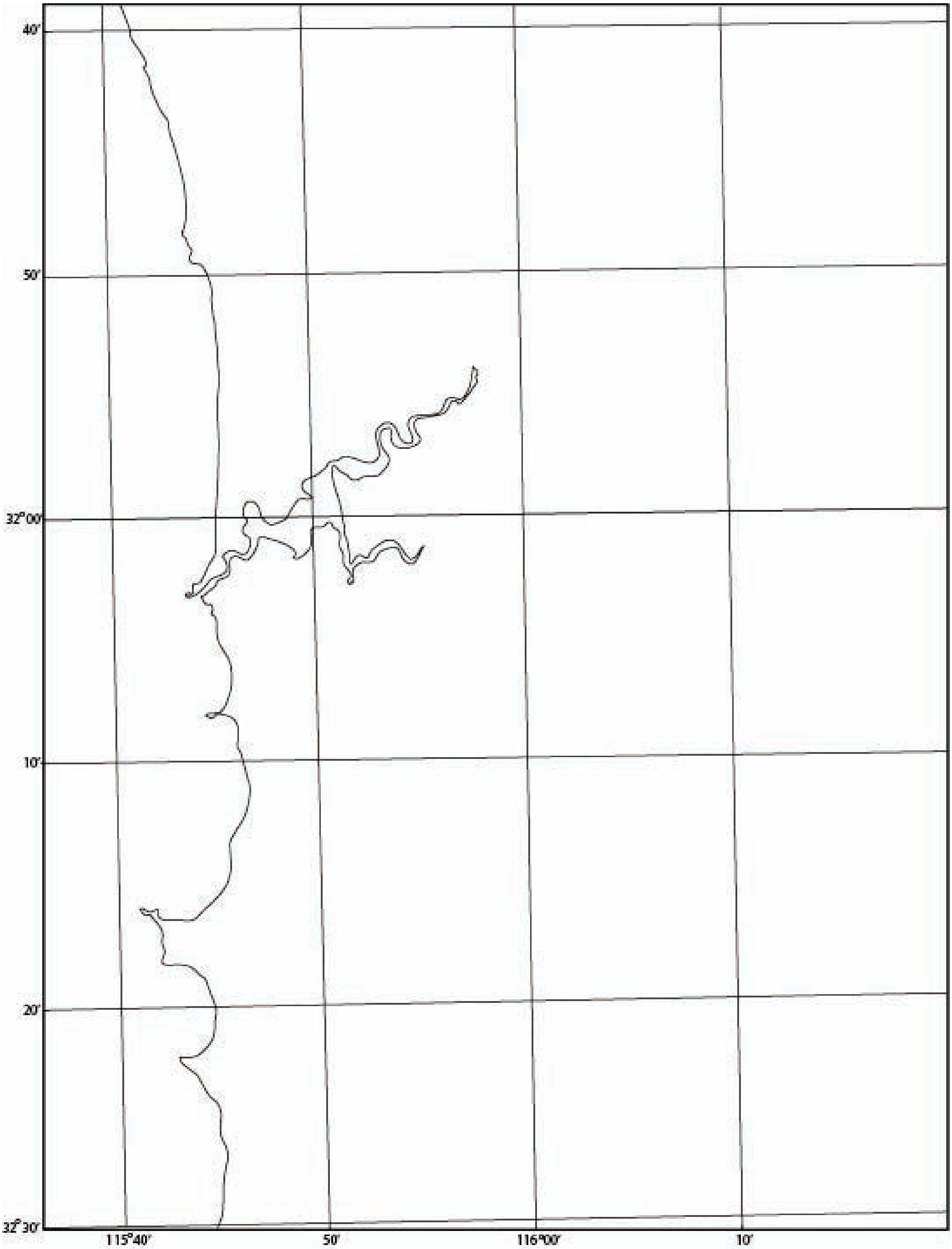
2. Based on information contained in the topographic map legend found on side 1 of the *Water cycle broadsheet* as well as your own research, describe or define the following water features:
   - reservoir
   - dam
   - intermittent swamp, lake or stream
   - perennial swamp, lake or stream
   - inundation
   - spring
   - catchment
   - tributary
   - drain.
3. Using map evidence, identify and describe the different ways in which people have changed the water and drainage features in the southern Perth region. Some of these can be identified by referring to the map, others you may need to infer.

Activity 4

Coordinates of latitude and longitude provide an accurate way of locating features on a map. The next set of activities uses latitude and longitude to plot a number of water resources and other features on the outline map provided.

