EDUCATING KIDS
ABOUT AGRICULTURE

Wickedly Water Efficient

Teacher Handbook

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Australian Government
Department of Agriculture, Water and the Environment

DELIVERED BY: FOOD & FIBRE EDUCATION SA, GEORGE the FARMER, AU2100 Growing Next Century's Natural Capital

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Welcome to Wickedly Water Efficient

ABOUT

The Wickedly Water Efficient programme, an initiative of Educating Kids about Agriculture with support from Primary Producers SA (PPSA), explores the journey of water across our landscape and the efficient use of water on farms to produce our food.

Over the 10⁺ lesson programme, students investigate agriculture in South Australia and learn about the importance of water in agriculture to produce food. Students learn about the water cycle, agricultural water use (irrigation), water movement from the soil through plants to the atmosphere and wickedly water efficient farmers. Students also have a chance to be wickedly water efficient themselves, growing fast crops under a range of experimental conditions. There are options to extend the lessons beyond the minimum ten lessons.

Students will also explore the role science, technology, engineering, and maths play in sustainable water use. Each school participating in the funded programme will receive a wicked water efficiency kit – which includes a rainfall gauge, soil moisture probes, different types of soil and plant growing resources.

WHY?

Water is a limited resource in South Australia. We live in the driest state in the driest inhabited continent. This means that our farmers cannot rely on rainfall alone to grow the variety of foods we enjoy and that we need to keep us healthy.

Water is, therefore, the most important input required for agriculture production in South Australia. Our farmers need to use it wisely and be wickedly water efficient to make sure they grow the best crop they can with the water they have on their farm.

In countries like ours with a dry and variable climate, irrigation from rivers, lakes or groundwater provides more productive and diverse agriculture than is possible from rainfall alone. Irrigation in south-eastern Australia is concentrated in the Murray–Darling Basin and there is more demand for irrigated products from this region than there is water to supply this demand.

In the future, it is likely that there will be even less water available for use because of changes in rainfall and higher temperatures, and thus lower catchment inflows, as a result of climate change. Bushfires and changing land use will also affect future water quality and quantity. To make matters even more challenging, it is likely that there will be more South Australians to feed as well and that is why wickedly efficient water use is so important to us.

Over the next ten weeks your students will work as young scientists and discover how we can use science to become more efficient with our water use when producing food on our farms, in our school gardens and in our own backyards.

GET IN TOUCH

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1 SAFETY

Learning to use materials and equipment safely is central to working scientifically. It is important, however, for teachers to review each lesson before teaching to identify and manage safety issues specific to a group of students.

A safety icon is included in lessons where there is a need to pay particular attention to potential safety hazards.

The following guidelines will help minimise risks:

- Be aware of your school's policy on safety in the classroom and for excursions.
- Check students' health records for allergies or other health issues.
- Be aware of potential dangers by trying out activities before students do them.
- Caution students about potential dangers before they begin an activity.
- Clean up spills immediately as slippery floors are dangerous.
- Instruct students never to smell, taste or eat anything unless they are given permission.
- Discuss and display a list of safe practices for science activities.

A risk assessment worksheet is provided for students to complete before undertaking the watering experiment.

2 UNIT AT A GLANCE

The 10-lesson plan, presented below, has been designed around double science lessons conducted over a school term. Teachers can adapt to single lessons or deliver these lessons at their own pace by using the Powerpoint presentations and worksheets provided to match their teaching and students' needs. There are options for extension provided in most lesson outlines.

The class watering experiment begins in Lesson 3 and continues with twice weekly watering and data collection until Lesson 10.

Continuous and end of term assessment options are provided.

Phase	Lesson	At a glance
ENGAGE	**Lesson 1** Why is water important?	To capture students' interest and find out what they know about how the importance of water, water scarcity and its use in agriculture.
EXPLAIN	**Lesson 2** The Scientific Method	To introduce the scientific method for experimental design.
EXPLORE	**Lesson 3 & 4** Further Investigation	To support students to plan and conduct an open investigation into how varying water volumes might affect a plant's growth, using terminology such as dependent and independent variables.
EXPLORE	**Lesson 5 & 6** The catchment water cycle	To provide students with an understanding of The Water Cycle and catchments. To support students to investigate the catchments that they live in and rely on for water supplies, including surface water and groundwater systems.
	Lesson 7 & 8 How do plants use water?	To provide students with an understanding of the unique properties of water and how plants use water to photosynthesise. To demonstrate how water moves through plants and what factors change plant water use.
EXPLAIN	**Lesson 9 & 10** Water use efficiency in Agriculture	To provide students with an understanding of how water is used in Agriculture in South Australia. To introduce the role of science in determining to how to make the most of available water in agriculture.

Phase	Lesson	At a glance
ELABORATE	**Excursion** Observation of irrigation practices (Excursion)	To demonstrate to students how water is used in South Australian Agriculture through a range of irrigation approaches. To elicit students' questions about water scarcity and agricultural water use.
EVALUATE	**Assessment Options**	
	Continuous assessment using worksheets.	To provide opportunities for students to represent what they know about how farmers use water efficiently to produce our food, and to reflect on their learning during the unit.
	Present investigation results.	To present their experimental findings by graphing changes in plant width and height over time for each of the treatments and the control. To allow students to explain these results with regard to their hypothesis and any observations made during the experiment.
	Design challenges	To support students to plan and design a water efficient farm to decrease water consumption.

3 ALIGNMENT WITH THE AUSTRALIAN CURRICULUM

The Wickedly Water Efficient teaching materials are written to align to the Year 5 and 6 levels of the Australian Curriculum: Science. The three strands—Science Understanding, Science Inquiry Skills and Science as a Human Endeavour - are interrelated and embedded throughout the unit. The Australian Achievement Standards and Curriculum mapping for both Years 5 and 6 are provided in the following sections for reference and reporting.

3.1 ACHIEVEMENT STANDARDS

The Australian Curriculum: Science Year 5 achievement standards indicates the quality of learning that students should demonstrate by the end of Year 5.

By the end of Year 5, students can classify substances according to their **observable properties and behaviours**. They explain everyday phenomena associated with the transfer of light. They describe the key features of our solar system. They **analyse how the form of living things enables them to function in their environments**. **Students discuss how scientific developments have affected people's lives, help us solve problems and how science knowledge develops from many people's contributions.**

Students follow instructions to pose questions for investigation and predict the effect of changing variables when planning an investigation. They use equipment in ways that are safe and improve the accuracy of their observations. Students construct tables and graphs to organise data and identify patterns in the data. They compare patterns in their data with predictions when suggesting explanations. They describe ways to improve the fairness of their investigations, and communicate their ideas and findings using multimodal texts.

The Australian Curriculum: Science Year 6 achievement standards indicates the quality of learning that students should demonstrate by the end of Year 6.

By the end of Year 6, students can compare and classify different types of observable changes to materials. They can analyse requirements for the transfer of electricity and describe how energy can be transformed from one form to another when generating electricity. They can explain how natural events cause rapid change to Earth's surface.
They can describe and predict the effect of environmental changes on individual living things. Students can explain how scientific knowledge helps us to solve problems and inform decisions and identify historical and cultural contributions.

Students can follow procedures to develop investigable questions and design investigations into simple cause-and-effect relationships. They can identify variables to be changed and measured and describe potential safety risks when planning methods. They can collect, organise and interpret their data, identifying where improvements to their methods or research could improve the data. They can describe and analyse relationships in data using appropriate representations and construct multimodal texts to communicate ideas, methods and findings.

The sections relevant to *Wickedly Water Efficient* are bolded above. By the end of the unit, teachers will be able to make evidence-based judgements on whether the students are achieving below, at or above the achievement standard for the sections bolded above.

3.2 CURRICULUM MAPPING

The Wickedly Water Efficient teaching materials are written to align to the Year 5 and 6 levels of the Australian Curriculum Science. The table below maps the different components of the 10-lesson programme to relevant areas of the curriculum.

<table>
<tr><th colspan="2">Understand how science works</th></tr>
<tr><td>Year 5</td><td>Year 6</td></tr>
<tr><td>In Year 5, students are introduced to cause and effect relationships through an exploration of adaptations of living things and how this links to form and function. Students begin to identify stable and dynamic aspects of systems and learn how to look for patterns and relationships between components of systems. They develop explanations for the patterns they observe.</td><td>In Year 6, students explore how changes can be classified in different ways. They develop a view of Earth as a dynamic system, in which changes in one aspect of the system impact on other aspects; similarly, they see that the growth and survival of living things are dependent on matter and energy flows within a larger system. Students begin to see the role of variables in measuring changes and the value of accuracy in these measurements. They learn how to look for patterns and to use these to identify and explain relationships by drawing on evidence.</td></tr>
<tr><th colspan="2">Science Understanding</th></tr>
<tr><th>Chemical sciences</th><th>Biological sciences</th></tr>
<tr><td>Recognising that substances exist in different states depending on the temperature</td><td>The growth and survival of living things are affected by physical conditions of their environment</td></tr>
<tr><th colspan="2">Nature and development of Science</th></tr>
<tr><td>Testing predictions relating to the behaviour of solids, liquids and gases by conducting observational experiments</td><td>Science involves testing predictions by gathering data and using evidence to develop explanations of events and phenomena and reflects historical and cultural contributions (numeracy)</td></tr>
<tr><th colspan="2">Science as a Human Endeavour</th></tr>
<tr><td colspan="2">Use and influence of science
Scientific knowledge is used to solve problems and inform personal and community decisions (personal and social capability, ethical understanding)</td></tr>
<tr><td>Considering how best to ensure growth of plants (critical & creative thinking)
Considering how decisions are made to grow particular plants and crops depending on environmental condition (critical & creative thinking)</td><td>Considering how personal and community choices influence our use of sustainable sources of energy (sustainability, personal and social capability, ethical understanding, critical & creative thinking)</td></tr>
</table>

Science Enquiry Skills

Questioning and predicting
With guidance, pose clarifying questions and make predictions about scientific investigations exploring the range of questions that can be asked about a problem or phenomena and with guidance, identifying those questions that could be investigated *(literacy, critical and creative thinking)*

Planning and conducting
Identify, plan and apply the elements of scientific investigations to answer questions and solve problems using equipment and materials safely and identifying potential risks
Decide variables to be changed and measured in fair tests, and observe measure and record data with accuracy using digital technologies as appropriate *(literacy, critical and creative thinking)*

Processing and analysing data and information
Construct and use a range of representations, including tables and graphs, to represent and describe observations, patterns or relationships in data using digital technologies as appropriate *(literacy, numeracy, ICT capability, critical and creative thinking)*

Compare data with predictions and use as evidence in developing explanations *(literacy, numeracy, critical and creative thinking)*

Evaluating
Reflect on and suggest improvements to scientific investigations *(critical and creative thinking, literacy-Yr6)*

Communicating
Communicate ideas, explanations and processes using scientific representations in a variety of ways, including multi-modal text *(literacy, ICT capability)*

4 LESSONS ONE & TWO – INTRODUCTION

RESOURCES

PowerPoint file: WWE Lessons One & Two Feb 2022

Refer to file: 2017 All the water in the world activity.pdf

Refer to APPENDIX A at back of booklet: Designing a watering experiment

Worksheet: WaterStorm Why is Water Important (docx or pdf)

4.1 Learning Objectives

Lesson 1

- Understand why water is important.
- Recognize that there is lots of water on Earth, but not much is freshwater.
- Understand how farmers use water to produce food.

