Earth and Environmental Science

Subject Outline
Stage 1 and Stage 2

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INTRODUCTION

SUBJECT DESCRIPTION

Earth and Environmental Science may be undertaken as a 10-credit subject or a 20-credit subject at Stage 1 and as a 20-credit subject at Stage 2.

The Earth system involves four interacting systems: the geosphere, atmosphere, hydrosphere, and biosphere. A change in any one 'sphere' can impact others on a range of temporal and spatial scales. In this subject, the term 'environment' encompasses terrestrial, marine, and atmospheric settings and includes Earth's interior. Environments are described and characterised with a focus on systems thinking and a multidisciplinary approach, including ecological, geological, biological, physical, and chemical aspects.

This subject emphasises ways in which Earth materials and processes generate environments, including habitats, where organisms live; the natural processes and human influences that induce changes in physical environments; and ways in which organisms respond to those changes.

Through their study of Earth and Environmental Science, students develop and extend their inquiry skills, including in designing and undertaking investigations, and collecting and analysing primary and secondary data. They interpret and evaluate information, synthesise and use evidence to construct and justify conclusions.

Students apply their understanding of the interaction of the four Earth systems to investigate, evaluate, and make predictions about the impact of human activities on the environment. Students develop and extend a range of understanding and inquiry skills that encourage and inspire them to pursue future pathways, including in the environmental science, geology, meteorology, oceanography, seismology, metallurgy, and scientific research.

CAPABILITIES

The capabilities connect student learning within and across subjects in a range of contexts. They include essential knowledge and skills that enable people to act in effective and successful ways.

The SACE identifies seven capabilities. They are:

- literacy
- numeracy
- information and communication technology capability
- critical and creative thinking
- personal and social capability
- ethical understanding
- intercultural understanding.

Literacy

In this subject students develop their literacy capability by, for example:

- critically analysing and evaluating primary and secondary data
- extracting earth and environmental science information presented in a variety of modes
- using a range of communication formats to express ideas logically and fluently, incorporating the terminology and conventions of earth and environmental science
- synthesising evidence-based arguments
- using appropriate structures to communicate for specific purposes and audiences.

Numeracy

In this subject students develop their numeracy capability by, for example:

- measuring with appropriate instruments
- recording, collating, representing, and analysing primary data
- accessing and investigating secondary data
- identifying and interpreting trends and relationships
- calculating and predicting values by manipulating data and using appropriate scientific conventions.

Information and communication technology capability

In this subject students develop their information and communication capability by, for example:

- locating and accessing information
- collecting, analysing, and representing data electronically
- modelling concepts and relationships
- communicating earth and environmental science ideas, processes, and information
- understanding the impact of ICT on the development of earth and environmental science and its application in society
- evaluating the application of ICT to advance understanding and investigations in earth and environmental science.

Critical and creative thinking

In this subject students develop critical and creative thinking by, for example:

- constructing, reviewing, and revising hypotheses to design-related investigations
- interpreting and evaluating data and procedures to develop logical conclusions
- analysing interpretations and claims, for validity and reliability
- devising imaginative solutions and making reasonable predictions
- envisaging consequences and speculating on possible outcomes
- recognising the significance of creative thinking on the development of earth and environmental science knowledge and applications.

Personal and social capability

In this subject students develop their personal and social capability by, for example:

- understanding the importance of earth and environmental science knowledge on health and well-being, both personally and globally
- making decisions and taking initiative while working independently and collaboratively
- planning effectively, managing time, following procedures effectively and working safely
- sharing and discussing ideas about earth and environmental science issues and developments, while respecting the perspectives of others
- recognising the role of their own beliefs and attitudes in gauging the impact of earth and environmental science in society.

Ethical understanding

In this subject students develop their ethical understanding by, for example:

- considering the implications of their investigations on organisms and the environment
- making ethical decisions based on an understanding of earth and environmental science principles
- acknowledging the need to plan for the future and to protect and sustain the biosphere
- recognising the importance of their responsible participation in social, political, economic, and legal decision-making.

Intercultural understanding

In this subject students develop their intercultural understanding by, for example:

- recognising that science is a global endeavour with significant contributions from diverse cultures
- respecting different cultural views and customs while valuing scientific evidence
- being open-minded and receptive to change in the light of scientific thinking based on new information
- understanding that the progress of earth and environmental science influences and is influenced by cultural factors.

ABORIGINAL AND TORRES STRAIT ISLANDER KNOWLEDGE, CULTURES, AND PERSPECTIVES

In partnership with Aboriginal and Torres Strait Islander communities, and schools and school sectors, the SACE Board of South Australia supports the development of

high-quality learning and assessment design that respects the diverse knowledge, cultures, and perspectives of Indigenous Australians.

The SACE Board encourages teachers to include Aboriginal and Torres Strait Islander knowledge and perspectives in the design, delivery, and assessment of teaching and learning programs by:

- providing opportunities in SACE subjects for students to learn about Aboriginal and Torres Strait Islander histories, cultures, and contemporary experiences
- recognising and respecting the significant contribution of Aboriginal and Torres Strait Islander peoples to Australian society
- drawing students' attention to the value of Aboriginal and Torres Strait Islander knowledge and perspectives from the past and the present
- promoting the use of culturally appropriate protocols when engaging with and learning from Aboriginal and Torres Strait Islander peoples and communities.

HEALTH AND SAFETY

It is the responsibility of the school to ensure that duty of care is exercised in relation to the health and safety of all students and that school practices meet the requirements of the *Work Health and Safety Act 2012,* in addition to relevant state, territory, or national health and safety guidelines. Information about these procedures is available from the school sectors.

The following safety practices must be observed in all laboratory work:

- Use equipment only under the direction and supervision of a teacher or other qualified person.
- Follow safety procedures when preparing or manipulating apparatus.
- Use appropriate safety gear when preparing or manipulating apparatus.

The following ethical and safety practices must be observed in all fieldwork:

- Obtain permission if conducting fieldwork on private land and Indigenous lands.
- Be environmentally sensitive in deciding where to collect samples and the amount of samples needed.
- Do not collect specimens or cause damage when visiting conservation sites.
- Follow safety procedures when observing features on sides of roads and in road cuttings.
- Use appropriate safety gear when visiting quarries and collecting samples.
- Observe care when visiting coastal areas to minimise the risk posed by freak waves.

Stage 1
Earth and Environmental Science

LEARNING SCOPE AND REQUIREMENTS

LEARNING REQUIREMENTS

The learning requirements summarise the knowledge, skills, and understanding that students are expected to develop and demonstrate through their learning in Stage 1 Earth and Environmental Science.

In this subject, students are expected to:

1. use science inquiry skills to design and conduct earth and environmental science investigations, using appropriate procedures and safe, ethical working practices
2. obtain, record, represent, and analyse the results of earth and environmental science investigations
3. evaluate procedures and results and analyse evidence to formulate and justify conclusions
4. demonstrate and apply knowledge and understanding of earth and environmental science concepts in new and familiar contexts
5. demonstrate understanding of science as a human endeavour
6. communicate knowledge and understanding of earth and environmental science concepts, using appropriate terms, conventions, and representations.

CONTENT

Stage 1 Earth and Environmental Science may be undertaken as a 10-credit or a 20-credit subject.

Science inquiry skills and science as a human endeavour are integral to students' learning in this subject and are interwoven through their study of science understanding, which is organised into six topics.

Through their study of these topics, students consider a range of the Earth hazards that illustrate the dynamic nature of the Earth's systems. They critically examine the scientific evidence for the origin of life, linking this with their understanding of the evolution of the Earth's hydrosphere and atmosphere. Students review evidence from the fossil record that demonstrates the interrelationships between major changes in the Earth's systems and the evolution and extinction of organisms. They investigate how the distribution and viability of life on Earth influences, and is influenced by, the Earth's systems.