1. Using the outline map of the Perth region provided below, plot the following features according to their latitude and longitude:
    - Perth airport weather station (side 2 of the *Water cycle broadsheet*)
    - Karnet weather station (side 2 of the *Water cycle broadsheet*)
    - Perth Desalination Plant 32^{o} 12’ S 115^{o} 46’ E
    - Canning dam 32^{o} 06’S 116^{o} 05’E
    - Wungong Dam 32^{o} 10’S 116^{o} 00’E
    - Serpentine Dam 32^{o} 20’S 115^{o} 57’E.
2. Mark in the approximate locations of the Swan Coastal Plain, the Darling Scarp and the Great Western Plateau. Explain how the topography of the region influences the location and types of water resources found here.
3. Explain how the location and distribution of water resources would affect the land use or urban planning of the Perth region. Consider the possible impacts of land use on water quality.
4. Using the *Southern Perth topographic map* found on side 1 of the *Water cycle broadsheet* mark on the urban settlements of Mundijong, Byford, Wattleup and Forrestdale on the Perth region outline map provided below. You will need to use the latitude and longitude on both maps to accurately complete this exercise. Describe the *site* and *situation* of two of these settlements.

Perth region outline map



Activity 5

When, where and how much rain falls is an important influence on the water resources of a region. The information provided on side 2 of the *Water cycle broadsheet* illustrates some of the rainfall characteristics associated with the Mediterranean-type climate of the south-west of Western Australia.

Rainfall is produced by three main methods. These are frontal, relief or orographic and convectional processes. It is often a combination of all three. In each case the cause of condensation and precipitation is uplift and cooling of moisture-bearing air moving in from the ocean.

<u>Frontal uplift</u>

Sub-polar low pressure cells found to the south of Australia shift northwards during the winter months. They attract air from the tropical Indian Ocean and from the cold Southern Ocean. The zone of contact between the tropical and polar air is the polar front. The denser cold air forces its way beneath the warm, moist, tropical air, lifting and cooling it. As it crosses the south-west it brings with it a band of rain-bearing clouds that mark the location of the frontal uplift. The cold westerly winds behind the initial front produce showery periods which gradually contract to the southern coastline as the front continues its eastward movement across the south-west of Western Australia.

1. Using the information contained on the weather map *Indian Ocean – evaporation and advection* write a detailed description of the weather and ocean characteristics associated with the frontal system. Include information on air pressure, wind direction, air masses and ocean temperatures.
2. Describe and explain the seasonal pattern of rainfall shown by the *Mediterranean climate - graphs*. Include information about the amount of rainfall occurring at different times of the year and its relationship with the seasons as illustrated by the changes in temperature.
3. Explain how this information is important to understanding the location and distribution of water resources in the south-west.

<u>Orographic uplift</u>

Even relatively small increases in the height of the land can produce rainfall. As frontal features cross the Swan Coastal Plain, they encounter the Darling Scarp and the Darling Ranges. As the air is forced to rise over these landforms, the amount of rainfall increases due to the orographic effect. Further inland, rainfall declines as the winter fronts pass across the Great Western Plateau.

4. Using the information provided by the *Mediterranean climate - graphs* and the *Annual rainfall - precipitation* map, describe and account for the changes in the amount of rainfall experienced when moving from west to east across the south-west of Western Australia.
5. How would this variation in rainfall affect the location of surface drinking-water catchments in the south-west?

<u>Convectional uplift</u>

Heat from the land or the sea produces low pressure systems mainly during the summer. Air is drawn into these systems and rises, producing cumulo-nimbus or thunderstorm clouds. They can build up as air continues to be drawn in and may sometimes produce violent wind squalls, tornadoes, heavy rainfall and hail. Their effect is often localised and short in duration. The hail storm that occurred in Perth in March 2010 was due to convectional uplift associated with hot, humid conditions.

6. Research the hailstorm that hit Perth in March 2010 and describe its impact on the city.
7. How useful are violent summer storms in providing additional drinking-water supplies for the Perth region?
8. Based on all of the information about water provided on side 2 of the *Water cycle broadsheet*, suggest a settlement in the south-west that would provide the best location for future population growth. Give reasons for your selection.

Activity 6

Evapotranspiration is the evaporation of water from soil, ocean and surface water features as well as the transpiration (loss of water) from plants. Potential evapotranspiration is the amount of water that would be converted into vapour and moved into the atmosphere if there was an unlimited surface water supply. The *Annual evapotranspiration – potential* map shows this potential in millimetres per year.