Lesson 2

- To introduce students to the scientific method
- To support students to plan and conduct an open investigation into watering and soil type variables that might affect a plant's growth

4.2 Teacher Background Information

Did you know?[1 2]

- Scientists are still trying to work out where the first water on Earth came from, it might have even come from Outer Space (Science American 2018)[3]. A person could survive a month without food but wouldn't survive 3 days without water.
- Earth is at the right distance from the Sun for water to occur as a liquid. Any further away and it would all be solid ice. Any closer and there would be 'runaway' climate change and it would all evaporate. Just look at Venus if you want to see what runaway climate change looks like!
- 75% of both a human brain and a living tree is composed of water
- Over 70% of the Earth's surface is covered in water but only 5% of all the water on Earth is freshwater.
- 97% of the earth's water is found in the oceans (too salty for drinking, growing crops, and most industrial uses except cooling).
- 3% of the earth's water is fresh.
- 2.5% of the earth's fresh water is unavailable: locked up in glaciers, polar ice caps, atmosphere, and soil; highly polluted; or lies too far under the earth's surface to be extracted at an affordable cost.
- 0.5% of the earth's water is available fresh water.[4]

[1] https://www.abs.gov.au/statistics/industry/agriculture/land-management-and-farming-australia/2016-17
[2] https://www.abs.gov.au/statistics/industry/agriculture/water-use-australian-farms/2018-19
[3] Scientific American (https://www.scientificamerican.com/article/how-did-water-get-on-earth/).
[4] https://www.usbr.gov/mp/arwec/water-facts-ww-water-sup.html

Water use in Agriculture

Agriculture (including irrigation, livestock and aquaculture) is by far the largest water consumer globally, accounting for 69% of annual water extractions from the Earth's freshwater resources. Water scarcity affects more than 40% of the world's people, which is why the United Nations Sustainable Development Goal 6 is all about avoiding the waste of water and making sure everyone has access to clean water.

Reference: United Nations 17 Goals for Sustainable Development https://sdgs.un.org/goals

4.3 Lesson Outline

Lesson 1 - This first double lesson starts with an overview of why water is important to all living things, not just humans, and why water is so important to agriculture. There are several infographics with facts about Australian farm outputs and how dependent Australians are on farmers to produce our food. Even students that live on farms are likely to rely on other farmers to ensure that they have a diverse and healthy diet. Volumes of water are discussed in megalitres with reference to an explanatory factsheet from the Murray Darling Basin Authority.

Earth is known as the blue planet because more than 70% of its surface is covered in water. Only 3% of that is freshwater, however, and only 1% is freshwater and available for human use. That 1% needs to be shared with rivers, wetlands and other living things that depend on freshwater. This proportionality is explained as a series of water droplets on Slides 6 to 9. Hold these slides until after the class Demonstration and/or Investigation Activity, below.

Investigation Activity

How much of the total water found on the Earth is freshwater and available for us to use?
Split into groups of three and take fifteen minutes to find out the percentage of water on Earth is: ocean water, groundwater, rivers, icecaps/glaciers, freshwater lakes, inland seas/salt lakes, and in the atmosphere. You can use any resource that is available to you.

AND/OR

Demonstration

This can be demonstrated using 1L of blue-coloured water to represent all the water in the world, from which 30ml can be poured off into a beaker to represent the freshwater component and then 10ml of that can be poured off into a smaller vessel to represent the 1% we can actually use. See 2017 All the water in the world activity.pdf.

Warm Up

Watch video: **https://vimeo.com/77933478**

A link to a 7½ minute video from Cool Australia's website is provided. This talks about the global water cycle with an emphasis on sustainable water use and reducing pollutants entering waterways. In class teaching about similar topics to those covered in this lesson and student research projects are also presented.

Assessment - WaterStorm Activity – Exploration

Using the WaterStorm Why is Water Important? Activity sheet, students share what they already know about the importance of water. Below is a list of focus questions for this topic.

These questions will depend on students' prior knowledge but could include:

- Why is water important to your life?
- List the ways in which we use water – directly and indirectly
- Where do we get water from?
- Where does water go after we've used it?
- List the ways in which water is used in agriculture?
- What do you already do to save water?
- What could you do to use less water in your life?

Using a think-pair-share strategy, ask the students to respond to the questions.
In a think-pair-share activity, students spend some time individually thinking about and recording their ideas. They then share their ideas with a partner and decide on the list for their pair. Two pairs of students form teams of four to develop a team list.

Concept mapping

Explain that concept mapping is an effective way of organising and visually representing the relationships between ideas. Students work in groups of three to create a concept map showing the different ways in which we use water.

Explain that a concept map has labels (ideas) and arrows with linking terms. Negotiate a starting list of concepts for the labels. Group present their concept map to the class while other students evaluate it and make suggestions for improvement.

Lesson 2 – if there is time during this first double lesson, introduce the concepts and terminology of experimental design using Slides 15 to 21. This will set the students up for Lessons 3 & 4 in which plan and begin their watering experiment.

Refer to APPENDIX - Designing a water experiment at the back of this booklet.

The watering experimental plan includes a Safety Plan that students should complete before undertaking the experiment.

5 LESSON THREE & FOUR – EXPERIMENTAL DESIGN

RESOURCES

PowerPoint file: WWE Lessons Three & Four Feb 2022

Refer to APPENDIX at back of booklet: Designing a watering experiment

Worksheets: WWE Experimental Plan Worksheet (docx or pdf)

WWE Safety Plan Worksheet (docx or pdf)

WWE Data Sheet (docx or pdf)

5.1 Learning Objective

- To support students to plan and conduct an open investigation into watering and soil type variables that might affect a plant's growth

5.2 Lesson Outline

This second double lesson centres around setting up the watering experiment that will run for the next six to seven weeks. Students will apply different volumes of water to radish seedlings in tubes. They will need to erect an hypothesis – an educated guess about what they think will happen – and complete the Experimental Plan Worksheet, including the Safety Plan Worksheet. Students will measure changes in height and width of the plants over the period of the experiment.

Plants need to be located undercover where they will not receive rain but will receive dappled light in summer or a few hours of sunlight in spring, winter or autumn. Note that the pots are black and will get hot enough to kill the plants if exposed to direct sunlight on hot days.

We have suggested that the specific volumes of water are applied twice a week (e.g. Tuesday and Friday or Monday and Thursday) in accordance with the three treatments. Treatment 1 is the smallest volume of only 1ml twice a week. This should not be enough to sustain the plant's water needs and it is expected that these seedlings will grow poorly and/or die during the experiment. Treatment 2 is 10ml twice a week and depending on the weather during the experiment, this should be enough to keep the plants alive and growing. Treatment 3 is 30ml twice a week. This should be too much. Water should drain out the bottom of the plant tube and the increased water should not result in further increase in growth or survival beyond Treatment 2. Plastic pipettes are provided for applying 1ml and beakers for larger volumes.

The volumes of water suggested for this experiment are refined from experiments conducted in Victor Harbor in the mild conditions of spring 2021. It may be necessary to increase volumes in hotter climates to 5ml, 30ml and 50ml twice a week, or even more, especially as the seedlings grow. It is OK to change the volume for each treatment part way through as long as the students have a sound reason for doing so and the logic is recorded for use in explaining the results.

The control will yield some information on the optimal watering to be wickedly water efficient. The control tubes are watered in accordance with the soil moisture probe, adding 10-15ml at a time. To avoid damage to the seedlings, it is best to place the soil moisture probe into the control near the edge and away from the roots and leave it in place while all four tubes are watered by the student group. They can record the soil moisture at the beginning and the end. The aim is for the control plants to always be moist but not overwatered.

Only the Control plants will be measured with the soil moisture probe at each watering. Students can test the soil moisture in the other pots to underpin their observations of different growth rates, but less frequent soil moisture probing is recommended to avoid unnecessary root damage.

Enough seedling tube racks have been provided for the plants to spaced out so that only three groups of four tubes are in each rack. This allows students to access the plant tubes easily for watering.

Make sure each pot is labelled correctly with the paint pen provided. It is very important that the right plant receives the right volume of water each time. See the photo below for labelling and plant pot layout (Figure 1).

A data sheet is provided for recording results.

Figure 1: Experimental pots set up showing the separation of each group of four pots by an empty row in the pot rack and the labelling of the control (C), Treatment 1 (1), Treatment 2 (2) and Treatment 3 (3).

6 LESSONS FIVE & SIX – THE WATER CYCLE

RESOURCES

PowerPoint file: WWE Lessons Five & Six Feb 2022

Worksheet: Water Storm The Water Cycle Worksheet (docx or pdf)

6.1 Learning Objectives

- Describe the water cycle including appropriate terminology: evaporation, transpiration, condensation, precipitation, infiltration, surface runoff, and groundwater.
- Label the water cycle diagram
- Describe the movement of water within the water cycle across a catchment.

6.2 Teacher Background Information

6.2.1 The Water Cycle

The following graphic (Figure 2) is used repeatedly in the Wickedly Water Efficient PowerPoint slides to describe parts of the water cycle and where irrigation changes the 'natural' water cycle. The icons and symbols could be used by the students to build their own water cycle models.

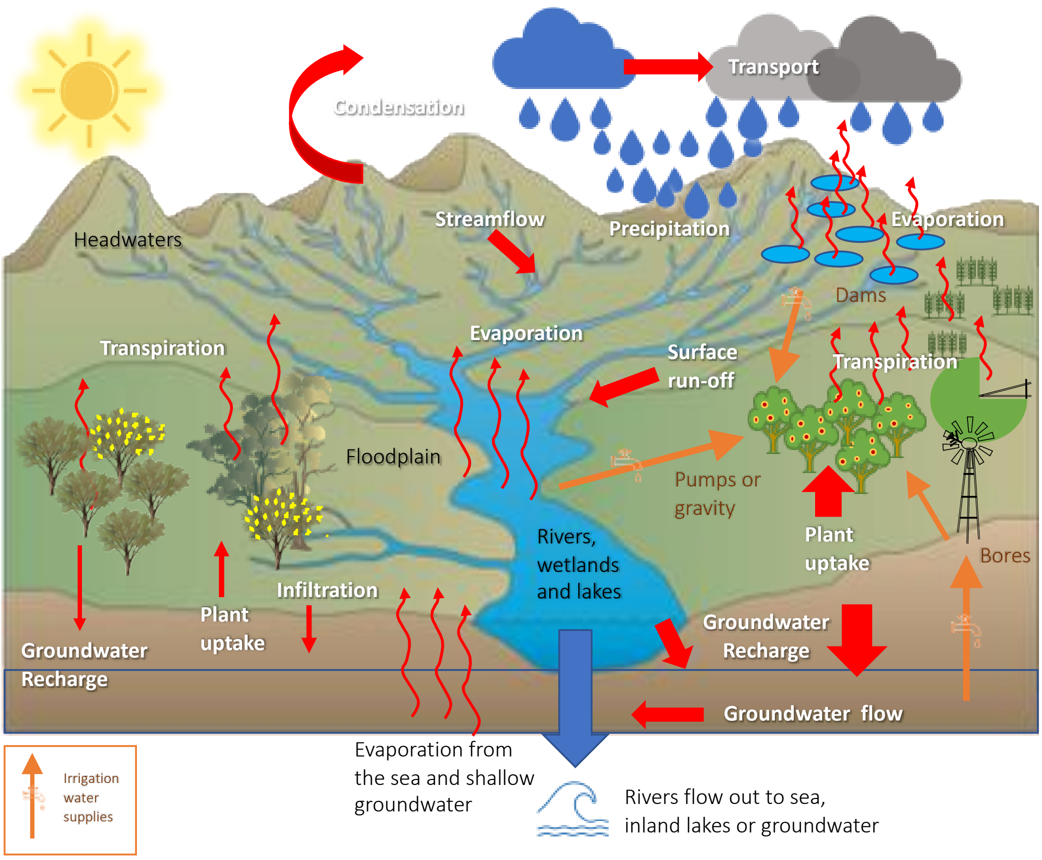


Figure 2: The water cycle showing key catchment components and processes (red arrows, white labels) and irrigation methods (orange arrows, grey labels).