Using an inquiry approach to learning through observation, speculation, prediction, experimentation, analysis, evaluation, and communication, students develop and extend their science inquiry skills and reinforce their understanding of science as a human endeavour.

The science inquiry skills and the understanding of science as a human endeavour that can be developed through practical and other learning activities in each topic are described in the *Science Inquiry Skills* and *Science as a Human Endeavour* sections that follow.

Programming

Stage 1 Earth and Environmental Science consists of the following topics:

- Topic 1: Turbulent Earth
- Topic 2: Composition of the Geosphere
- Topic 3: Processes in the Geosphere
- Topic 4: The Earth's Atmosphere
- Topic 5: Importance of the Hydrosphere
- Topic 6: Biosphere

For a 10-credit subject, students study aspects of at least two of these topics.

For a 20-credit subject, students study aspects of at least four topics.

Topics can be studied in their entirety or in part, taking into account student interests, and preparation for pathways into future study of earth and environmental science.

Science Inquiry Skills and *Science as a Human Endeavour* must be integrated into both 10-credit and 20-credit programs. Stage 1 Earth and Environmental Science students who intend to study Earth and Environmental Science at Stage 2 would benefit from a Stage 1 program that includes Topic 2: Composition of the Geosphere.

Note that the topics are not necessarily designed to be of equivalent length – it is anticipated that teachers may allocate more time to some than others.

Each topic is presented in the subject outline in two columns, with the science understanding in the left-hand column supported by possible strategies, contexts, and activities in the right-hand column.

The *Science Understanding* column covers the content for teaching, learning, and assessment in this subject. The possible strategies, contexts, and activities are provided as a guide only. They are neither comprehensive nor exclusive. Teachers may select from these or choose to use others.

The following symbols have been used in the right-hand column to indicate where different kinds of suggestions have been made:

indicates a possible teaching and learning strategy

indicates a possible activity to develop Science Inquiry Skills

indicates a possible Science as a Human Endeavour context

An inquiry-based approach is integral to the development of the science understanding. The *Possible Strategies, Contexts, and Activities* column presents ideas and opportunities for the integration of the science inquiry skills and the understandings related to science as a human endeavour. Teachers may use some or all of these examples, or other relevant examples, to enable students to develop and extend their knowledge, skills, and understanding.

Science Inquiry Skills

In Earth and Environmental Science investigation is an integral part of the learning and understanding of concepts, by using the scientific method to test ideas and develop new knowledge.

Practical investigations involve a range of individual and collaborative activities, during which students develop and extend the science inquiry skills described in the table that follows.

The practical activities may take a range of forms, such as developing models and simulations that enable students to develop a better understanding of particular concepts. They include laboratory and field studies during which students develop investigable questions and/or testable hypotheses, and select and use equipment appropriately to collect data. The data may be observations, measurements, or other information obtained during the investigation. Students display and analyse the data they have collected, evaluate procedures, describe their limitations, consider explanations for their observations, and present and justify conclusions appropriate to the initial question or hypothesis.

For a 10-credit subject, it is recommended that 8–10 hours of class time would involve practical activities.

For a 20-credit subject, it is recommended that 16–20 hours of class time would involve practical activities.

Science inquiry skills are also fundamental to students investigating the social, ethical, and environmental impacts and influences of the development of scientific understanding and the applications, possibilities, and limitations of science. These skills enable students to critically consider the evidence they obtain so that they can present and justify a conclusion.

Science inquiry skills are presented in two columns, with a range of science inquiry skills in the left-hand column side by side with possible strategies, contexts, and activities in the right-hand column. The *Science Inquiry Skills* column describes teaching, learning, and assessment in this subject.

The symbols in the *Possible Strategies, Contexts, and Activities* column in the table that follows are provided as a guide to the possible approaches, resources, and/or activities that teachers may use. They are neither comprehensive nor exclusive. Teachers may select from them and/or choose to use others.

These science inquiry skills are integrated throughout the topics that are detailed in this subject outline. In each topic, the symbols in the *Possible Strategies, Contexts, and Activities* column are provided as a guide to the possible contexts that teachers may use to develop and extend student understanding of science inquiry skills. They are neither comprehensive nor exclusive. Teachers may select from them and/or choose to use others.

Science Inquiry Skills	**Possible Strategies, Contexts, and Activities**
Scientific methods enable systematic investigation to obtain measureable evidence. • Design investigations, including: – a pre-investigation trial that develops the procedure – a hypothesis or inquiry question – types of variables ➢ dependent ➢ independent ➢ factors held constant (how and why they are controlled) ➢ factors that may not be able to be controlled (and why not) – materials required – the procedure to be followed – the type and amount of data to be collected – identification of ethical and safety considerations.	Class activities to develop skills could include: – designing investigations without implementation – changing an independent variable in a given procedure and adapting the method – researching, developing, and trialling a method – improving an existing procedure – identifying options for measuring the dependent variable – researching hazards related to the use and disposal of chemicals and/or earth and environmental science materials – developing safety audits – identifying relevant ethical and/or legal considerations, including accessibility of investigation sites, in different contexts.
Obtaining meaningful data depends on conducting investigations using appropriate procedures and safe, ethical working practices. • Conduct investigations, including: – selection and safe use of appropriate materials, apparatus, and equipment – collection of appropriate primary and/or secondary data (numerical, visual, descriptive) – individual and collaborative work.	Class activities to develop skills could include: – identifying equipment, materials, or instruments fit for purpose – practising techniques and safe use of apparatus – comparing resolution of different measuring tools – distinguishing between and using primary and secondary data.

Science Inquiry Skills	Possible Strategies, Contexts, and Activities
The results of investigations are presented in a well-organised way to allow them to be interpreted. • Present results of investigations in appropriate ways, including – use of appropriate SI units, symbols – use of field notes – construction of appropriately labelled tables – drawing of graphs, linear, non-linear, lines of best fit as appropriate – use of significant figures.	Class activities to develop skills could include: – practising constructing field notes Clino app; Field Move – practising constructing tables to tabulate data with column and row labels with units – identifying the appropriate representations to graph different data sets – selecting appropriate axes and scales to graph data – clarifying understanding of significant figures www.astro.yale.edu/astro120/SigFig.pdf – comparing data from different sources to describe as quantitative, qualitative.
Scientific information can be presented using different types of symbols and representations. • Select, use, and interpret appropriate representations, including: – mathematical relationships, such as ratios – diagrams – equations to explain concepts, solve problems, and make predictions.	Class activities to develop skills could include: – drawing and labelling diagrams – constructing flow diagrams – recording images – writing chemical formulae and equations – interpreting satellite images – construction of maps and cross-sections.
The analysis of the results of investigations allows them to be interpreted in a meaningful way. • Analyse data, including: – identification and discussion of trends, patterns, and relationships – interpolation/extrapolation where appropriate – selection and use of evidence and scientific understanding to make and justify conclusions.	Class activities to develop skills could include: – analysing data sets to identify trends and patterns – determining relationships between independent and dependent variables – using graphs from different sources, e.g. CSIRO, BOM, or ABS, to predict values other than plotted points – calculating mean values and rates of reaction, where appropriate.
Critical evaluation of procedures and outcomes can determine the meaningfulness of conclusions. • Evaluate the procedures and results to identify sources of uncertainty, including: – random and systematic errors – replication – sample size – accuracy – precision – validity	Students could evaluate procedures and data sets provided by the teacher to determine and hence comment on the limitations of possible conclusions. Use an example of an investigation report to develop report-writing skills, www.biologyjunction.com/ap_sample_lab_12-dissolved_oxygen.htm

Science Inquiry Skills	Possible Strategies, Contexts, and Activities
– reliability – effective control of variables. • Discuss the impact that sources of uncertainty have on experimental results. • Recognise the limitations of conclusions.	
Effective scientific communication is clear and concise. • Communicate to specific audiences and for specific purposes using: – appropriate language – terminology – conventions.	Class activities could include: – reviewing scientific articles or presentations to recognise conventions – developing skills in referencing and/or footnoting – distinguishing between reference lists and bibliographies – opportunities to practise scientific communication in written, oral, and multimedia formats.