The evaporation of water from reservoirs and their catchments can have a significant effect on water levels in dams. Water from reservoirs (such as the Canning dam) is used by people, but water is also lost by evaporation. This needs to be replaced each year just to maintain the water level in the reservoir.

1. Study the map of annual evapotranspiration on side 2 of the *Water cycle broadsheet* and write a paragraph describing the change to variations in evapotranspiration rates within the south-west of Western Australia. Include data and references to actual locations. Suggest reasons for the different rates shown on the map.
2. Compare the annual evapotranspiration with the annual rainfall. Explain how these two factors affect the operation of the water cycle in the south-west of Western Australia.

Surface runoff occurs after the soil has been sufficiently saturated to allow any additional water to flow overland, usually in defined streams and rivers. The amount of water carried by rivers will depend on:

- the size of the catchment
- the amount of infiltration (soaking of water) into the ground
- the amount of rainfall
- the intensity and seasonal pattern of rainfall
- the variation in rainfall across the catchment.

Some rivers will have perennial or permanent flows while others will be seasonal or intermittent. In arid areas where rainfall is low and unreliable, rivers may be dry for many years and then carry large amounts of water following a period of heavy rainfall.

3. Write a paragraph describing the surface runoff or drainage pattern in the south-west of Western Australia.

4. Based on the annual rainfall in the south-west and the location and extent of the rivers, identify examples of rivers which are most and least likely to carry large volumes of water. Give reasons for your choices.
5. Rank the different rivers numbered on the drainage map from those best able to supply drinking water to those least able, considering quantity of water. Explain how you decided on your ranking. Identify other information that you would need in order to make a complete assessment of the suitability of the different rivers in the south-west as potential drinking water sources.
6. Investigate the top three rivers in your ranking and see if they are sites of existing dams and reservoirs.

Topic 2 – Water catchments: an investigation

Reference: *Water catchments broadsheet*.

Careful planning is needed to ensure that adequate water supplies are available to meet the social, economic and environmental needs of the south-west of Western Australia. To achieve this, decisions need to be made about the protection of catchments to provide safe drinking water, water for agriculture, industry, recreation and water to sustain the environment.

In this investigation you will look at the impact of people and planning decisions on two catchments in the Upper Collie River Basin. After completing the tasks that have been provided (activities 1 to 5), you will produce a presentation on the following topic using information and evidence gained from the *Water catchments broadsheet* as well as other sources.

The investigation

Issues and solutions involved in maintaining and developing safe, good quality drinking-water supplies from surface water catchments.

Planning for this topic should include information related to the following:

- land use issues within surface water catchments
- competing uses for water supplies
- catchment environments (landforms, soils, vegetation and climate)
- land use planning decisions and consequences
- water quality and quantity
- relevant data and examples from the case study area.

Presentation

Your topic can be presented as a written report, a poster, a PowerPoint, web page or as a debate.

The Collie River Catchment

The Upper Collie River Catchment covers an area of approximately 2 800 km^2 and contains a number of rivers that form the various tributaries of the Collie River. These include the Harris, Bingham, Collie South and Collie East. The catchment extends eastwards from the Darling Scarp across the Darling Range and plateau. Significant water supply sources within the catchment include the Wellington, Harris and Mungalup reservoirs and the groundwater aquifers of the Collie Basin. The climate of the catchment is Mediterranean, with an annual average rainfall between 950 mm on the western margin of the catchment and 550 mm on the eastern edge. The last 40 years have seen a decline in annual rainfall of between 15 and 20 per cent, which in turn has resulted in a significant reduction in flows into the main reservoirs.

The Wellington and Harris reservoirs are two important water bodies in the Upper Collie River Basin. The Wellington dam was originally constructed in the 1930s as one of a number of public works projects designed to provide jobs for thousands of unemployed people in Western Australia. The main purpose of the reservoir was to supply water to the south-west for irrigation on the coastal plain. The height of the dam wall was increased in 1944 and then again in 1960. This trebled the storage capacity to around 186 GL supplying water for irrigation and the Great southern towns water supply scheme (GSTWSS, a drinking water supply scheme that supplies Collie and 32 other south-west towns). Today the dam wall is 34 m high and 366 m long.