You may think that every drop of rain that falls from the sky, or each glass of water that you drink, is brand new, but it has been constantly recycled by the global water cycle for at least 4.3 billion years. Think about that. You might be drinking the same water that an ichthyosaurus swam in, or a Mesopotamian used in the very first irrigation scheme. Scientists are still trying to work out where the first water on Earth came from, it might have even come from Outer Space (Science American 2018). Wherever it came from, we know that water cycles around the Earth and never, ever stops.

Follow the water in Figure 2 as it cycles around the Earth, as follows:
The heat of the sun provides energy to make the water cycle work.

Evaporation: The sun's heat evaporates liquid water from surface water bodies (e.g. the sea, wetlands, rivers, lakes, dams) and out of surface soils, converting it to water vapor. This invisible water vapor rises into the atmosphere, where the air is colder.

Condensation: The colder air temperatures cause the water vapor to condense into water droplets and form clouds made up of a large number of droplets. This process is the reverse of evaporation and explains things such as droplets on the outside of a cold drink.

Transport: Air currents move clouds all around the Earth's atmosphere depending on changes in atmospheric pressure and other factors.

Precipitation: When the water droplets in the clouds become too big and heavy for the air to hold them, they fall to Earth as rain, or maybe hail, sleet or snow if it is cold and they freeze.

A catchment is an area of land which collects water when it rains, typically surrounded by hills and draining into a river. Rain that falls outside the edge of one catchment, is falling in a different catchment and runs into a different river. Water connects different catchments, however, because water evaporated in one catchment might fall as rain in another or groundwater may connect two surface water catchments under the ground.

Surface run-off: In cold climates, such as the Snowy Mountains in the headwaters of the River Murray, precipitation can be stored as snow, ice, and glaciers that melt when the weather warms up to become run-off. In warmer areas, rainfall turns into run-off more quickly. Rain can soak in or run-off immediately depending on how much falls at once, how much water the soil can absorb, the slope of the land and other factors. Water always runs downhill and always takes the easiest path (the path of least resistance). This means that fast-moving water can cause erosion or even tear out buildings, bridges, boulders or trees that are in its way. Wild rivers change course when new channels scour out soil and from new channels, but most of our rivers are held back by weirs, levee banks or other infrastructure so they can no longer change course.

Streamflow: Surface runoff that flows into watercourses (e.g. rivers, creeks) moves along channels in the landscape to receiving water bodies, such as wetlands, lakes or the ocean.

Infiltration: Some rainfall, run-off and watercourse water will soak (infiltrate) into the ground. The amount depends on soil type, slope, rainfall intensity and moisture holding capacity. More water will run off a steep slope than flatter ground and after bursts of high intensity rainfall than after steady gentle rain.

Groundwater recharge: Water that soaks into the ground can recharge the underlying groundwater if it infiltrates past the plant roots and into the water table. Some groundwater goes very deep into the ground and can be stored underground for a long time. Groundwater in some Mount Lofty Ranges streams is at least 30,000 years old (DEWNR 2011). Water moves 'downhill' underneath the ground the same as it does above the ground because of gravity and pressure. This means that groundwater can 'discharge' at low points in the landscape, forming springs or flowing into the sea, rivers, lakes or wetlands.

Plant uptake: Plants take up soil water through their roots. In natural catchments, this is either rainfall or run-off that has soaked into the soil or groundwater close to the surface.

Transpiration: Plants need water to grow. When the plants are photosynthesising, the water evaporates from their leaves through open stomata. This is called transpiration. The rate of transpiration varies dependant on other weather conditions including humidity, temperature and sunlight intensity/availability.

Flows out to sea: Groundwater and river water flow back into the oceans, and some of it evaporates.

References: Scientific American (https://www.scientificamerican.com/article/how-did-water-get-on-earth/).

6.2.2 Catchments

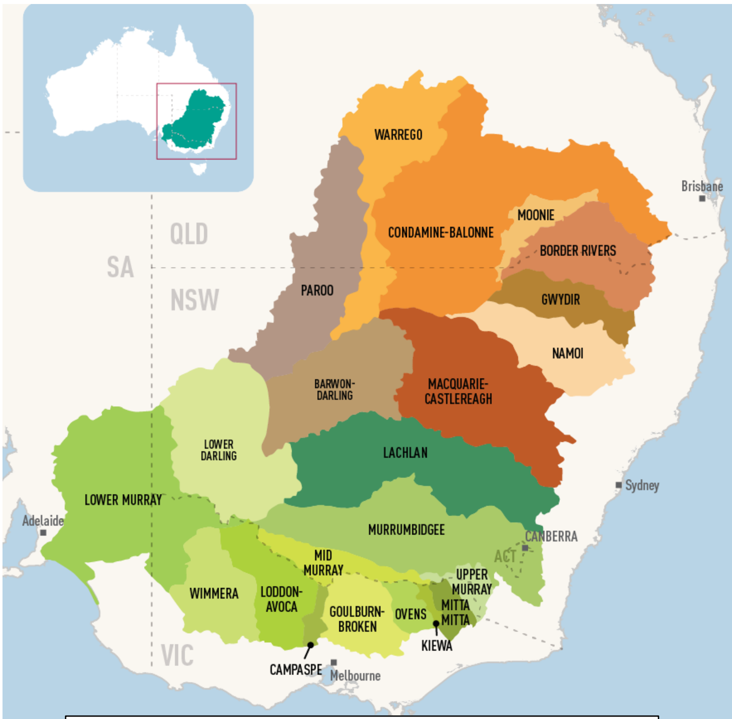


Figure 3: Murray Darling Basin Catchments

A catchment is an area of land, usually surrounded by hills or mountains, where water naturally collects. Gravity causes all rain, melting snow and other water in the catchment to run downhill where it flows into creeks, rivers, lakes or oceans.

Some water also seeps below ground where it settles in the soil or in the space between rocks. This is called groundwater.

Some catchments do not flow out to the sea and vast reserves of groundwater build up over thousands of years, such as the Great Artesian Basin that underlies north-eastern South Australia and parts of NSW and Qld.

Catchment boundaries are based on where rivers run and where the water falls. Those catchments that are actively managed have their own rules for water use, based on the environmental water requirements as well as cultural, social and economic needs. The Murray Darling Basin catchment is vast and has 22 sub-catchments (Figure 3).

6.2.3 South Australia's Water Supply

Most South Australians, whether we live in urban areas or in the country from Port Lincoln to Keith, rely on River Murray water for the water in our homes and to produce the food that we eat (Figure 4). We are the most downstream of the five Basin States and do not have significant headwaters, which means that we rely on the upstream States (NSW, Victoria, Queensland and the ACT) leaving water in the river for us to use and to dilute the salts, nutrients and other pollutants that come with the River Murray water that enters South Australia.

In addition, declining trends in streamflow have been observed throughout the agricultural regions of South Australia over the last 30 years (SA Government 2018). In 12 of the past 15 years, streamflows across our state were less than the 30-year average and many groundwater resources have also declined. This can further increase our reliance on the River Murray or alternate sources of water that might be very energy intensive, such as desalinisation.

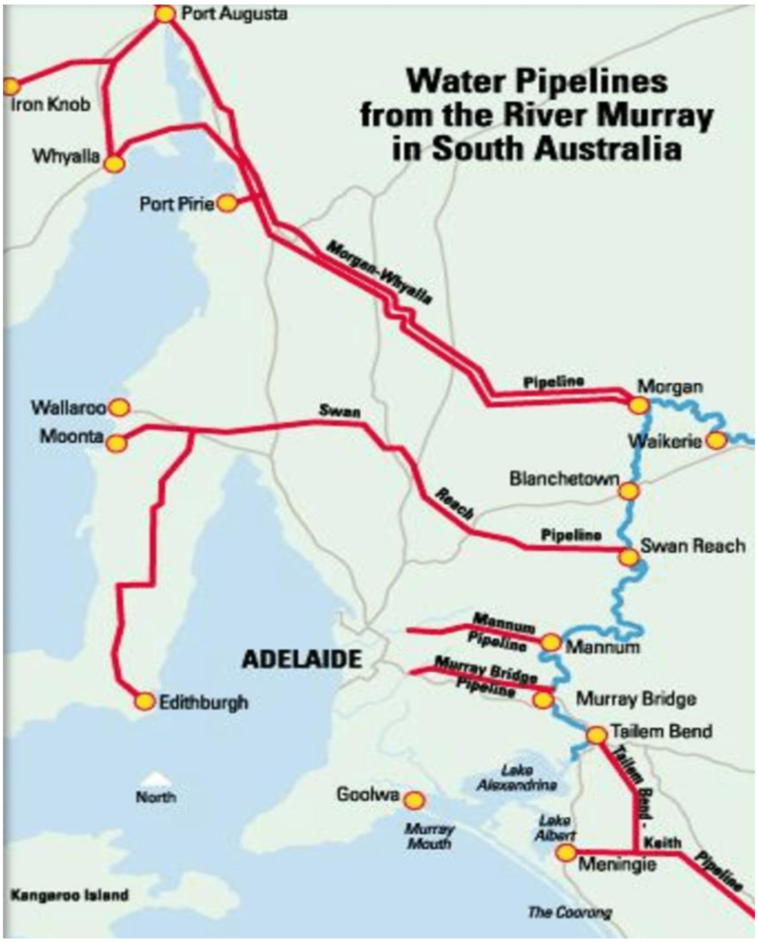


Figure 4. Map of South Australia highlighting the water pipelines of the River Murray, illustrating how reliant the state is on the river as a water source (Deakin University, 2015).