Science as a Human Endeavour

Through science, we seek to improve our understanding and explanations of the natural world. The *Science as a Human Endeavour* strand highlights the development of science as a way of knowing and doing, and explores the use and influence of science in society.

The development of science concepts, models, and theories is a dynamic process that involves analysis of evidence and sometimes produces ambiguity and uncertainty. Science concepts, models, and theories are continually reviewed and reassessed as new evidence is obtained and as new technologies enable different avenues of investigation. Scientific advancement involves a diverse range of individual scientists and teams of scientists working within an increasingly global community of practice, using international conventions and activities such as peer review.

Scientific progress and discoveries are influenced and shaped by a wide range of social, economic, ethical, and cultural factors. The application of science may provide great benefits to individuals, the community, and the environment, but may also pose risks and have unexpected outcomes. As a result, decision-making about socio-scientific issues often involves consideration of multiple lines of evidence and a range of needs and values. As an ever-evolving body of knowledge, science frequently informs public debate, but is not always able to provide definitive answers.

Through the exploration of *Science as a Human Endeavour*, students increase their understanding of the complex ways in which science interacts with society.

The understanding of *Science as a Human Endeavour* encompasses:

1. Communication and Collaboration

- Science is a global enterprise that relies on clear communication, international conventions, and review and verification of results.
- International collaboration is often required in scientific investigation.

2. Development

- Development of complex scientific models and/or theories often requires a wide range of evidence from many sources and across disciplines.
- New technologies improve the efficiency of scientific procedures and data collection and analysis; this can reveal new evidence that may modify or replace models, theories, and processes.

3. Influence

- Advances in scientific understanding in one field can influence and be influenced by other areas of science, technology, engineering, and mathematics.
- The acceptance and use of scientific knowledge can be influenced by social, economic, cultural, and ethical considerations.

4. Application and Limitation

- Scientific knowledge, understanding, and inquiry can enable scientists to develop solutions, make discoveries, design action for sustainability, evaluate economic, social, and environmental impacts, offer valid explanations, and make reliable predictions.
- The use of scientific knowledge may have beneficial or unexpected consequences; this requires monitoring, assessment, and evaluation of risk and provides opportunities for innovation.
- Science informs public debate and is in turn influenced by public debate; at times, there may be complex, unanticipated variables or insufficient data that may limit possible conclusions.

Science as a Human Endeavour underpins the content, strategies, contexts, and activities for all topics that are detailed in this subject outline, and the understandings should be integrated and used in a 10- credit or 20-credit program, as points of reference for student learning.

The  symbols in the right-hand column of each topic, under the heading *Possible Strategies, Contexts, and Activities*, are provided as a guide to the possible contexts that teachers may use to develop student understanding of science as a human endeavour. They are neither comprehensive nor exclusive. Teachers may select from them and/or choose to use others.

Topic 1: Turbulent Earth

Natural hazards such as earthquakes, tsunamis, and volcanic eruptions affect life on Earth. In this topic students collect, analyse, and interpret data relating to the cause and impact of Earth hazards. They critically analyse the range of factors that influence the magnitude, frequency, intensity, and management of Earth hazards at local, regional, and global levels. Students explore how human activities can contribute to the frequency, magnitude, and intensity of some of these hazards and investigate ways in which scientific data are used to predict and mitigate the damage caused by these hazards.

Science Understanding	Possible Strategies, Contexts, and Activities
Interactions of Earth systems may result in Earth hazards. • Describe different types of Earth hazards. • Describe how Earth hazards affect life, health, poverty, and the environment. • Investigate how human activity influences the frequency and intensity of some hazards. • Explain how occurrence of Earth hazards in one sphere can affect Earth processes in other spheres. • Discuss different strategies that have helped lessen the severity of Earth hazards.	Explore Earth hazards: earthquakes, tsunamis, volcanic eruptions, hurricanes, floods, droughts, landslides, extreme weather, lightning-induced fires, sinkholes, coastal erosion and comet/asteroid impacts www.qa.gov.au www.bom.gov.au/climate/cange/ Examine examples of life affected by Earth hazards: - 1986 Lake Nyos (crater lake volcano and CO_2) - Cyclone Tracey, Cyclone Yasi and Larry (banana crop wipe out) - Christchurch 2011 earthquake, Fukushima 2012 earthquake, Nepal 2015 earthquake. Investigate examples of sphere interaction, such as how ash clouds influence global weather, earthquakes that occur under the ocean affect the hydrosphere by forming tsunamis, lightning strikes in the atmosphere affect the biosphere by starting fires, and the effect of bushfires on atmospheric conditions. Explore the construction of tsunami barriers in Japan, design of earthquake-resistant buildings, monitoring of volcanic and seismic activity.
Processes within the geosphere generate Earth hazards. • Describe how plate tectonics generate earthquakes, volcanic eruptions, and tsunamis. • Discuss how earthquakes, volcanic eruptions, and tsunamis affect other Earth systems processes.	Explore how: - Earthquakes, volcanic eruptions, and tsunamis are related - volcanoes can cause ash clouds that may influence global weather - a massive eruption can cause flash flooding - Hawaiian volcanic fog forms - volcanic activity occurs at the East Pacific Rise and El Niño cycles. Watch video of Sakurajima volcano in Japan erupting. www.sciencephoto.com/media/246259/view Investigate factors causing earthquakes using the Quakecaster apparatus.

Science Understanding	Possible Strategies, Contexts, and Activities
	Geoscience pathways newsletter
The impact of extra-terrestrial bodies can affect Earth systems. • Describe an extra-terrestrial impact and how it affects Earth systems.	Explore how extra-terrestrial impacts can: - cause a tsunami if the impact is over water - cause an earthquake - affect global climate - cause the extinction of species.
Earthquake and volcanic eruption data can be used to map hazardous zones and to predict future events. • Describe how Earth hazards are monitored by measuring various factors. • Discuss how data can contribute to future predictions of Earth hazards.	Compare the effectiveness of various tsunami early warning systems. Use changes in size and shape of the volcano cone, chemistry of volatiles and Earth tremors to predict eruptions. Use the Quakecaster apparatus to explore why earthquakes are very difficult to predict.

Topic 2: Composition of the Geosphere

This topic introduces students to the geosphere, the solid part of the Earth. Students learn how minerals are classified and used according to their properties, while rocks are classified according to their origins through igneous, sedimentary, and metamorphic processes as well as their compositions and textures. They are also introduced to the formation of soil resulting from interactions between the spheres. The development of the geological time scale based on fossil evidence and geological principles has led to revisions of the age of the Earth. The multidisciplinary nature of earth and environmental science is evident with physical, chemical and geological aspects relevant in concepts such as radioactive decay, the formulae of minerals, and the evidence of fossils.