The Harris reservoir is located in the northern part of the Collie catchment and is much smaller than the Wellington reservoir with a capacity of 72 GL. It was built in 1990 to supply water to the GSTWSS due to problems of rising salinity in the Wellington reservoir. In contrast, the Harris reservoir contains much lower levels of salt, and is not exposed to the same level of recreational and land use activities as Wellington, therefore the contamination risks to water quality are reduced. A pipeline was also constructed to divert water from the Harris to the Stirling reservoir to supplement the Perth integrated water supply system (a drinking water supply scheme that supplies Perth, Mandurah and the Goldfields).

When the Wellington dam was first built the water from the reservoir was fresh with about 280 mg/L of salt. Salinity is measured as total dissolved solids (TDS). Salinity in the reservoir began to increase prior to 1960 as a result of ongoing clearing in the catchment. In 1978, the state government decided to halt the release of more crown land for farming and clearing, and existing farms were controlled for clearing by legislation. Logging of native forest was done in a more sustainable way and still continues. A state government plan of reforestation has seen almost 7 000 ha of private land purchased in the catchment and planted with trees. Despite these actions, the salinity of the Collie River just upstream of the reservoir continued to increase. While the rise now appears to have halted, the water flowing into the reservoir remains at approximately 950 mg/L TDS. The World Health Organization (WHO) guideline for maximum salt in drinking water is 500 mg/L TDS.

The Harris dam was built because water in the Wellington dam had become unsuitable for drinking. It is located within a hilly and higher area of the northern part of the Collie catchment and contains water that once flowed from a relatively undisturbed area of forest into the Wellington reservoir. The presence of forest and the absence of urban settlement and agriculture have protected the water quality within the Harris Dam Catchment Area.

Water quality

Chemical, physical and biological properties can affect water quality and the cost of treatment to ensure that it is safe for people to drink. The most serious risk to humans is from pathogens. These are micro-organisms that can cause a range of diseases. They include different bacteria, protozoa and viruses, and are often deposited in human and animal waste (i.e. faeces). These pathogens can cause mild to severe gastroenteritis and even death. Drinking-water supplies are frequently tested for a range of micro-organisms to make sure that the water quality meets *Australian drinking water guidelines* (ADWG) and WHO standards. The optimum is to have no detections of pathogens in a water sample.

Chemicals from urban, industrial, mining and farming activities can also contaminate drinking water. These chemicals can include heavy metals, oils and other hydrocarbons, pesticides and herbicides. These can cause illness to people if consumed in their drinking water. Naturally occurring minerals are also carried by water. These are dissolved from the rocks and soils that it passes through. Minerals such as iron, salts and manganese can affect the taste and quality of drinking water. Good-quality drinking water contains less than 500 mg/L TDS. Concentrations between 500 and 800 mg/L TDS are considered fair, and levels above 1 000 mg/L TDS are unacceptable.

Nutrients (such as nitrogen and phosphorus) from natural or human sources will also affect water quality. Based on health considerations, the ADWG have set a value of 50 mg NO_3/L (as nitrate) to protect bottle-fed infants under three months of age. Up to 100 mg NO_3/L (as nitrate) can be safely consumed by adults and children over three months of age. Where a water supply has between 50 and 100 mg NO_3/L nitrate, people caring for infants need to use alternative water sources when making up bottle feeds for babies. High nitrate levels can encourage the growth of algae and the reduction in oxygen levels in the water. It can also affect human health.

Turbidity gives water a cloudy or murky appearance. It is caused by very small particles which are suspended in the water. Turbidity is mainly the result of suspended soil and organic particles. Turbidity levels vary with the seasons and are affected by factors such as weather conditions, fires and the amount of flow within the streams. Increased levels of turbidity can affect water temperature and algal growth. Generally levels of 5 NTU (nephelometric turbidity units – a measure of visibility) or less are desirable. This level of turbidity corresponds to cloudy water. Levels of 25 NTU are murky with little or no visibility beyond a metre. Turbidity can also negatively affect water quality treatment processes such as chlorination to disinfect drinking water.

For the sources that it operates around the state (including Harris reservoir as described above), Water Corporation monitors the raw water (untreated source water) in accordance with the ADWG. Raw water is regularly monitored for a range of water quality parameters including pathogens, chemicals, salinity and aesthetic-related characteristics (such as turbidity). It is important to appreciate that raw water data does not represent the quality of drinking water distributed to the public. Barriers such as storage and water treatment, to name a few, exist downstream of the raw water to ensure it meets the requirements of the ADWG. For more information on the quality of drinking water sources around the state, refer to the most recent Water Corporation drinking water quality annual report at www.watercorporation.com.au/W/waterquality_annualreport.cfm.