Sustainable water management and planning is vital to our long-term water security, the environment, and the economy of our state. During the past decade there has been a significant investment in water conservation and efficiency measures in South Australia and the Murray-Darling Basin. Water has been returned to the environment to help meet environmental water needs and keep our water resources suitable for agricultural use.

Most surface water and/or groundwater resources in the South Australian agricultural zone are 'prescribed' under the Water Resources Act and that means that local Water Allocation Plans have been developed to provide rules for water-sharing. The high competition for water in the Murray-Darling Basin is now managed through the Basin Plan (MDBA 2012). There are also specific policies in place for crisis management during drought and to address the impacts of a changing climate.

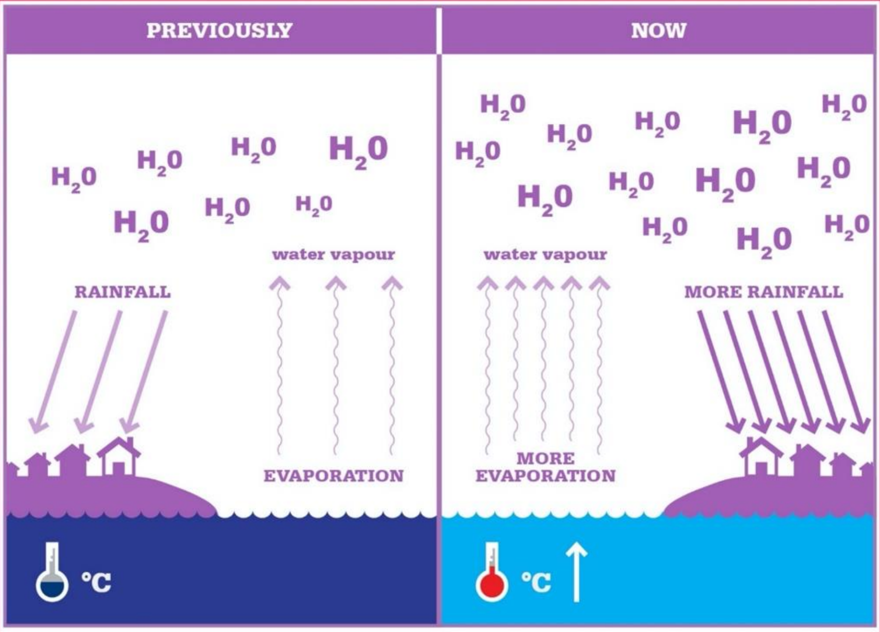
South Australian Water Catchment Areas
http://location.sa.gov.au/viewer/?map=hybrid&x=140.27689&y=-34.61958&z=7&uids=161

6.2.4 Climate Change

Climate change is a dynamic process that affects different parts of the water cycle in different places and at different times (Figure 5). Some parts of the water cycle are likely to speed up as warming global temperatures increase the rate of evaporation worldwide. More evaporation, in turn, leads to more precipitation, as a global average. We are already seeing impacts of higher evaporation and precipitation rates, and the impacts are expected to increase over this century as the climate warms from Greenhouse Gases that we have already emitted.

Higher evaporation and precipitation rates are not evenly distributed around the world. Some areas may experience heavier than normal precipitation, and other areas may become prone to droughts, as the traditional locations of rain belts and deserts shift in response to a changing climate. Some climate models predict that coastal regions will become wetter and the middle of continents will become drier. Also, some models forecast more evaporation and rainfall over oceans, but not necessarily over land.

Warmer temperatures associated with climate change and increased carbon dioxide levels may speed plant growth in regions with ample moisture and nutrients. This could lead to increased transpiration, the release of water vapor into the air by plants as a result of photosynthesis, which in turn speeds up delivery of water to the atmosphere and increases precipitation.



The influence of climate change on the water cycle. LEFT: The pre-climate change water cycle. RIGHT: The water cycle operating under higher surface ocean and air temperatures. The symbol H_2O represents water vapour.

www.climatecommission.gov.au

Figure 5: Influence of Climate Change on the water cycle.

Changes in the water cycle are increasing the risk of droughts in some areas and floods in others and sometimes the risk of both in one place at different times:

- Higher temperatures mean there is more evaporation from the land and sea and transpiration from plants into the atmosphere
- As air gets warmer, it can hold more water vapour. This can lead to more intense rainstorms that are difficult to capture for human use in dams and reservoirs and are more likely to cause damage from erosion and siltation.
- Intense rainstorms also increase the risk of flooding. Much of the water runs off into rivers and streams, doing little to dampen soil, and is transported downstream to coastal and floodplain areas where most of our towns and cities lie.
- These changes in water movement across the landscape combined with increased temperatures, increases the risk of drought.

6.3 Lesson Outline:

Students will be most likely use class time to water their plants. This double lesson is designed to allow 2 groups of students to go out to do their watering at a time while other students are in the class completing the WaterStorm Activity Sheet. Slides 1 to 21 can be presented and discussed before the first group of students go out to water and then they will have the information they need to complete the WaterStorm Activity when they are not watering. If the Warm Up activity is undertaken, then allow the students to investigate themselves before presenting the slides.

Warm Up (optional)

Investigation Activity

Where does water come from? Is rain brand new water? Split into groups of three take fifteen minutes to brainstorm where water comes from investigate whether rain is brand new water. You can use any resource that is available to you.

Assessment - WaterStorm Activity – Exploration

The Water Cycle WaterStorm Activity sheet is a copy of the Water Cycle diagram with the labels blanked out. There is a condensed glossary at the bottom of the sheet to act as prompts. The worksheet is designed to be challenging. Teachers can refer to the background information in Section 6.2 above to assist students and explore the different processes in the water cycle.

Group Discussion Questions

- Which of the stages in the water cycle required energy from the Sun? (Evaporation and Transpiration.)
- Which of the stages requires water to give off heat? (Condensation) (slide 7). Click on the diagram and the correct labels will be circles. Go to next slide.
- Which of the stages are driven by the force of gravity?” (slide 8). (Precipitation, Runoff, Infiltration, Groundwater Flow)
- Where are the headwaters in the Murray Darling Basin?
- How far is it from the headwaters of the Murray Darling Basin to the sea?
  The Murray Mouth is near Goolwa in South Australia, it is the only connection between the vast Murray-Darling Basin and the sea.
- What ranking does the River Murray have in terms of the world’s big rivers?
- What headwaters are closest to the city of Adelaide and what catchments do they feed?
- How much of Adelaide’s water comes from these catchments in wet years? What about in dry years?
- What catchment is your school in?
- Do you live in a different catchment?
- Where are the headwaters for your catchment?
  Does your catchment connect to the sea? if not, where does the water go?
- How can climate change affect the water cycle?

6.4 Additional Activities

Rain gauges are some of the most basic, yet necessary tools used to measure weather today. They were created in 1441 for agricultural purposes and are still widely used today. Monitoring droughts is one of the most important uses for rain gauges worldwide, especially when it comes to agriculture as farmers rely on rain to water their crops and livestock. Many farmers check their rain gauges every day and use that data to plan their crops or irrigation.

Rain Gauge Installation and Monitoring

The Wickedly Water Efficient resource kit contains a rain gauge that can be installed somewhere at school where it will collect rain. Ideally, it will be away from overhanging buildings and trees that may affect the amount of rain collected in the gauge. Depending on the weather, it can be checked daily and emptied. Students can design and complete a rainfall chart based on their recordings and compare to that recorded on the Bureau of Meteorology website.

Rain Gauge Construction

Students can also make their own rain gauges using the following materials and methods. This type of rain gauge needs to be 'zeroed' regularly because the gravel in the bottom occupies some volume in the bottom of the bottle. This design does, however, allow it to be used to measure evaporation as well as rainfall if monitored and 'zeroed' regularly.

Remember to check your rain gauge, even on days when it doesn't rain, so that you can keep your gauge 'zeroed' by topping up any loss of water due to evaporation. If it rains and you want to "zero" your rain gauge after taking a reading, carefully pour off the water, leaving just enough to cover the gravel to the zero level of the ruler.

<u>Materials</u>

Empty two-litre plastic bottle (pre-cut into two pieces)
Ruler
Permanent marker
Gravel or small stones

<u>Instructions</u>

1. Put the gravel in the bottom of the bottle, up to where the bottle starts its straight edge.
   The gravel will help to stop the bottle blowing over.
2. Pour some water in, just enough to cover the gravel.
3. Holding the ruler against the bottom section of the plastic bottle use a marker pen to draw a line on the bottle every centimetre. Make sure you mark on the number of centimetres too! Do this until you reach 20 centimetres.
4. Place the funnel top upside down in the bottom cut off section. Push it in so that it fits snugly.
5. Your rain gauge is now ready to go. Put your rain gauge somewhere outside, away from overhanging trees or fences.

7 LESSONS SEVEN & EIGHT – HOW PLANTS USE WATER

RESOURCES

PowerPoint file: WWE Lessons Seven & Eight Feb 2022

Worksheet: Water Storm How Plants Use Water Worksheet (docx or pdf)

7.1 Learning Objectives

- Describe how plants use water
- Describe photosynthesis using appropriate terminology
- Test a hypothesis regarding water movement in celery

7.2 Teacher Background Information

This section covers how plants use water to photosynthesise and introduces appropriate terminology and scientific equations. Plants need water to photosynthesis and grow (Figure 6). Biochemical energy that drives the plant's growth is generated in chloroplasts – the green parts of plants – using sunlight, water and carbon dioxide. Plants generally obtain water through their roots in moist soil and 'pump' it to their leaves using a process known as transpiration. This 'pump' is driven by water lost from the leaf when the plant opens its stomata to exchange gases - to let in carbon dioxide and give off oxygen. It only occurs in plant tubes narrow enough for cohesion-adhesion to 'pull' up the next water molecule making an unbroken chain from root to shoot.