Science Understanding	Possible Strategies, Contexts, and Activities
Minerals are constituents of the geosphere and are classified according to their chemical composition. • Discuss the limitations of using criteria to categorise substances as minerals. Minerals may be identified by their characteristic properties. • Identify common rock-forming minerals by observing their properties. • Discuss how the uses of minerals are related to their properties.	Examine some of the resources at ESWA Revise chemical symbols for elements that are commonly found in minerals. Investigate properties such as colour, streak, cleavage, hardness, lustre, density, magnetism, and reaction to dilute hydrochloric acid. Identify minerals such as quartz, feldspar, biotite, muscovite, calcite, augite, and clay minerals (kaolinite). Identify hand specimens of minerals and metallic ores www.glencoe.com/sites/common_assets/-science/virtual_labs/ES03/ES03.html Explore how use of minerals such as diamonds has improved the efficiency of industrial processes.
Rocks are composed of characteristic assemblages of mineral crystals or grains that are formed through igneous,	Use a simple diagram when explaining the interactions within the rock cycle. Use examples of rocks found in the local

Science Understanding	Possible Strategies, Contexts, and Activities
sedimentary, and metamorphic processes, as part of the rock cycle. • Classify rocks as one of igneous, sedimentary, or metamorphic by identification of their characteristic minerals and texture. • Describe the processes that form igneous, sedimentary, and metamorphic rocks.	area, for classification. www.glencoe.com/sites/common_assets/-science/virtual_labs/ES04/ES04.html Organise a cemetery field trip
Interactions between the atmosphere, geosphere, hydrosphere, and biosphere lead to the formation of soil. • Describe the composition of soil as rock and mineral particles, organic material, water, gases and living organisms • Discuss the relationship between a soil, its origin, and its possible uses.	Prepare a presentation that describes the life of a grain of quartz. Observe some examples of physical and chemical weathering in a local area. Test soil samples from students' backyards and predict the suitability of these sites for various activities such as construction of houses or growing plants.
Radioisotopes have been used to establish an absolute time scale and place the age of the Earth at 4.5 billion years old. • Explain how the half-life of radioactive elements is used to date Earth materials. Radioisotopes have been used to date organic remains. • Carbon-14 is used to date middens and megafauna up to 50 000 years old. The relative geological time scale has been constructed using fossils and geological principles. • Explain, with the aid of diagrams, how the relative ages of rock strata can be determined using fossil evidence and the principles of superposition, cross-cutting relationships, inclusions, and correlation.	Explore how the development of dating techniques has altered the estimated age of the Earth. Explain why older time spans that predate the reliable fossil record (before the Proterozoic Eon) are defined by the absolute age. Interpret radioactive decay curves from a half-life simulation practical. Use α and β emitters to collect data for graphing. Interpret radioactive decay curves from a half-life simulation practical. Use α and β emitters to collect data for graphing. Investigate how radioisotopic dating of artefacts has provided evidence of Aboriginal and Torres Strait Islander communities in certain areas. Locate on a map of the world some of the oldest and youngest rocks known. Conduct a field investigation in the local area. Determine the relative ages of rocks found in the field.

Topic 3: Processes in the Geosphere

Energy from the Earth’s interior drives movements of tectonic plates in the geosphere, which causes changes to structures in the geosphere and also volcanic and earthquake activity. Students investigate evidence that provides information about the structure of the Earth, and learn how scientists analyse this evidence to develop models of the Earth’s structure.

Science Understanding	Possible Strategies, Contexts, and Activities
Observation of present day processes can be used to infer past events and processes, by applying the principle of uniformitarianism. • Explain how features of sedimentary rocks can provide information about their history.	Conduct a field investigation in the local area. Apply the principle of uniformitarianism to interpret geological features seen in the field, e.g. volcanic landforms in south-east SA. Use the principle of uniformitarianism to interpret the surface of other objects in the solar system, such as Pluto. Discuss limitations of the use of the principle of uniformitarianism.
The study of seismic waves and meteorites provides evidence for the layered structure of the Earth. • Explain how the presence of shadow zones provides information about the layered structure of the Earth. • Explain how the composition of a meteorite can provide evidence of the internal composition of the Earth. • Describe the structure, relative thickness, composition and state of each layer of the Earth’s interior. • Describe how continental crust is different from oceanic crust.	Illustrate different types of crust using clay ball Earth.
Some processes within and between Earth systems require energy that originates from the interior of the Earth. • Interpret graphs of the Earth’s geothermal gradient. • Describe the transfer of geothermal energy from the decay of naturally occurring radioactive elements to rocks.	Discuss how radioactive decay produces heat.
Transfers and transformations of energy in the Earth’s interior cause plume formation and drive the movement of tectonic plates, through processes such as mantle convection, slab pull, and ridge push. • Describe how plumes from the mantle can transfer heat energy from the Earth’s interior to produce ‘hot-spot’ volcanic activity and form an island chain. • Explain why new crust is pushed away from mid-ocean ridges. • Explain why an oceanic plate is subducted	Demonstrate simple convection cells in the laboratory using coloured dye in a heated beaker. Visit, or investigate online, the Centre for Tectonics Resources and Exploration at the University of Adelaide. Watch and discuss a video of Marum lava lake in Vanuatu www.sciencephoto.com/media/247789/view View and discuss some animations describing aspects of plate tectonics, including the occurrence of hotspot

Science Understanding	Possible Strategies, Contexts, and Activities
in collisions with a continental plate.	volcanoes. Explore the relationship between the ages of the Hawaiian Islands and plate movement. Demonstrate slab pull simply by sliding a blanket from a bench top. Investigate seafloor spreading of tectonic plates. http://highhillhomeschool.blogspot.com.au/2014-08/sea-floor-spreading-activity-for-kids.html Explore Alfred Wegener's theory of Plate Tectonics.

Topic 4: The Earth's Atmosphere

The composition of gases in the Earth's atmosphere has varied over time. Students examine different theories to explain how the atmosphere was derived, and explore reasons for its changing composition. They examine effects of atmospheric ozone in protecting the environment and albedo on the climate and use the mechanisms that cause atmospheric circulation to explain wind direction. Students investigate how the movement of atmospheric air masses influences local ecosystems and weather patterns.

Science Understanding	Possible Strategies, Contexts, and Activities
Different theories exist that describe how the Earth's atmosphere was derived. • Discuss theories, such as volcanic outgassing, about the derivation of the Earth's atmosphere. • Compare the approximate proportion of nitrogen, oxygen, argon, and carbon dioxide in the Earth's atmosphere at different times in its history. • Explain why nitrogen is essential for life.	Investigate recent research that identifies the source of the Earth's nitrogen during the early history of its development. Investigate the gases that are typically released during modern volcanic activity, and the range of their relative proportions.
The composition of the Earth's atmosphere has been significantly modified by photosynthesising organisms. • Describe fluctuations in the proportion of oxygen in the Earth's atmosphere over geological time.	Research the action of cyanobacteria, the historic and contemporary formation of stromatolites, and the critical importance of the historical action of these bacteria to the 'Great Oxygenation Catastrophe' and to the evolution of life on Earth.
The modern atmosphere has a layered structure: the troposphere, mesosphere, stratosphere, and thermosphere. • Discuss the key features that characterise the four main layers of the atmosphere. • Describe the variation of temperature with altitude in the layers of the atmosphere.	Construct a scaled drawing (on a very large piece of paper) of a part of the Earth's cross-section, including the layers of the atmosphere. Include, for example, the highest mountain, deepest ocean trench, and the altitudes of highest-flying aircraft and earth orbiting satellites. Construct a scaled drawing of the layers of the atmosphere that includes a plot of temperature vs height.