<u>Harris reservoir water quality</u>

The Water Corporation regularly monitors the quality of raw water in the Harris reservoir because it is a drinking water supply. It has a turbidity range of 0.4 – 9.2 NTU with a median of 0.9 NTU. The pathogens found in samples taken from the water included *Escherichia coli* (30.5 per cent of samples), however, these were small detections that did not exceed WHO recommendations. Nitrates were low with a median concentration of less than 0.05 mg/L. Salinity has a median of 189.5 mg/L. For more information about the Harris reservoir's drinking water supply, visit www.water.wa.gov.au and click on Publications > Find a publication > Series browse > Water resource protection > then scroll down to find *Harris Dam Catchment Area drinking water source protection plan.*

Wellington reservoir water quality

The salinity in the Wellington reservoir is currently too high to supply drinking water, at about 950 mg/L TDS. A snapshot of the water quality flowing into the Wellington reservoir was taken in 2008 by the Department of Water as part of the *Statewide river water quality assessment*. The monitoring showed a turbidity of 3.16 NTU and total nitrogen at 0.52 mg/L. Pathogen readings were not taken. For more information and an interactive map showing the results of the *Statewide river water quality assessment* go to www.water.wa.gov.au > Tools and data > Monitoring and data > Water quality assessment.

Impacts of dams

The building of dams has meant that we have access to supplies of safe, good quality, reasonable-cost drinking water. However there are some impacts that the building of dams have on the environment. These may include:

- significant evaporative loss of water resources especially if the reservoir is broad and shallow, meaning that the water in the reservoir can become more salinised
- reduction of natural flood cycles that renew topsoil on surrounding agricultural lands
- potential reduction of tannins (tea-stained coloured water from leaves and other organic matter) in water downstream, hence more light penetration in water and change to aquatic flora and fauna
- denial of upstream passage for migrating fish
- loss of water flow downstream
- if there is variable rainfall, erosion can occur on the reservoir banks and cause sedimentation in the dam.

There are no plans for additional public water supply dams to be built. The government is currently considering deproclaiming (removing from legislated protection) a number of future public water supply dam sites (such as the Murray River). Future sources are likely to be from groundwater, desalination and/or water recycling.

Research, planning and conducting

The activities that follow will help you develop an understanding of the characteristics, issues and solutions associated with sustainable catchment management. These are shown by information related to the Collie catchment found on the *Water catchments broadsheet*.

Activity 1

1. Study the different information sources found on the broadsheet to produce a detailed, annotated (labels and notes) sketch map of the Collie catchment showing the following features:
    - main rivers, tributaries and water reservoirs
    - areas of forest
    - areas of high salinity
    - areas of higher and lower rainfall

- areas of significant mining and farming
- relief characteristics and significant landform areas.

2. Reproduce the final sketch map on an A3 sheet of paper in a frame measuring approximately 30 by 30 cm.
3. Include a scale, title, legend and labels around the margin of the map.