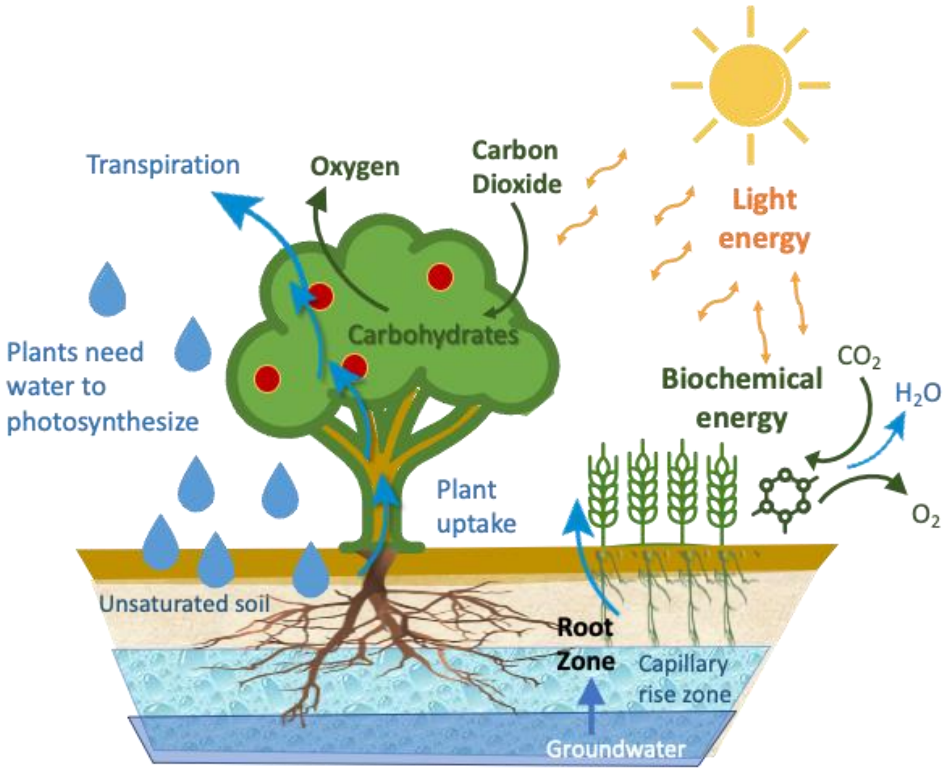


Figure 6: Plant water use during Photosynthesis

7.2.1 Capillary rise or capillary action

Water is wicked. It is a unique molecule with unique chemistry. It is made up of two hydrogen atoms and one oxygen atom (H_20). The hydrogen atoms have a weak positive charge and the oxygen has a weak negative charge. This means that water molecules can stick to each other (cohesion) and pull each other along (i.e. the positively-charged hydrogen atoms 'hold hands' with the negatively-charged oxygen atoms in another water molecule). It also means that this chain of cohesive water molecules can adhere to other surfaces. This is called cohesion-adhesion and is the process that allows plants to move water from the soil to the atmosphere.

If a tube is narrow enough to be a 'capillary tube', a chain of water molecules can be pulled along by cohesion with the walls of the tube and adhesion to each other (Figure 7). This is known as 'capillary rise'. Plants have capillary tubes (like tiny straws) inside of them known as 'xylem' cells that carry water from the roots to the photosynthesising leaves by capillary action. The evaporation of water molecules through the open stomata pulls on the chain of water molecules that reaches right to the tips of the roots. The root cells pull in more water from the soil to replace the water been drawn up. This is how water is carried right to the very top of the tallest trees powered by nothing but the sun. Capillary rise is behind the design or self-watering pots or wickedly water-efficient wicking beds that grow productive crops with as little water as possible by always having a reservoir of water to replace soil water as it is taken up by the plants. Soils can also have channels through them that are narrow enough to act as 'capillary tubes' that can draw groundwater up into the plant root zone. Capillary rise can be a problem for farmers, however, if the groundwater rising into the root zone is saline because the salt will reduce the growth of plants or even kill them. This is known as dryland salinity and can cause loss of productive land.

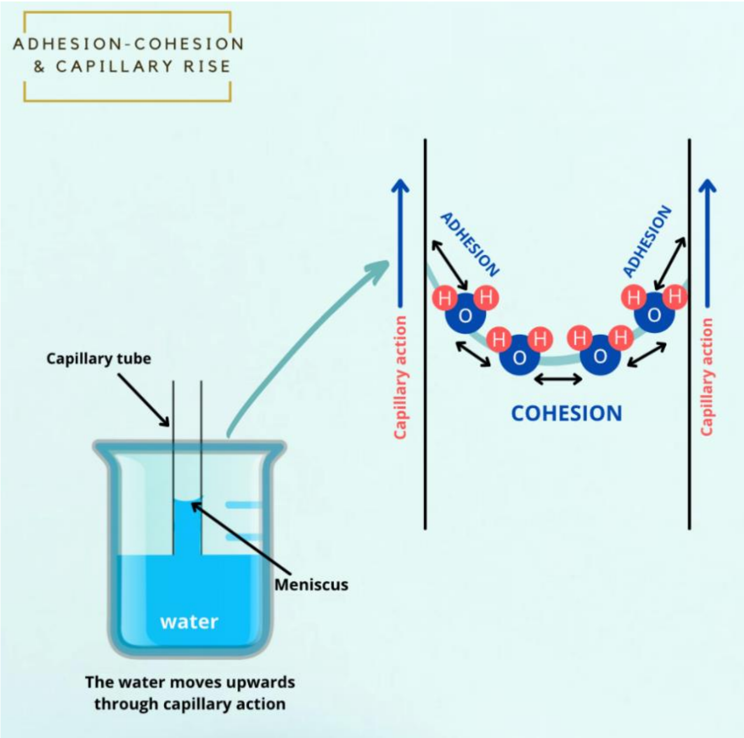


Figure 7: Adhesion-cohesion and capillary rise

7.2.2 Photosynthesis Equation

Equations show what is used and made, and how things change. For example, baking uses a lot of equations.

Here's an equation we could use for baking a cake: Butter + Eggs + Flour + Sugar + Heat --> Cake

Butter, eggs, flour, and sugar are the ingredients in the equation (reactants), the heat of the oven powers the reaction and cake is the product. The arrow shows change. The ingredients are changed into the product, or in other words, butter, eggs, flour, and sugar are changed into cake.

Photosynthesis also has an equation. Sun, water, and carbon dioxide are the ingredients used in the equation. Oxygen and glucose are made in the process, which means that they are the products. Thus we can say that, in the photosynthesis equation, sun, water, and carbon dioxide change into oxygen and glucose.

Here's our full photosynthesis equation:

Sunlight + Water + Carbon Dioxide --> Oxygen + Glucose (Food)

7.2.3 Photosynthesis

Photo = light, Synthesis = to make

Photosynthesis is the process by which plants take solar energy and turn into (biochemical) energy that they use to grow. Plants are called primary producers or 'autotrophs' because they harvest sunlight to make their own 'food'. In contrast, we are consumers or 'heterotrophs' because we eat plants and the animals that feed upon them as our food. Thus, we depend on plants for our energy in one form or another.

Photosynthesis requires sunlight, water and carbon dioxide (Figure 6). Special green pigments in the leaves called chlorophyll, and other green parts of the plant (photosynthetic tissue or chloroplasts), convert carbon dioxide (CO_2) and water into carbohydrates (e.g. glucose, sucrose) and release oxygen into the atmosphere. By contrast, we breathe in oxygen (O_2), release CO_2 and our cells get glucose from digestion of the food we eat. This means that we rely on plants to cycle gases and keep the atmosphere healthy for us as well as providing the energy in our food. Thanks plants!!

When the green parts of a plant photosynthesise, they are using light energy to 'fix' carbon out of the atmosphere into biochemical energy that they use to grow (build biomass) and power all of their cells, including those that are not green and therefore don't photosynthesis. We eat different parts of different crops that are all powered by photosynthesis, whether they are green or not. For example, wheat is a seed, tomatoes are a fruit, and lettuce is a leaf. Only the lettuce is a green, photosynthetic leaf but all those plant parts are powered by photosynthesis in the green parts of the plant they grew on.

Plants bring carbon out of the atmosphere and back into the biosphere (the global sum of all ecosystems), which helps to reduce atmospheric CO_2 and the greenhouse effect that is causing climate change. Plant material that we don't eat can be composted to increase soil carbon. Healthy agricultural soils with high carbon content absorb greenhouse gases in addition to CO_2, such as methane that has 21 times the global warming capacity of CO_2, which is great news for mitigating climate change. Increasing soil carbon also helps the soils to retain water and makes it easier for plants to take up water and nutrients through their roots.

Plant uptake - Plants take up water and most of their nutrients through their roots from the soil. Soils feed plants and therefore farmers need to feed and water the soil to grow productive crops.

The part of the soil being used by plants is called the ‘root zone’. Most plants, except those adapted for life in wetlands, require soil that contains water, but is unsaturated, meaning that some of the gaps between the soil particles are filled with water and some are filled with air. In saturated soils, all the gaps are filled with water and the roots become “waterlogged” or starved of oxygen and die-off. This can happen in waterlogged soils after heavy rain, in wetlands or in areas where shallow groundwater is high enough to ‘flood’ the root zone.

Transpiration is the process by which water moves up the stem of a plant from root to leaf. It is ‘pulled’ upwards by water molecules evaporating from the surface of the leaf during photosynthesis when the stomata are open. Stomata are tiny cells shaped a bit like two green sausages that open by taking on water to become ‘turgid’ (swollen with water). Open stomata let CO_2 into the photosynthesising parts in the leaf. When this happens O_2 is released to the atmosphere, but water vapour also escapes. This means that plants need a continual supply of enough water to their roots to supply their rate of photosynthesis (transpiration), which in turn determines how quickly they can grow. Plants that are limited by water supply cannot take up as many nutrients or generate as much energy, and thus cannot grow as well as plants that have enough water to meet their needs. Plant cells that have enough water are ‘turgid’ and their stomata work efficiently to let gases in and out. On the contrary, if plant cells do not have enough water, they are considered ‘flaccid’ and the plant becomes droopy and starts to wilt. Once the leaves have dried out too much the plant has become ‘terminally wilted’ and can’t be revived by watering.

7.3 Lesson Outline

As for Lessons 5 & 6, students will be most likely using class time to water their plants. This double lesson is also designed to allow 2 groups of students to go out to do their watering at a time while other students are in the class completing the WaterStorm Activity Sheet. This lesson can be extended by allowing the students to undertake the celery experiment in class.

Slide 2 is a quick check on how the experiment is going and see if any adjustments are necessary. Slides 3 to 16 provide the details on photosynthesis, outlined in Section 7.2 above, and can be discussed before the first group of students go out to water. The whole class will then have the information they need to complete the WaterStorm Activity.

Transpiration is demonstrated by using celery stems to draw up blue coloured water. It will take about 4 hours to clearly see the water moving up the stalk and up to 24 hours for the leaves to become coloured. The celery experiment can be done in the classroom, or it can be prepared by the teacher in advance and just shown to the students, depending on lesson time available and how quickly the teacher moves through the material. It is important to record the time that the different celery stalks are placed into the coloured water to measure the rate of rise.

Warm Up (optional)

Investigation Activity

How does a plant get its food? Split into groups of three take fifteen minutes to brainstorm?
You can use any resource that is available to you.

Assessment - WaterStorm Activity – Exploration

The How Plants Use Water WaterStorm Activity sheet has a list of questions relating to photosynthesis that students can answer whilst other students are watering their experiment and/or setting up the celery experiment (below).

Extension Activity – Explore water movement through plants

Students undertake an experiment to demonstrate how water moves through celery. The water carrying (xylem) tubes in the celery stalk will become coloured by the food colouring and will be a very clear demonstration of the upward movement of water through plants (Figure 8).

Inquiry Question:

- What do you think is going to happen when we place the celery into the coloured water (make a hypothesis)?

Fill a glass jar 1/3 full of water and then add a 5-6 drops of food colouring to each one (blue works well as a contrast to celery stalk).

Cut your celery stems on a diagonal to allow the greatest possible surface area for the coloured water to pass through and to stop the celery adhering to the bottom of the container. Then place them into the jars of dyed water.