Science Understanding	Possible Strategies, Contexts, and Activities
The net transfer of solar energy through the atmosphere to Earth’s surface is influenced by the interaction of ultraviolet radiation with atmospheric ozone and albedo. • Explain the importance of the ozone layer in protecting living organisms from damaging UV radiation. • Describe how albedo affect the Earth’s climate.	Discuss whether the Earth is an absorber or a reflector. Investigate the development of the ozone layer over time. Investigate progress in the global effort to repair the ‘hole in the ozone layer’.
Greenhouse gases in the Earth’s atmosphere produce a phenomenon known as the greenhouse effect. • Explain how greenhouse gases absorb and reradiate some of the thermal radiation emitted from Earth’s surface to warm the atmosphere.	Use examples of atmospheric gases that act as greenhouse gases, such as water vapour, nitrous oxide, methane and carbon dioxide, to explain the greenhouse effect. Investigate the evidence for contemporary warming of the Earth’s atmosphere. www.glencoe.mheducation.com/sites/0078778026/-student_view0/unit5/chapter15/virtual_lab.html Design an investigation based on the resource *Global warming in a jar.* www.hometrainingtools.com/a/weather-experiments-project Describe how new technologies have informed us about the runaway greenhouse effect on Venus and the absence of a greenhouse effect on Mars.
The movement of atmospheric air masses due to heating and cooling, and the Earth’s rotation, causes systematic atmospheric circulation; this is the dominant mechanism for the transfer of thermal energy around the Earth’s surface. • Explain how convection currents promote atmospheric circulation. • Explain how convections cells promote atmospheric circulation in each hemisphere. • Explain how the Coriolis effect influences wind direction around the Earth. • Explain how the movement of atmospheric air masses influences local ecosystems.	Explore atmospheric (convection) cells such as polar cells, the Ferrel Cell and the Hadley Cell. Compare the climates of different regions at similar latitudes. Explore the NOAA resource toasty wind. Conduct practical activities from the Weather Experiments website. www.hometrainingtools.com/a/weather-experiments-project
The interaction between the Earth’s atmosphere and oceans changes over time and can result in anomalous global weather patterns. • Discuss the causes and effects of ENSO (El Niño and La Niña).	Make predictions about phenomena such as El Niño and La Niña, based on previous data from the BOM ENSO resources.

Topic 5: Importance of the Hydrosphere

Water exists in three phases on the Earth and plays an important part in the interactions between the Earth's systems. Students investigate evidence that gives rise to different theories about the origins of water on the Earth. They study the properties of water and how these affect its role in biotic and abiotic environments. They learn how the action of oceans, as heat sinks, leads to formation of ocean currents and how the global ocean conveyer belt influences climate in regions around the world.

Science Understanding	Possible Strategies, Contexts, and Activities
Water is present on the Earth as a result of volcanic outgassing and the impact of icy extra-terrestrial bodies. • Discuss theories of the origin of the Earth's water.	Research estimates of the total volume of water that is believed to exist on Earth. Research recent data about the composition of comets. Discuss the densely cratered surface of the moon as an indication of the frequency of impacts in the early history of the solar system.
Water occurs in three phases on the Earth, solid, liquid, and gas. • Describe examples of the occurrence of the three phases of water in each of the Earth's spheres. • Describe the hydrological cycle. • Explain why evaporation from large bodies of water, e.g. the ocean and rivers, is important for atmospheric moisture. • Discuss global water distribution. • Explain the importance of water's unique properties in sustaining life on Earth and in shaping Earth processes.	Use T and P phase diagrams to explain why and where water naturally occurs on Earth. Use data from the water cycle to compare relative quantities of water existing as salt water, fresh water, ice and biological water, and in rivers, lakes, streams, and groundwater systems. USGS website Consider the essential roles of water in photosynthesis and as a transport agent providing food and oxygen and eliminating waste in organisms. Describe glaciation, weathering, and erosion Use properties such as boiling point, density in solid and liquid phases, surface tension, and solvent properties to explain the importance of water. Discuss the sustainability of local sources of water used for various purposes, and identify measures that could be used to save or recycle water locally.
The behaviour of the global oceans as a heat sink, and the Earth's rotation and revolution, cause systematic ocean currents; these are described by the global ocean conveyer model. • Oceans can absorb large quantities of heat for a small change in temperature. • Earth's wind belts causes surface ocean currents. • Upwelling, downwelling, and deep currents all contribute to create the Global Ocean Conveyer model.	Investigate the thermohaline gradient using salt solutions of different concentrations. Explore the relationship between the Earth's prevailing winds and the direction of the Ocean's currents.

Topic 6: Biosphere

The fossil record provides evidence of the diverse life forms that have existed over time. Students investigate different types of fossil evidence and explore their connections to past environments. Students investigate how interactions among the spheres affect the communities of organisms in different ecosystems. They study the importance of processes such as photosynthesis and the cycling of nutrients and energy for sustaining life on Earth.

Science Understanding	Possible Strategies, Contexts, and Activities
Fossil evidence indicates that life first appeared on Earth approximately 4.5 billion years ago. • Discuss the significance of prokaryotes as the first life on Earth in the Archean Eon. • Explain how life then evolved into eukaryotes.	Link the appearance of photosynthetic organisms, stromatolites, to changes in oxygen production in Topic 4. Visit, or investigate online, the state, territory, or national museum to look at the Ediacaran fossils exhibit. Identify and explain the importance of Ediacaran fauna Observe preserved specimens of stromatolites in local rocks. Watch and discuss David Attenborough's *First Life* DVD.
Laboratory experimentation has informed theories about how life emerged. • Explain how scientists use systematic investigation to replicate primeval conditions on Earth that could possibly produce chemicals that are essential for life to begin. • Describe the atmospheric and oceanic conditions that are thought to have existed in the Archean Eon.	Explain how the Miller-Urey experiment is used to replicate primeval conditions on Earth that could possibly produce chemicals that are essential for life to begin. Describe possible environmental settings and conditions in which this could occur. Describe the limitations of the Miller-Urey Experiment. Watch animation of primordial Earth. Research evidence for the origin of life on Earth. Use a physical model to show the development of our current atmosphere using *Earth's atmosphere – step by step evolution*. www.sciencephoto.com/media/467534/view Modelling the Earth's early atmosphere
In any one location, the characteristics and interactions of the atmosphere, geosphere, hydrosphere, and biosphere give rise to unique and dynamic communities. • Describe the difference between biotic and abiotic features of an ecosystem. • Explain how a change in these features can create different environments. • Identify, measure, and record the appropriate characteristics in a field location. • Describe how these factors may affect the distribution and abundance of organisms found in a particular location.	Conduct a field investigation focused on an environmental monitoring and ecosystem study. Conduct a field trip to a local ecosystem, e.g. national park, beach, river system, to investigate biotic and abiotic features and how changing these would affect the communities of living organisms in the ecosystem. Select appropriate biotic and abiotic characteristics for the field study location, such as temperature, available water, nature of the substrate, organisms present, available light, UV, and wind. Watch a TED talk such as How Can We Make Crops Survive Without Water? Use online sites for modelling ecosystems Glencoe Virtual Lab: How do organisms react to changes in abiotic factors?