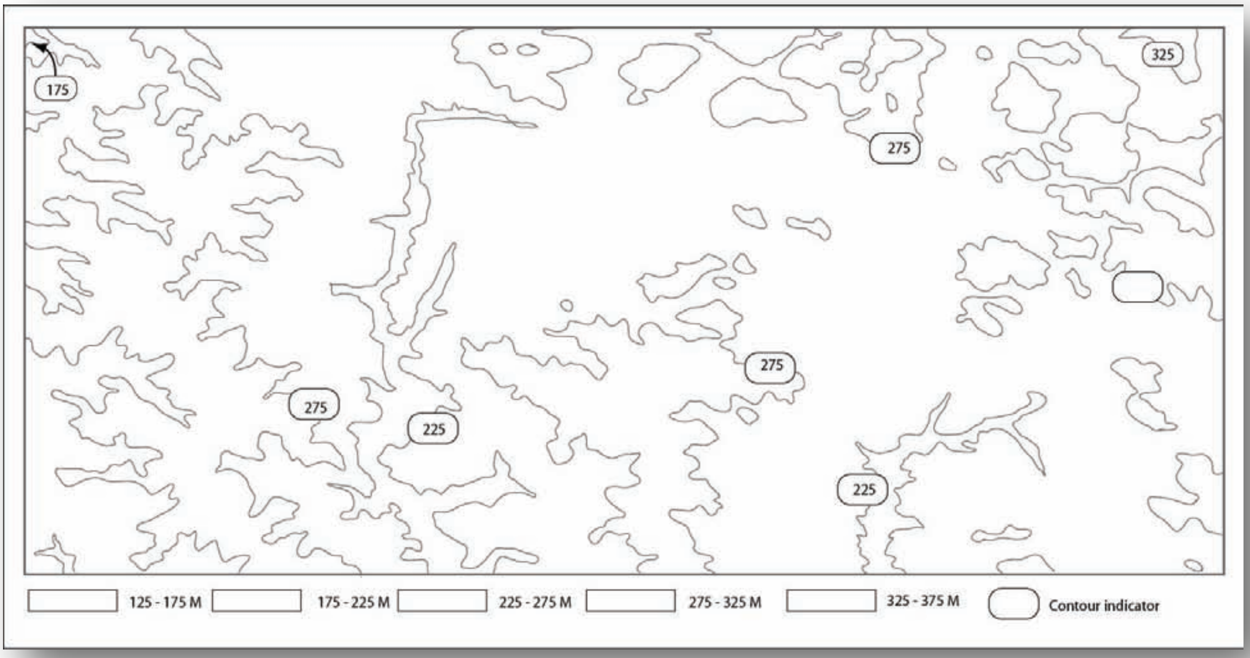
Activity 2

1. Describe the *site* of the Harris and the Wellington reservoirs making special reference to:
   - elevation or height
   - landforms
   - area or size
   - shape.
2. Describe the location or *situation* of the Harris and Wellington reservoirs making special reference to:
   - geographic location within the south-west
   - surrounding or adjacent areas and features
   - distances, directions and position.

Activity 3

1. Use the contour map provided below to show the shape and area of the Harris reservoir. Note that the contour interval is 50 m and shading may be used to show the areas of the map with similar heights.
2. Study the contour patterns and suggest reasons why this site was considered to be suitable for the construction of a dam.
3. Identify and briefly describe three factors that you think would be important when choosing a site suitable for the construction of a dam to supply drinking water.
   HINT: visit http://drinkingwater.water.wa.gov.au for information, scroll down to find examples of drinking water source protection plans.

Harris contour map



Activity 4

1. Using the information shown on the *Water quality factors* diagram, found on side 2 of the broadsheet, describe the characteristics of the different water types indicated by the letters A, B, C and D.
2. Based on the information provided on the Harris and Wellington reservoirs, suggest which water type(s) each reservoir corresponds to.

Activity 5

1. Draw up the table shown below and then summarise the characteristics listed for the Harris and the Wellington reservoirs and their catchments.

Characteristics	**Harris Dam Catchment Area**	**Wellington Dam Catchment Area**
Catchment size and location, water inflow and change over time.		
Water quality characteristics and potential human health consequences.		
Water uses and importance.		
People's activities and impacts within each catchment.		

2. Evaluate each catchment as a source of suitable drinking water.
3. Suggest and discuss at least four important strategies that could be put in place to protect water catchments and the quality of water supplies they contain.
   HINT: visit www.water.wa.gov.au > Managing our water > Water quality > Water quality protection notes.

Activity 6

Choose one of the sub-catchments supplying water to the Wellington reservoir for the site of a new dam and complete the following (do not choose Harris or Mungalup dams, as they already supply drinking water):

1. Draw a map to show the location of the dam and the probable extent of the reservoir.
   HINT: Consider the contours and their shape as well as the location and number of streams that will provide inflow into the reservoir.
2. Explain why you chose the catchment.
3. Explain why you chose the site of the dam wall.
4. Identify factors or arguments against the construction of the new reservoir and discuss how these could be dealt with.

Completing the investigation

Now that you have finished the activities provided, it is time to complete the investigation on the topic:

Issues and solutions involved in maintaining and developing safe, good quality drinking-water supplies from surface water catchments.

Conclusion

Your investigation should have a conclusion in which you consider the importance of maintaining and protecting surface water reservoirs and their surrounding catchments.

Topic 3 – Groundwater: the Gnangara mound

Reference: *Groundwater broadsheet*.

The area of the Swan Coastal Plain located to the north of the Swan River is a region of significant groundwater aquifers. Here the geology is made up of different layers of sand, clay and rock. The sandy layers are sandwiched between the confining beds of clay and rock to form confined and unconfined aquifers. This region is called the Gnangara mound and it covers approximately 2 200 km^2. The high point of the mound is located between Muchea and Lake Pinjar where the watertable is about 75 m above sea level (ASL). Groundwater moves from here towards the ocean and surrounding major waterways (Swan River, Ellen Brook and Gingin Brook).