Take photographs or make observational drawings of their appearance straight away. After 1 hour check the appearance of the celery stalks. The observations could be 'quantified' by measuring how far up the celery stalks the water has travelled over time (e.g. after 1, 4, 6, 15 and/or 24 hours). Students could then prepare a graph with time on the x-axis and height of celery stalk on the y-axis.

Students could also prepare a poster that reflects what happened during the celery experiment.

This could include:

- Observations over time
- Graphs of height of rise by time
- Testing their hypothesis – did they find what they expected to find?
- Thinking about what could change the results and how they could test other hypotheses

Figure 8: Water movement through celery plants

8 LESSONS NINE & TEN – EFFECTS OF SOIL TYPES

RESOURCES

PowerPoint file: WWE Lessons Nine & Ten Feb 2022

Worksheet: WWE Soil Type Moisture Probe Data Sheet (docx or pdf)

8.1 Learning Objectives

- To provide students with an understanding of water use efficiency and the effects of soil type.
- To provide students with an understanding of irrigation methods used in agriculture.

8.2 Teacher Background Information

8.2.1 Importance of Irrigation for Agricultural Production

Most of Australia has a very low rainfall on a global scale, with the exception of the tropics during the wet season. Our rainfall is also highly variable from season to season and from year to year. Dryland farming crops, which rely on rainfall alone, are restricted in South Australia to cereals (e.g. wheat, barley), pulses (e.g. chickpeas), pastures (e.g. dryland lucerne, grasses) and a few niche tree crops (e.g. dry-grown olives). Dryland farmers still need reliable water sources for farm practices such as spraying or processing grains and for livestock that are run in between cereal crops to improve soil health. See Growing Great Grains for more information about cereal crops.

In most parts of Australia, farmers cannot rely on rainfall alone to grow many of the foods that we like to eat and need for a healthy and varied diet. Almost all of our food crops are not native Australian plants and evolved in areas with much higher rainfall and/or cooler climates. Macadamia nuts are probably the most well-known native plant food, but due to economic pressure and demands, even these trees are grown with irrigation to extend their range, reduce growing times and increase yield. This means that farmers need to irrigate crops to produce the diversity of food we eat, but South Australia is the driest state in the driest, inhabited continent. This, in turn, means we need to get water from multiple sources to support our agriculture. In 2018-19, agricultural production in South Australia was worth $6.8 billion, which was 11% of the total gross value of agricultural production in Australia ($60 billion) [5]. More than 50% of the value of our state's irrigated agriculture comes from the Murray-Darling Basin in South Australia, highlighting our reliance on the River Murray, which has its headwaters in other Australian states.

8.2.2 Irrigation and Catchment Water

Irrigation is the largest user of water in Australia, comprising about 70% of total water use. Irrigated crops in the Murray-Darling Basin include rice, cotton, canola, vegetables, fruits, nuts and other tree crops as well as irrigated pasture, hay and grain for use in beef and dairy production. Some of these crops, such as vines and trees, are perennial and require water every year. Other crops, such as

[5] https://www.agriculture.gov.au/abares/research-topics/aboutmyregion/sa

vegetables, cotton and rice, are annuals and are only planted when the farmer predicts that there will enough irrigation water available to produce a crop.

The Murray-Darling Basin (MDB) is known as the food bowl of Australia and yet most of the run-off bringing water into the MDB falls on less than 15% of the land area – except during big floods, which might occur every 50 to 100 years. Water in the MDB is highly regulated. There are lots of storage dams in the catchment, that can hold 34,000 GL of water, and that doesn't include farm dams. These big dams (e.g. Hume and Dartmouth Dams) are used to store water after periods of run-off that can be released steadily into the River Murray over the irrigation season (typically September to April). Weirs along the river were originally built for navigation but they hold the water at a stable level, which enabled farmers to pump water or use gravity to deliver water to their crops. Large irrigation developments with associated towns now occur along most of the length of the River Murray and irrigation industries are the foundation of river community economics.

Irrigated agriculture changes the way water moves through the landscape. Water is taken from different parts of the environment, such as rivers, lakes, wetlands and groundwater, and used intensely in relatively small parts of the catchment to grow crops. The native vegetation that once covered these areas has been largely cleared. Irrigated crops generally demand more water than most native Australian plants to be productive. This means that the amount of water being applied to the soil is much higher and, in some cases, large amounts of water pass the root zone of the crops and end up in the groundwater. Rising groundwater tables from this increased recharge can bring salt into productive farmland and reduce crop production.

Irrigators use different methods to capture water depending on where they are in the catchment. Farm dams are used by famers in hilly country to capture surface run-off during wet periods and store it on their property for the irrigation season when rainfall is not enough to grow productive crops. Farm dams reduce the amount of water available for the environment by capturing run-off destined for rivers, creeks and lakes. The total amount of water that can be captured in farm dams in the Mount Lofty Ranges is capped at 30% of run-off and dams are fitted with 'low flow bypasses' to make sure water is shared with the environment.

Pumps and pipes or gravity-fed channels are used to move water from the source to the farm, if needed. Some farmers pump from the source into an above-ground dam (known as a turkey nest dam). Others pump straight from the source into the pipes that run around their farm and do not store water on their properties. Once the water is on the farm, it is distributed in a number of ways using pumps and/or gravity, depending on the lay-out of the farm.

8.2.3 Water Use in Australian Agriculture

Farmers use a range of methods to deliver water to their crops, such as drippers, sprinklers, centre pivots or channels with sluice gates to flood areas. Drippers are the most efficient method because they deliver water directly to the plant roots at a slow rate that can be absorbed by the soil, but they are the least flexible and are not suited to irrigation of pastures or similar large-scale crop.

Water Use Efficiency

Water use efficiency is a measure of how much of the water available to the crop is converted into fruit, vegetables, grains, pasture and other agricultural products. As we learnt above, plants need water to grow but not all of the water in the plant root zone will be taken up by the plant to support photosynthesis. Some will evaporate from the soil surface or infiltrate past the root zone and not be used by the plant at all (Figure 9).

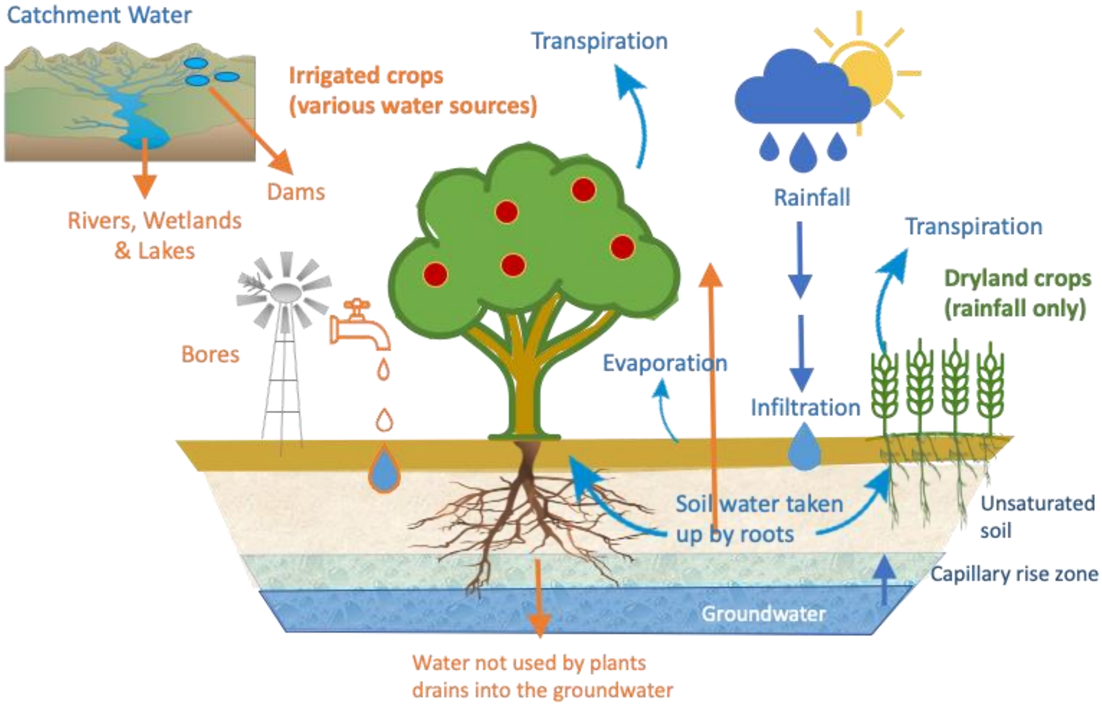


Figure 9: Water use by plants in dryland and irrigated crop production.

All water used for irrigation contains salt and most policies that work out sustainable amounts of water that be used for irrigation are based on keeping enough water in the river or groundwater system to keep salinity at low levels. In the Murray-Darling Basin, historic irrigation practices have impacted heavily on river and soil salinities, as well as causing the rise of saline groundwater in some areas. That is why the information gathered through programs such as Water Table Watch in the South Australian Riverland are so important for helping Governments and farmers to work together to keep salt out of the river, wetlands, floodplains and productive soils. These programs help everyone because the salinity of the river water can have a huge impact on irrigated production if it gets too high, as well as damaging our precious ecosystems. Higher salt levels in irrigation water mean that the plant has to work harder to pull water out of the soil (like trying to drink a really thick smoothie through a thin straw) and if salt levels get too high, the plants will grow poorly or can even die.

Irrigation can flush the salts out of the root zone, but inefficient irrigation can lead to large amounts of water draining past the root zone into the groundwater. This can make the groundwater more salty and closer to the surface. If the groundwater rises too high, the crop plants can die from salt impacts and/or waterlogging of the root zone and not having enough air around their roots.

Some methods of irrigation are more efficient than others. Best irrigation practices vary from farm to farm and from crop to crop, but generally farmers will manage their farms to minimise evaporation, deliver as much of the water they use to plant roots as possible (reducing water loss along the delivery line or from runoff) and only applying what the plant needs to minimise drainage into groundwater.

See Figures 10, 11 and 12 for different types of irrigation. The PowerPoint contains bullet points on differences between them.

Figure 10: Dripper Irrigation

This Photo by Unknown Author is licensed under CC BY-SA-NC

Figure 11: Centre Pivot Sprinkler

This Photo by Unknown Author is licensed under CC BY

Figure 12: Irrigation Channel used for Flood Irrigation

This Photo by Unknown Author is licensed under CC BY

Dryland farmers that do not use irrigation can also be wickedly water efficient. Their approach is different, however, focussing on increasing soil water holding capacity before sowing and growing healthy crops that can grow more quickly (i.e. produce more biomass in a shorter time) and/or produce more seed (grain) with the water that is available in the soil during the rainy season.

It can take a dryland farmer several years to build the soil's capacity to hold water using strategies such as increasing soil carbon content by retaining stubble, using no-till or minimum till farming practices, changing the contours of the land to capture more run-off, controlling weed growth, including legume crops and/or animals in crop rotations to build soil health, keeping good records of crops and rainfall patterns and using real-time weather data to learn about the best timing for sowing crops to make the most of the rainfall on their farm. See Growing Great Grains for more information about dryland farming.