Science Understanding	Possible Strategies, Contexts, and Activities
	www.ted.com/talks/jill_farrant_how_we_can_make-_crops_survive_without_water www.glencoe.com/sites/common_assets/science/-virtuallabs/CT08/CT08.html
The characteristics of past environments and communities can be inferred from the sequence and internal textures of sedimentary rocks, and from enclosed fossils and trace fossils. • Explain ways in which fossils form. • Relate the present environment of living organisms to the past environment of fossils of similar organisms. • Describe the formation of sedimentary structures that are used to determine the facing of beds.	Investigate various aspects of past environments using numerous 'Earthlearningideas' activities. Examine how factors such as the presence of water, nature of the substrate, atmospheric and water temperature impact on the organism assemblages in a past environment. Investigate sedimentary structures that are used to determine the facing of beds - cross bedding and way up - cross bedding 2 - graded bedding - ripple marks Dinosaur Death www.earthlearningidea.com/English/Evolution_of_Life.html www.earthlearningidea.com/PDF/194_Cross_bedding_1.pdf www.earthlearningidea.com/PDF/159_Cross_bedding_2.pdf www.earthlearningidea.com/PDF/Symmetrical_Ripple_Marks-pdf.
The diversification and proliferation of living organisms over time and the catastrophic collapse of ecosystems can be inferred from the fossil record. • Explain the relationship between the fossil record and the eras in the geological timescale. • Explain why some fossils are useful as index fossils. • Explain why the fossil record is inevitably incomplete, especially for organisms that lived more than 600 Ma years ago. • Explain the significance of fossils within the geological timescale and as indicators of past environments. • Describe the Cambrian Explosion and its significance. • Discuss possible theories about the extinction of Dinosaurs the end of the Cretaceous Period.	Investigate the Ediacaran fauna at the palaeontology exhibit at a state, territory, or national museum. Model the geological timescale using 'Earthlearningidea' *A time-line in your own backyard.* Conduct a field investigation to examine the stratigraphy, and observe fossils, for example, at Maslin's Bay or Port Willunga. Identify specimens of each of the following and describe the time and environment in which they lived: - Ediacaran fauna - Trilobites - Dinosaurs - Ammonites - Archaeocyatha - Graptolites - Megafauna (diprotodont). Research the scientific evidence for the causes of the death of the Megafauna.
Energy from the sun is converted into chemical energy in the form of biomass. • Explain the importance of photosynthesis in converting light energy into chemical energy that is stored in glucose. • Explain that net primary production (NPP) is the rate at which plants in an ecosystem produce net useful chemical energy.	Obtain data on photosynthesis that can be tabulated and graphed. Observe and discuss a very simple activity on manipulating factors that affect photosynthesis. Design practical investigations, individually or in groups, into factors affecting the rate of photosynthesis. Choose from a large number of ideas for

Science Understanding	Possible Strategies, Contexts, and Activities
	activities on photosynthesis. www.reading.ac.uk/virtualexperiments/ves/preloader-photosynthesis-full.html www.glencoe.com/sites/common_assets/science/virtual_labs/LS12/-LS12.html www.juliantrubin.com/fairprojects/botany/photosynthesis.html
The availability of energy and matter are one of the main determinants of ecosystem carrying capacity. • Explain how biotic and abiotic factors affect carrying capacity.	Use interactive resources to model carrying capacity: - Rabbits vs Wolves online modelling - student activity Musky Fish - simple bio population intro graphing activity. www.shodor.org/interactivate/activities/RabbitsAndWolves www.intotheoutdoors.org/wp-content/uploads/2013/06/BioCarryCapacity_Lesson.final.pdf www.populationeducation.org/sites/default/files/pop_ecology_files.pdf
Energy is stored, transferred, and transformed in the carbon cycle. • Describe the key processes and the role they play in the carbon cycle including photosynthesis, respiration, decomposition and combustion. • Identify the main carbon sinks. • Describe the differences between the fast and slow carbon cycle. • Identify where these processes occur in the carbon cycle. • Explain the interactions between the forms of carbon and each of the spheres.	Discuss how the Amazon basin acts as a carbon sink Explore fast and slow carbon cycles.
Biogeochemical cycling of nitrogen and phosphorus in matter between the biosphere, geosphere, atmosphere, and hydrosphere. • Describe the key processes in the nitrogen cycle, including nitrification, denitrification, nitrogen fixation, ammonification, eutrophication. • Identify where these processes occur in the Nitrogen cycle. • Explain the interactions between the forms of nitrogen and each of the spheres. • Discuss the key processes in the phosphorous cycle including the conversion of inorganic phosphate to organic phosphate and the role of earth and environmental science processes. • Explain why the atmosphere does not play a significant role in the phosphorous cycle but does in the nitrogen cycle.	Explore the nitrogen cycle on a virtual farm. Explore the nitrogen cycle in a Virtual Lab: Nitrogen in a Marine Environment. Investigate the carbon cycle in an interactive activity. www.sites.ext.vt.edu/resources/4h/nitrogencycle/nitrogencycle.swf www.mhhe.com/biosci/genbio/virtual_labs/BL_24/BL_24.html www.learner.org/courses/envsci/interactives/carbon/

ASSESSMENT SCOPE AND REQUIREMENTS

At Stage 1, assessment is school-based.

EVIDENCE OF LEARNING

The following assessment types enable students to demonstrate their learning in Stage 1 Earth and Environmental Science.

- Assessment Type 1: Investigations Folio
- Assessment Type 2: Skills and Applications Tasks

For a 10-credit subject, students provide evidence of their learning through four assessments. Each assessment type should have a weighting of at least 20%.

Students complete:

- at least one practical investigation, either in the laboratory or in the field
- at least one science as a human endeavour investigation
- at least one skills and applications task.

For a 20-credit subject, students provide evidence of their learning through eight assessments. Each assessment type should have a weighting of at least 20%.

Students complete:

- at least two practical investigations, either in the laboratory or in the field
- at least two science as a human endeavour investigations
- at least two skills and applications tasks.

ASSESSMENT DESIGN CRITERIA

The assessment design criteria are based on the learning requirements and are used by teachers to:

- clarify for the student what he or she needs to learn
- design opportunities for the student to provide evidence of his or her learning at the highest level of achievement.

The assessment design criteria are the specific features that:

- students should demonstrate in their learning
- teachers look for as evidence that students have met the learning requirements.

For this subject, the assessment design criteria are:

- investigation, analysis, and evaluation
- knowledge and application.

The specific features of these criteria are described below.

The set of assessments, as a whole give students opportunities to demonstrate each of the specific features by the completion of study of the subject.

Investigation, Analysis, and Evaluation

The specific features are as follows:

IAE1 Design of an earth and environmental science investigation

IAE2 Obtaining, recording, and representation of data, using appropriate conventions and formats

IAE3 Analysis of data and other evidence to formulate and justify conclusions

IAE4 Evaluation of procedures and their effect on data.

Knowledge and Application

The specific features are as follows:

KA1 Demonstration of knowledge and understanding of earth and environmental science concepts.

KA2 Application of earth and environmental science concepts in new and familiar contexts

KA3 Demonstration of understanding of science as a human endeavour

KA4 Communication of knowledge and understanding of earth and environmental science concepts and information, using appropriate terms, conventions, and representations.

SCHOOL ASSESSMENT

Assessment Type 1: Investigations Folio

For a 10-credit subject, students undertake at least one practical investigation, either in the laboratory or in the field, and one investigation with a focus on science as a human endeavour.

For a 20-credit subject, students undertake at least two practical investigations, either in the laboratory or in the field, and two investigations with a focus on science as a human endeavour.

Students inquire into aspects of earth and environmental science through practical discovery and data analysis, and/or by selecting, analysing, and interpreting information.

Practical/Field Investigations

As students design and safely carry out investigations, they develop their science inquiry skills by formulating investigable questions and hypotheses, selecting and using appropriate equipment, apparatus, and techniques, identifying variables, collecting, representing, analysing, and interpreting data, evaluating procedures and considering their impact on results, drawing conclusions, and communicating their knowledge and understanding of concepts.

Practical/field investigations may be conducted individually or collaboratively, but each student should present an individual report. Students should be given the opportunity to investigate a question or hypothesis for which the outcome is uncertain.

A practical/field report should include:

- introduction with relevant earth and environmental concepts, a hypothesis and variables, or investigable question
- materials/apparatus, method/procedure outlining steps taken*
- identification and management of safety and/or ethical risks*
- results*
- analysis of results, identifying trends, and linking results to concepts
- evaluation of procedures and data, identifying sources of uncertainty
- conclusion.