The superficial or unconfined aquifer in the Gnangara mound is the shallow layer of groundwater that is easily reached via wells or domestic bores. Beneath this are two deeper layers of confined or artesian aquifers called the Leederville and the Yarragadee. The Yarragadee aquifer is up to 1 000 m below the surface of the coastal plain and is about 200 m thick. It extends from Geraldton to Augusta.

Almost 60 per cent of Perth's water supplies come from the confined and unconfined aquifers of the Gnangara mound. About 30 per cent of this is extracted directly from the shallow unconfined aquifer. To be sustainable this must be replenished each year by infiltration. The Leederville aquifer is generally below the superficial aquifer and supplies about 15 per cent of the groundwater needs; however, it is brackish and sometimes not as high-quality as the superficial aquifer. The deep artesian bores that have been drilled into the Yarragadee aquifer extract approximately 15 per cent of Perth's water supplies. Water extracted from the deep artesian supplies is of high quality and only requires disinfection to make it suitable for human consumption. Water from the surface reservoirs found in the Darling Ranges to the east of Perth is mixed with groundwater from the Gnangara mound to improve its quality, and is distributed through the Perth integrated water supply scheme by the Water Corporation.

Groundwater usually requires a series of treatments before suppling consumers, to ensure that it meets drinking water standards. This may include the following:

- aeration to increase oxygen levels and to oxidise dissolved iron
- the addition of chlorine to disinfect the water (i.e. pathogen inactivation)
- coagulation and flocculation to bind small particles of dirt and organic matter together
- clarification for removal of particulates by sedimentation
- filtration
- use of lime to decrease acidity
- fluoridation (this measure was introduced in the 1960s to reduce tooth decay in children and adults).

<u>Sustainability of the groundwater supplies</u>

The watertable level of the Gnangara mound is dropping. This is due to:

- groundwater extraction through bores for public drinking water and private use
- a decline in rainfall in the south-west
- the impact of large areas of pine plantation located on the mound
- the demands of market garden irrigation
- expanding urban population.

Water levels in the unconfined aquifer have been falling since 1975. By 1998, the watertable in the northern section of the mound had decreased by about 6 m and by 2 – 3 m in the southern area. Decreases in the confined aquifers have been greater with falls of between 5 and 15 m in the Leederville aquifer and 5 to 25 m in the Yarragadee aquifer.

Strategies to halt the decline in the water levels within the Gnangara mound include a reduction in the rates of extraction, the proposed recharge of groundwater by the injection of treated recycled water and the reduction in evapotranspiration by the staged removal of the Gnangara pine plantation.

Contamination of the unconfined aquifer can occur when pollutants move through the soil to the watertable. Any plume of contaminated water moves in the same direction as the groundwater flow. Potential sources of groundwater pollution include fertilisers from intensive horticulture, pathogens from animal waste and septic tanks, leakage of fuels from service stations, seepage from unlined landfill sites and general contamination from urban and industrial land uses. As a result of actual or potential pollution of the groundwater in the Gnangara mound, land-use planning controls in the region have imposed conditions on the use of the land. Urban planning documents identify an underground water pollution control area over the Gnangara mound. The most stringent protection is provided by priority 1 areas. These are the areas which generally have the highest quality groundwater and usually development is not permitted.

Water recycling

Perth's population of over 1.5 million people produce around 335 million litres of wastewater every day. Wastewater from showers, baths and washing machines make up almost all of the household water that is disposed of into the metropolitan sewerage system. Nearly all of this is treated to remove chemicals and micro-organisms in wastewater treatment plants and is then discharged into the ocean. In some areas it is used to irrigate parks or is recycled for industrial use.

An alternative use of this recycled water is to return it to the groundwater aquifers after treatment. This has the potential to meet up to 20 per cent of Perth's water needs by the year 2060. The combination of advanced water treatment methods and the natural filtering effects of the sandy Swan Coastal Plain would help ensure that the water being recycled is of a good quality. Along with the groundwater currently being extracted it would undergo further treatment before once again contributing to Perth's water supply. The recycling of water is currently being investigated by the Water Corporation with a trial being conducted to determine the viability and safety of this process.

<u>Groundwater activities</u>

Using the information provided and the *Groundwater broadsheet*, complete the following activities.