All wickedly water efficient farmers use science to make the most of the water they have. Irrigators measure rainfall and soil moisture levels to work out exactly how much water they need to apply, and when they need to apply it, to get the best crop yields in the most efficient way. They may also need to measure the salinity of their irrigation water to avoid applying water that is too salty and/or only applying it to top up rainfall and let the rain wash the salts out of the root zone. Dryland farmers need to monitor their actual rainfall, soil moisture and crop growth as well as watching weather forecasts to know when to plant and how best to manage their crops.

8.3 Lesson Outline

As for previous lessons, students will be most likely using class time to water their plants. This double lesson is also designed to allow 2 groups of students to go out to do their watering at a time while other students are in the class looking at how soil type affects soil moisture in sample soils and around the school yard. This lesson can be extended by also looking at soil texture and conducting a Group WaterStorm activity in which students discuss the inquiry questions listed below.

Warm Up Activity (optional or extension)

1. Watch this video: http://thewaterweeat.com/

How was water used to produce the food in your lunch box? Split into groups of three and take fifteen minutes to investigate. You can use any resource that is available to you.

2. Watch these videos: https://virtualfarm.melbournefoodbowl.com.au/home.html

This website can be used to explore different elements of a farm, such as water, biodiversity, climate, soil type and catchment slope.

3. How water efficient are you?

Ask students to calculate their individual or household water footprint. They can check their individual and household water footprint/water calculator with the Hunter Water Calculator https://waterusage.hunterwater.com.au/question/household/1

Main Activity – Exploration – Soil Moisture

Measuring soil moisture

What is a soil moisture meter? Soil moisture meters are small hygrometers, or tools that let you measure average moisture levels, that you can insert into the earth to determine how moist it is. These measurements can help with decisions about when, and how much water, a plant needs. Soil moisture probes work by measuring the soil's electrical conductivity. The wetter the soil, the higher the electrical conductivity. They do not need batteries because the water in the soil creates a voltage difference across the two electrodes in the probe, allowing a current to flow that is registered by the needle. The wetter the soil, the stronger the current.

Soil Texture and Water Holding Capacity

Set up black soil tubes with different types of soil. There are eight tubes that can be placed in the rack and four types of soil – clay, gravel, sandy clay and sand. As a class, fill two tubes with each of the four soil types. The tubes have holes in the bottom that may need to covered with a piece of hand towel to stop the soil falling out.

Water the tubes and make sure the soil in the tubes are evenly wet. Leave to equilibrate for 30 to 60 mins and then test each tube for how much water they have held onto. The gravel should be the driest, sand second driest, with the sandy clay being moist and the clay wet. Pure clay is not suitable for many plants when wet because the air gaps are small and become flooded with water. Sand particles are much larger and hold more air, but the downside is that they also hold less water.

Check the soil moisture in the tubes a few days or a week later and see if the sandy-clay and the clay are still holding water.

Students present their soil moisture meter findings in a chart or other graphic, explaining:

- Were there any differences in soil moisture readings?
- How big were those differences?
- Were the patterns of soil moisture what they had predicted in their hypothesis (worked out before measuring and when selecting locations to test)?

We have provided you with clean playsand, clean gravel and clean clay (in the form of kitty litter). It should be free of biological contaminants, but it is best if masks are worn when transferring soil to pots because of the risk of inhaling small particles.

Soil Moisture around the School

Use the soil moisture probes to compare soil moisture at various locations around the school yard.

- Gently insert the probe end into the soil so that it is buried four-fifths of the way deep. Don't force it, it will snap off quite easily. If you meet resistance, try another spot.
- Wait 60 seconds, then check the moisture level reading in the display window.
- Record the location and moisture level on your activity sheet.
- Repeat across numerous locations – look for signs of wetter or drier soils:
    - School oval
    - Garden bed
    - Under tree canopy

Compare and explain the results.

Be very careful pushing the soil moisture probes into the soil. They are delicate.

Soil Texture and Water

Estimating or measuring soil texture provides valuable information about soil properties affecting crop and pasture growth. Soil texture affects the movement and availability of air, nutrients and water in a soil. A simple and quick measure of soil texture is the way a soil feels when manipulated by hand.

<u>Activity</u>

Take a small handful of soil (to fit comfortably in the palm of your hand.)

Add water to the sample

Add enough water to make a ball. Knead for 1–2 minutes, adding more water or soil until it just stops sticking to your fingers.

Form a soil ribbon

Gently press out the soil between your thumb and index finger to form a hanging ribbon.

Compare to chart to determine soil texture

Record your results on your activity sheet

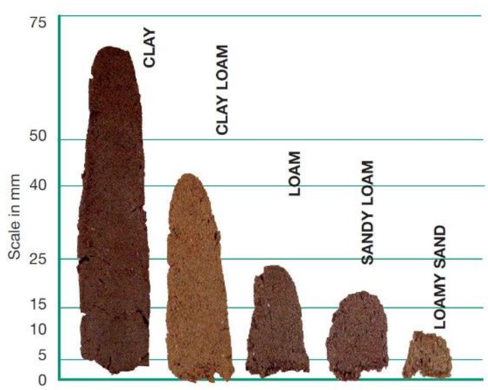


Figure 13: Soil type and ribbon length

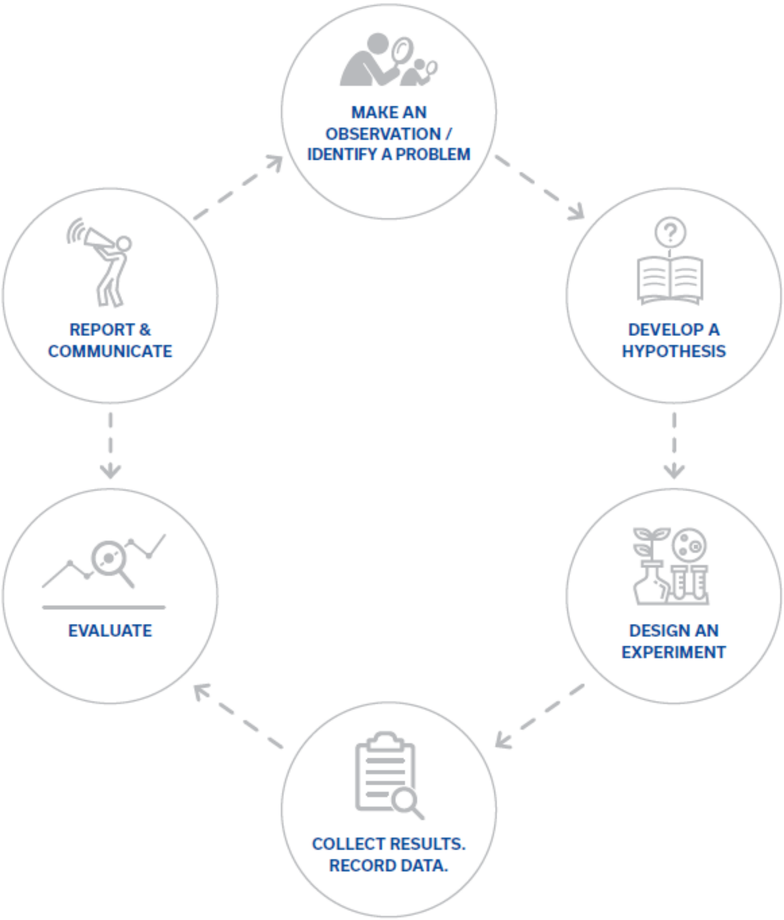
9 End of Unit Questions

Group Discussion and/or Assessment Questions

- What agriculture occurs in your catchment (or a catchment of your choice)?
- What do those farmers need to grow their crops?
- What methods and equipment do those farmers use to irrigate their crops?
- What is Drip Irrigation? Describe how drip irrigation works.
- What are Centre-Pivots? Describe how centre pivots work and what shape crop they water. Can you find an aerial photo of a centre pivot in your selected catchment?
- What affect does soil type have on irrigation?
- Besides irrigation, how do farmers use water?
  Guide the discussion, clarify that irrigation accounts for the majority of agricultural water use, but water is also needed to raise livestock, clean & sterilize facilities (e.g. dairies or food processing plants) to prevent illness and for mixing up and applying sprays and water soluble fertilisers (sometimes combined with irrigation and called fertigation).
- What is Goyder's Line and what does it mean for dryland farming in South Australia? Do you think Goyder's Line will be in a different location in the future?
- How do Governments regulate water use and share water between all users, including the environment?
- What native Australian foods could we eat that do not need to be irrigated in their local regions?
- Why do you think South Australian farmers have stopped using open channels and flood irrigation along the River Murray? Describe flood irrigation and discuss how efficient it is (e.g. how might water be lost from this system before or after it reaches the crop?).
- Are there any places where flood irrigation is still used? Why is it used there?
- How can farms make better use of water supplies?
- Should more storage dams be built?
- How much water does the environment need us to leave in rivers?
- How can farmers measure how much water they are using?
- How will climate change affect our water sources?

APPENDIX A: Designing a watering experiment

The approach you use to set up an experiment is called the experimental design. It is part of the overall scientific method that scientists use to learn about the world around us. The scientific method includes the following steps, which are explored in this booklet, especially in Lessons 2, 3 and 4.



Everyday problems raise questions that a scientist conducts experiments to answer, but first the scientist needs to raise an hypothesis (a statement that the scientist makes about what they expect to happen in the experiment) and design an experiment to specifically test that hypothesis.

To make sure that the experiment tests that specific hypothesis, and as few other factors as possible, the scientist needs to consider a number of 'treatments" and a 'control' that helps the scientist work out the effects of the treatments from other background factors and work out if the hypothesis is supported or not.

When designing an experiment, you can be as creative as you like and choose a topic which interests you, then research – **Where does your water come from and where does it go to after you use it?** Hypothesise, Investigate – explore and report!

Plant scientists, agronomists and farmers want to create an ideal growing environment for plants. Their goal is to produce as much food per plant, per millimetre of rainfall per metre square of soil.

Did you know there are hundreds of experiments happening all around Australia to help understand plant growth and development?

Let’s try designing our own experiment and see what we find!

Step 1: Choose Your Topic

Your first task is to select your research topic. This is what you are going to explore in your work as a junior scientist. A research topic can be based on an observation you have made, for example:

- Some plants grow well on the eastern aspect of the hill, but not the western aspect.
- Some plants seem to grow better when they are in sandier soils.
- Plants do not grow as well with irregular watering.

Some topics you could choose include:

- The effect of water volume on growth
- The effect of water timing on growth
- The effect of water quality on plant growth
- The effect of soil type on plant growth

Step 2 Develop a Hypothesis

All research scientists design a hypothesis at the beginning of their experiment.
A hypothesis is a statement of what you are testing in your research. It enables you to test or compare two or more things. It is a statement about what you predict you might find.

A hypothesis can take the shape of “If ____then ____” statements, or any other statement that clearly shows the expected response to the treatments.