The report should be a maximum of 1000 words, if written, or a maximum of 6 minutes for an oral presentation or the equivalent in multimodal form.

*The materials/apparatus, method/procedure outlining steps to be taken, identification and management of safety and/or ethical risks, and results sections are excluded from the word count.

Suggested formats for presentation of a practical/field investigation report include:

- a written report
- a multimodal product.

Science as a Human Endeavour Investigation

Students investigate an aspect of earth and environmental science with an emphasis on science as a human endeavour. This investigation focuses on at least one aspect of Science as a human endeavour described on pages 11 and 12, and may draw on a context suggested in the topics being studied or explore a new context.

Student consider, for example:

- how humans seek to improve their understanding and explanation of the natural world
- how working scientifically is a way of obtaining knowledge allows for the analysis of scientific claims, but also allows for change in scientific theory in the light of new evidence, possibly due to technological advances
- the role of social, ethical, and environmental factors in advancing scientific research and debate
- how scientific theories have developed historically and speculate on how theory and technology may continue to advance understanding and endeavour
- links between advances in science and their impact and influence on society.

Students access information from different sources, select relevant information, analyse their findings, and develop and explain their own conclusions from the investigation.

Possible starting points for the investigation could include, for example:

- an article from a scientific journal (e.g. Cosmos, New Scientist)
- a blog, an infographic, or TED talk based on an aspect of earth and environmental science
- an advertisement or a film clip in which an earth and environmental science concept is misconstrued
- an expert's point of view on an aspect of earth and environmental science
- a new development in the field of earth and environmental science endeavour
- the impact of a technique used in an earth and environmental science context and its historical development
- concern about an issue that has environmental, social, economic, or political implications
- emerging earth and environmental science-related careers
- changes in government funding for earth and environmental science-related purposes, e.g. for scientific research into conservation planning, safe disposal of nuclear waste, water quality, greenhouse effect, energy supplies.

The science as a human endeavour investigation should be a maximum of 1000 words if written or a maximum of 6 minutes for an oral presentation, or the equivalent in multimodal form.

For this assessment type, students provide evidence of their learning in relation to the following assessment design criteria:

- investigation, analysis, and evaluation
- knowledge and application.

Assessment Type 2: Skills and Applications Tasks

For a 10-credit subject, students undertake at least one skills and applications task.

Students may undertake more than one skills and applications task, but least one should be under the direct supervision of the teacher. The supervised setting (e.g. classroom, laboratory, or field) should be appropriate to the task.

For a 20-credit subject, students undertake at least two skills and applications tasks. Students may undertake more than two skills and applications tasks, but least two should be under the direct supervision of the teacher. The supervised setting (e.g. classroom, laboratory, or field) should be appropriate to the task.

Skills and applications tasks allow students to provide evidence of their learning in tasks that may be:

- routine, analytical, and/or interpretative
- posed in new and familiar contexts
- individual or collaborative assessments, depending on the design of the assessment.

A skills and applications task may require students to, for example: use earth and environmental science terms, conventions, and notations; demonstrate understanding; apply knowledge; graph or tabulate data; analyse data; evaluate procedures; formulate conclusions; represent information diagrammatically or graphically; design an investigation to test a hypothesis or investigable question.

Skills and applications tasks should be designed to enable students to demonstrate knowledge and understanding of the key earth and environmental science concepts and learning, and the science inquiry skills covered in the program. Students use appropriate earth and environmental science terms and conventions to explain links between earth and environmental science concepts, and apply this knowledge to solve problems. Some of these problems could be defined in a practical, social, or environmental context.

Skills and applications tasks may include:

- modelling or representing concepts
- developing simulations
- a practical assessment such as a 'completion practical' with associated questions
- a graphical skills exercise
- a multimodal product
- an oral presentation
- a video or audio recording
- participation in a debate
- an extended response
- a written assignment
- a structured interview
- an excursion report
- a historical study
- multiple-choice questions in combination with other question types
- short-answer questions
- a response to text(s).

For this assessment type, students provide evidence of their learning in relation to the following assessment design criteria:

- investigation, analysis, and evaluation
- knowledge and application.

PERFORMANCE STANDARDS

The performance standards describe five levels of achievement, A to E.

Each level of achievement describes the knowledge, skills and understanding that teachers refer to in deciding how well a student has demonstrated his or her learning on the basis of the evidence provided.

During the teaching and learning program the teacher gives students feedback on their learning, with reference to the performance standards.

At the student's completion of study of a subject, the teacher makes a decision about the quality of the student's learning by:

- referring to the performance standards
- taking into account the weighting of each assessment type
- assigning a subject grade between A and E.

Performance Standards for Stage 1 Earth and Environmental Science

	Investigation, Analysis and Evaluation	Knowledge and Application
A	Designs a logical, coherent, and detailed earth and environmental science investigation. Obtains, records, and represents data, using appropriate conventions and formats accurately and highly effectively. Systematically analyses data and evidence to formulate logical conclusions with detailed justification. Critically and logically evaluates procedures and their effects on data.	Demonstrates deep and broad knowledge and understanding of a range of earth and environmental science concepts. Applies earth and environmental science concepts highly effectively in new and familiar contexts. Demonstrates a comprehensive understanding of science as a human endeavour. Communicates knowledge and understanding of earth and environmental science coherently with highly effective use of appropriate terms, conventions, and representations.
B	Designs a well-considered and clear earth and environmental science investigation. Obtains, records, and displays findings of investigations, using appropriate conventions and formats mostly accurately and effectively. Logically analyses data and evidence to formulate suitable conclusions with reasonable justification. Logically evaluates procedures and their effects on data.	Demonstrates some depth and breadth of knowledge and understanding of a range of earth and environmental science concepts. Applies earth and environmental science concepts mostly effectively in new and familiar contexts. Demonstrates some depth of understanding of science as a human endeavour. Communicates knowledge and understanding of earth and environmental science mostly coherently with effective use of appropriate terms, conventions, and representations.
C	Designs a considered and generally clear earth and environmental science investigation. Obtains, records, and displays findings of investigations, using generally appropriate conventions and formats with some errors but generally accurately and effectively. Makes some analysis of data and evidence to formulate generally appropriate conclusions with some justification. Evaluates some procedures and some of their effects on data.	Demonstrates knowledge and understanding of a general range of earth and environmental science concepts. Applies earth and environmental science concepts generally effectively in new or familiar contexts. Describes some aspect of science as a human endeavour. Communicates knowledge and understanding of earth and environmental science generally effectively, using some appropriate terms, conventions, and representations.
D	Prepares the outline of a earth and environmental science investigation. Obtains, records, and displays findings of investigations, using conventions and formats inconsistently, with occasional accuracy and effectiveness. Describes data and formulates a simple conclusion. Attempts to evaluate procedures or suggest an effect on data.	Demonstrates some basic knowledge and partial understanding of earth and environmental science concepts. Applies some earth and environmental science concepts in familiar contexts. Identifies some aspect of science as a human endeavour. Communicates basic earth and environmental science information, using some appropriate terms, conventions, and/or representations.
E	Identifies a simple procedure for a earth and environmental science investigation. Attempts to record and display some descriptive results of an investigation, with limited accuracy or effectiveness. Attempts to describe results and/or attempts to formulate a conclusion. Acknowledges that procedures affect data.	Demonstrates limited recognition and awareness of earth and environmental science concepts. Attempts to apply earth and environmental science concepts in familiar contexts. Shows some recognition of science as a human endeavour. Attempts to communicate information about earth and environmental science.