Activity 1

Write a detailed description of the Gnangara groundwater mound including its:

- location, size and shape
- relief, landform and important water features
- land use across the mound
- structure and geological characteristics
- groundwater characteristics.

Include maps and diagrams to assist in providing a complete description.

Activity 2

Draw an outline map of the Gnangara groundwater mound region using the *Gnangara groundwater mound – land use map* on side 1 of the broadsheet. Based on the types of land uses shown on the map and information about groundwater pollution risks:

1. Classify the different areas on the blank map as high, medium or low pollution risk areas. Use colours and a key to identify the three areas.
2. Briefly explain why there are different degrees of groundwater pollution risks across the Gnangara mound.
3. Compare your map with the current distribution of bores that supply public drinking water. Evaluate the extent to which the location of the bores has been influenced by the differences in the levels of pollution risk shown by your map.
4. Identify some strategies that could be put in place to reduce the impact of the different land uses on the quality of the groundwater resource.

HINT: Research water quality protection notes covering various land uses. See www.water.wa.gov.au > Managing our water > Water quality.

Activity 3

Using the *Groundwater systems model* found on side 2 of the broadsheet, write a detailed explanation of the ways in which the groundwater supplies in the Gnangara mound can be managed sustainably. Consider the following:

- the balance between extraction and replenishment rates
- factors affecting evapotranspiration
- factors affecting infiltration, inflows and groundwater outflows
- our drying climate.

Activity 4

You have been asked to prepare a questions and answers brochure on the recycling of wastewater to address Perth's future water needs.

- Prepare five questions that would most likely be asked by the public about this water recycling initiative.
- Research and prepare a short paragraph answer for each of the questions that would provide the information to the public.
- Include at least two graphs and two diagrams in your brochure.

HINT: Research the Water Corporation's website www.watercorporation.com.au

Activity 5

Using the information provided on the different water sources and their associated supply costs, evaluate the advantages and disadvantages of each in meeting Perth's current and future water needs. Consider the following:

- the reasons why there is such a big difference in the costs associated with the different water sources
- the environmental impacts of using the different sources
- the capacity to sustainably meet the future water needs of the Perth region.

Write two paragraphs outlining the conclusions can you draw from the information provided by the graphed data.

Activity 6

Develop a poster to be put in shopping centres within the Perth metropolitan area, informing people of the importance of protecting and sustainably managing the groundwater resources found in the Gnangara mound. The poster should be designed to illustrate the following:

- the different uses of the groundwater
- the risk of pollution from land uses
- the location and importance of the groundwater resource
- the ways that the groundwater can be sustainably managed
- the steps that can be taken to minimise the risk of contamination.

HINT: Visit http://drinkingwater.water.wa.gov.au for information.

References

Department of Water 2007, *Harris Dam Catchment Area drinking water source protection plan*, Department of Water, Perth, available <http://www.water.wa.gov.au/PublicationStore/first/76344.pdf>

Government of Western Australia 1909, *Metropolitan Water Supply Sewerage and Drainage Act* (WA), reprinted under the *Reprints Act 1984* (WA) as at 27 April 2008, available <www.slp.wa.gov.au/legislation/statutes.nsf/main_mrtitle_588_homepage.html>.

– 1947, *Country Areas Water Supply Act*, reprinted under the *Reprints Act 1984* (WA) as at 14 April 2008, available <www.slp.wa.gov.au/legislation/statutes.nsf/main_mrtitle_208_homepage.html>.

National Health and Medical Research Council (NHMRC) & Natural Resource Management Ministerial Council (NRMMC) 2004a, National Water Quality Management Strategy: *Australian drinking water guidelines*, Australian Government, Canberra, available <www.nhmrc.gov.au/publications/synopses/eh19syn.htm>.

Water & Rivers Commission 2004, *A fresh future for water: salinity situation statement for the Collie River catchment: a summary*, Water & Rivers Commission, Perth, available <http://www.water.wa.gov.au/PublicationStore/first/13228.pdf>

Western Australian Planning Commission 2003, Statement of planning policy no.2.7: *Public drinking water source policy*, Government Gazette Western Australia, 10 June 2003, pp. 2077-82, Government of Western Australia, Perth, available <http://www.planning.wa.gov.au/Plans+and+policies/Publications/149.aspx>

World Health Organization 2004, *Guidelines for drinking-water quality – Volume 1 – Recommendations*, 3rd edn, World Health Organization, Geneva, available <www.who.int/water_sanitation_health/dwq/gdwq3rev/en/index.html>.

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