EXAMPLE HYPOTHESES:
If plant growth is limited by the amount of water available in the soil, then increasing the amount of water will increase plant growth.

If a plant is provided with the right amount of water, it will grow as well or better than a plant provided with more water.

If a plant is provided with too little water, it will not grow as well as a plant that has more.

The plant being watered with 2ml per week will die, whilst the plants watered with 10ml or more per week will grow at the same rate.

Variables

A hypothesis proposes a relationship between two or more variables. A variable is defined as ‘something likely to, or able to, be changed’.

In science, an experiment contains two variables. One is “independent” and the other is “dependent.”

Watch this video for an explanation of variables. https://youtu.be/_VdOB4JJE_8

The independent variable is the one you, the "scientist" vary in your treatments (i.e. different water volumes).

The dependent variable is the change that you observe and/or measure because of the independent variable (leaf colour, height, number, weight).

Controlled variables are factors that you want to stay the same throughout the experiment, such as the amount of light the plants with different amounts of water are getting so that differences in light do not confuse the effects of the different amounts of water being applied in the treatments. They are controlled throughout the experiment so scientists can see how the treatments (independent variables) affect the measured response (dependent variable).

A 'control' can also be established to measure the relative rates of change in the treatments. In this experiment, the control is watered in accordance with the soil moisture probe with the aim of keeping the soil moist. It thereby tests whether the treatment volumes are more or less than what the plant needs.

Replicates are a series of experimental units (e.g. pots) receiving the same treatment that help to average out the measured responses to treatments and give a level of insurance in case something goes wrong.

Ideally, replicates are randomised in their placement within the experimental plot to control for location-specific factors, such as wind or sun coming from a certain direction. We have not included that in this experimental design because we suggest the students line up their pots in order – control, treatment 1, treatment 2 and treatment 3 – to help them apply the correct volumes to the correct plant pots.

Step 3: Design your experiment

The experimental design considers the best way of testing your hypothesis – that is, how the independent variable (treatment) affects the dependent variable (measured response).

For example, when designing an experiment to test the effect of watering rate on plant growth. It is not just a matter of 'chucking some water on' – the amount and timing matters, plus a whole range of other aspects ...

You could consider how you manage the external variables and work out how to control these:

• RATE:
How much water will impact plant growth? You might be guided by what is recommend on the plant label, BUT what would happen if you halved the amount to save money? Or if you doubled the amount – would the plants grow even bigger?

You need to design specific rates of water application (e.g. mm per day) and design your experiment to effectively test these, keeping rates accurate and consistent. All treatments and replicates should be labelled with unique codes to avoid any confusion.

• ENVIRONMENTAL FACTORS:
If you are testing plant growth, sunlight and temperature can impact growth. So, all plants should be placed in the exact same climate and ideally replicates should be mixed up (randomised) to account for any small-scale differences.

• APPLICATION TIMING:
All water applications must be applied at the same time of day and in the same way (e.g. using the same equipment for each replicate). The timing of application can influence how a plant utilises the water in its growth stage.

• WATER TYPE:
You must also think about the type of water you use – not all water is created equal! If you are testing differing amounts of water, you must use the same type of water in all treatments, and the same equipment in each experiment. This controls for water quality variables, such as salinity, pollutants, nutrients etc.

• MEASURING APPARATUS AND METHODS:
These must be kept consistent to minimise the chance of error or variation in measurements. Use the same measuring pipettes, beakers, cylinders, rulers, soil moisture meters (provided in your kit) etc.

Make the same decisions about the resolution of your measurements (e.g. measure to closest 1 mm). If you chose a coarse measurement (e.g. cm), decide whether to 'round up' or 'down' if a measurement falls between two units (e.g. 1.5 cm gets rounded up to 2 cm, but 1.4 cm gets rounded down to 1 cm).

• POTS:
The size (volume and surface area) and colour of the pot can influence how water and fertiliser disperse, and may even alter the soil temperature. Keep consistent and mix up placement of replicates to get an even effect across all treatments.   Remember the pots we are using are black and will get hot in the sun!!

• SOIL OR GROWTH MEDIUM:
Soil type can influence growth through a range of variables, such as nutrient availability, soil texture and the soil microbe populations. All treatments must have the same soil to control for these variables. We have used the same brand of potting mix without water holding additives.

Spend some time on experimental design to think of as many variables that you need to control for and you will minimise the risk of something 'uncontrolled' impacting the accuracy of your results.

Remember, you are trying to specially test your hypothesis, that is, how the treatments (independent variable) affect the measured responses (dependent variable). Managing these 'controlled' variables, keeping them constant and controlling for other variables that might affect the measurements ensures a great experimental design.

Step 3.1 Treatments

Once you have selected your independent variables, you need to consider how many treatments you test. For example, depending on your hypothesis the treatments might include:

Treatment 1: Watering daily at a particular volume (X ml/day)

Treatment 2: Watering once a week with seven times that volume (7X ml/week)

Treatment 3: Watering once a week with the same volume (X ml/week)

Note: our experiment involves watering different amounts twice a week, but you could run it again with other variables, including those given as examples here.

You must also have a control. In this experiment, the control is what happens when you water according to soil moisture meter readings, aiming to keep the soil moisture in the 'green' zone where the soil is moist. These plants will not be 'limited' by water availability.

Without the control, how could you measure what the impact of watering regime actually is!

For example:

In this experiment, the scientist is testing the hypothesis:

• If plant growth is limited by the amount of water in the soil, then increasing the amount of water will increase plant growth.

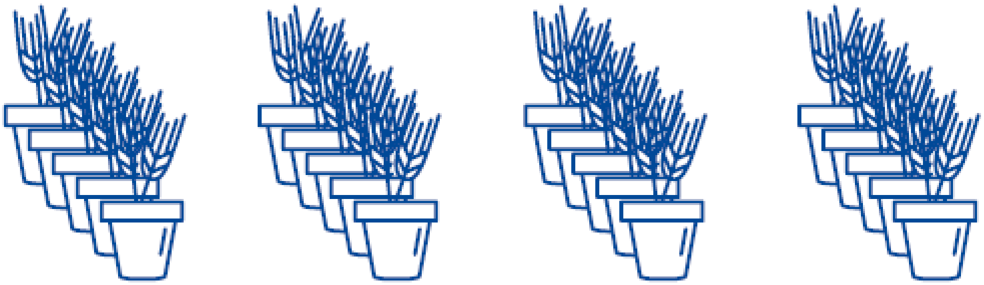
• The constants include: the type of pots, type of soil, amount of light, temperature, fertiliser (if used), type of seed (bean), the watering can (i.e. consistent measurements)

• The independent variable is the amount of water.

• The dependent variables are the growth of the plant as a result of the amount of water.

1ML 10ML 30ML CONTROL (MOISTURE PROBE)

The above experiment is looking good … BUT what happens if an insect ate the plant? You would have no experiment left! Any good experiment MUST have replications of the treatments. Replicates ensure you not only minimise risks, but you increase the reliability of the results, i.e. what you are seeing as a result of your independent variable is not just happening by chance. It is good practice to mix up the locations of the replicates of each treatment so control for other variables, e.g. shading of pots on the southern side of the tray.



1ML 10ML 30ML CONTROL (MOISTURE PROBE)

It can help to place these in a table to help you keep track of your data. Also be sure to clearly label the pots so you know what is in each one.

Step 3.2 Develop a safety plan

Part of being a good scientist is managing risks and ensuring the safety of both yourself and others.
EVERY EXPERIMENT NEEDS ITS OWN RISK EVALUATION PLAN WHICH MUST BE APPROVED BY YOUR TEACHER PRIOR TO COMMENCING.

To develop your plan, you need to consider:

- What are the risks involved in your experiment?
- Am I using chemicals that are dangerous and allowed? Can I use an alternative product? Can I manage this risk by wearing gloves, a mask and lab coat? Or is the risk too great – and therefore choose another experiment.
- Is there anything that I could be breathing in (fumes, dust, spores). If so, will I need a fume hood, a well-ventilated space, or a mask?
- Is there anything that I could hurt myself with? Boiling water, sharp knives, scalpels etc?
- How can I reduce this risk?

We have provided a Safety Plan worksheet for our class experiment. This can be extended using the risk management check list on page 16. This helps you think about your risks and what mitigation efforts are you going to put in place to stop these risks becoming hazards or accidents?

The key risk points to consider are:

Risk: a situation that involves exposure to danger

Risk Mitigation: a measure you put in place to reduce the chance of or prevent a risk from becoming a hazard

Hazard: anything that has the potential to harm the health or safety of a person

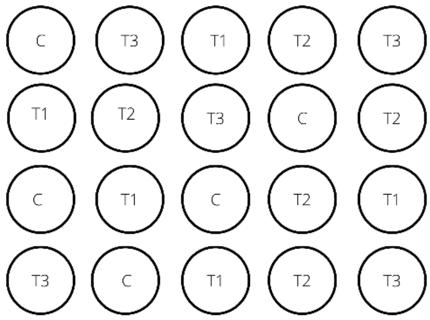
Experiment Checklist:

When designing your experiment, you must comply with the following:

- You must have a control and at least 3 treatments
- There must be a minimum of 3 replicates per treatment
- You must develop a safety plan prior to implementing your experiment, and your teachers must approve this.
- You must control the variables to ensure your experiment is as accurate as possible.
- You must confirm with your teacher on your chosen topic before proceeding with your experiment.
- You must monitor and collect data weekly, recording it in this booklet or a computer spreadsheet.

Step 4: Grow your plants considering the ‘best practice’ tips

1. First, decide how many plants or treatments you want to grow.
2. Select what you grow your plants in. Your set up might look like the below diagram. Be sure to label each individual cup so there is no confusion!
3. Commence your watering system.
4. Watch and monitor seedling growth! Record results at regular intervals.



Control: replicated 5 times
Treatment 1: replicated 5 times
Treatment 2: replicated 5 times
Treatment 3: replicated 5 times

TIPS

Make sure you set up your experiment in an appropriate area at home/school (out of reach of others, pests and that it considers your controls/variables).

Set up the pots with on surface that can get wet during drainage, and where your pots will not be knocked over or damaged during the experiment. We want to control the amount of water each pot receives so they will need to be under cover so they do not get rained on, but they need enough light to grow. A verandah that gets some direct sunlight each day is ideal but remember the pots are black and get hot very quickly.

Consider whether you want to measure the drainage from the pots and how this might change your layout. Mix up your replicates and controls to ‘control’ for variables such as shading or strong wind. Use a waterproof pen to label each treatment.

Any water added MUST be recorded as this is a variable. It must also be equal over each replicate / treatment.

Make sure to record daily observations in your Research Journals at the back of this booklet, and remember to take plenty of photos and/or videos to add to your presentations.

Use the three templates provided to:

1. Develop your experimental plan (WWE Experimental Plan Worksheet)
2. Prepare your safety plan (WWE Safety Plan Worksheet)
3. Record your data (WWE Data Sheet)

Step 5: Evaluate your results

Graph your results (time along x-axis and height or width along y-axis) and discuss what they mean.

Was your hypothesis supported?

What have you learnt about water use efficiency?