ASSESSMENT INTEGRITY

The SACE Assuring Assessment Integrity Policy outlines the principles and processes that teachers and assessors follow to assure the integrity of student assessments. This policy is available on the SACE website (wwww.sace.sa.edu.au) as part of the SACE Policy Framework.

The SACE Board uses a range of quality assurance processes so that the grades awarded for student achievement in the school assessment are applied consistently and fairly against the performance standards for a subject, and are comparable across all schools.

Information and guidelines on quality assurance in assessment at Stage 1 are available on the SACE website (www.sace.sa.edu.au).

SUPPORT MATERIALS

SUBJECT-SPECIFIC ADVICE

Online support materials are provided for each subject and updated regularly on the SACE website (www.sace.sa.gov.au). Examples of support materials are sample learning and assessment plans, annotated assessment tasks, annotated student responses, and recommended resource materials.

ADVICE ON ETHICAL STUDY AND RESEARCH

Advice for students and teachers on ethical study and research practices is available in the guidelines on the ethical conduct of research in the SACE on the SACE website. (www.sace.sa.edu.au).

Stage 2
Earth and Environmental Science

LEARNING SCOPE AND REQUIREMENTS

LEARNING REQUIREMENTS

The learning requirements summarise the knowledge, skills, and understanding that students are expected to develop and demonstrate through their learning in Stage 2 Earth and Environmental Science.

In this subject, students are expected to:

1. use science inquiry skills to design and conduct earth and environmental science investigations, using appropriate procedures and safe, ethical working practices
2. obtain, record, represent, and analyse the results of earth and environmental science investigations
3. evaluate procedures and results and analyse evidence to formulate and justify conclusions
4. demonstrate and apply knowledge and understanding of earth and environmental science concepts in new and familiar contexts
5. demonstrate understanding of science as a human endeavour
6. communicate knowledge and understanding of earth and environmental science concepts, using appropriate terms, conventions, and representations.

CONTENT

Stage 2 Earth and Environmental Science is a 20-credit subject.

Students consider how human beings use the Earth's resources and the impact of human activities on the environment. They assess the evidence that informs public debate on social and environmental issues such as use of the Earth's resources, and climate change. They conduct a detailed investigation into an aspect of human activity that impacts on two or more of the Earth's systems.

Using an inquiry approach to learning through observation, speculation, prediction, experimentation, analysis, evaluation, and communication, students develop science inquiry skills and reinforce their understanding of science as a human endeavour.

Science inquiry skills and science as a human endeavour are integral to students' learning in this subject and are interwoven through the science understandings, which are organised into four topics. The science inquiry skills and the understanding of science as a human endeavour that can be developed through practical and other learning activities in each topic are described in the *Science Inquiry Skills* and *Science as a Human Endeavour* sections that follow.

Programming advice

Stage 2 Earth and Environmental Science consists of the following topics:

- Topic 1: Earth Systems
- Topic 2: Earth's Resources
- Topic 3: Earth's Sustainable Future
- Topic 4: Climate Change

Students study all four topics and with the *Science Inquiry Skills* and *Science as a Human Endeavour* sections integrated into the science understanding.

Each topic is presented in the subject outline in two columns, with the science understanding in the left-hand column supported by possible strategies, contexts, and activities in the right-hand column.

The *Science Understanding* column covers the prescribed content for teaching, learning, and assessment in this subject. The possible strategies, contexts, and activities are provided as a guide only. They are neither comprehensive nor exclusive. Teachers may select from these or choose to use others.

The following symbols have been used in the right-hand column to indicate where different kinds of suggestions have been made:

indicates a possible teaching strategy

indicates a possible Science as a Human Endeavour context

indicates a possible activity to develop Science Inquiry Skills

An inquiry-based approach is integral to the development of the science understanding. The *Possible Strategies, Contexts, and Activities* column presents ideas and opportunities for the integration of the science inquiry skills and the understandings related to science as a human endeavour. Teachers may use some or all of these examples, or other relevant examples, to enable students to develop their knowledge, skills, and understanding.

Science Inquiry Skills

In Earth and Environmental Science, investigation is an integral part of the learning and understanding of concepts, by using scientific methods to test ideas and develop new knowledge.

Practical investigations involve a range of individual and collaborative activities during which students develop and extend the science inquiry skills described in the table that follows.

The practical activities may take a range of forms, such as developing models and simulations that enable students to develop a better understanding of particular concepts. They include laboratory and field studies during which students develop investigable questions and/or testable hypotheses, and select and use equipment appropriately to collect data. The data may be observations, measurements or other information obtained during the investigation. Students display and analyse the data they have collected, evaluate procedures, and describe their limitations, consider explanations for their observations, and present and justify conclusions appropriate to the initial question or hypothesis.

For a 20-credit subject, it is recommended that 16–20 hours of class time would involve practical activities.

Science inquiry skills are also fundamental to students investigating the social, ethical, and environmental impacts and influences of the development of scientific understanding and the applications, possibilities, and limitations of science. These skills enable students to critically consider the evidence they obtain so that they can present and justify a conclusion.

Science inquiry skills are presented in two columns, with a range of science inquiry skills in the left-hand column side by side with possible strategies, contexts, and activities in the right-hand column. The *Science Inquiry Skills* column describes the prescribed teaching, learning, and assessment in this subject.

The symbols in the *Possible Strategies, Contexts, and Activities* column in the table that follows are provided as a guide to the possible approaches, resources, and/or activities that teachers may use. They are neither comprehensive nor exclusive. Teachers may select from them and/or choose to use others.

These science inquiry skills are integrated throughout the topics that are detailed in this subject outline. In each topic, the symbols in the *Possible Strategies, Contexts, and Activities* column are provided as a guide to the possible contexts that teachers may use to develop student understanding of science inquiry skills. These suggestions are neither comprehensive nor exclusive. Teachers may select from them and/or choose to use others.

Science Inquiry Skills	Possible Strategies, Contexts, and Activities
Scientific methods enable systematic investigation to obtain measureable evidence. • Design investigations, including: – a pre-investigation trial that develops the procedure – a hypothesis or inquiry question – types of variables ➢ dependent ➢ independent ➢ factors held constant (how and why they are controlled) ➢ factors that may not be able to be controlled (and why not) – materials required	Class activities to develop skills could include: – designing investigations without implementation – changing an independent variable in a given procedure and adapting the method – researching, developing, and trialling a method – improving an existing procedure – identifying options for measuring the dependent variable – researching hazards related to the

Science Inquiry Skills	Possible Strategies, Contexts, and Activities
– the procedure to be followed – the type and amount of data to be collected – identification of ethical and safety considerations.	use and disposal of chemicals and/or earth and environmental science materials – developing safety audits – identifying relevant ethical and/or legal considerations, including accessibility of investigation sites, in different contexts.
Obtaining meaningful data depends on conducting investigations using appropriate procedures and safe, ethical working practices. • Conduct investigations, including: – selection and safe use of appropriate materials, apparatus, and equipment – collection of appropriate primary and/or secondary data (numerical, visual, descriptive) – individual and collaborative work.	Class activities to develop skills could include: – identifying equipment, materials, or instruments fit for purpose – practising techniques and safe use of apparatus – comparing resolution of different measuring tools – distinguishing between and using primary and secondary data.
The results of investigations are presented in a well-organised way to allow them to be interpreted. • Present results of investigations in appropriate ways, including: – use of appropriate SI units, symbols – use of field notes – construction of appropriately labelled tables – drawing of graphs, linear, non-linear, lines of best fit as appropriate – use of significant figures.	Class activities to develop skills could include: – practising constructing field notes Clino app; Field Move – practising constructing tables to tabulate data with column and row labels with units – identifying the appropriate representations to graph different data sets – selecting appropriate axes and scales to graph data – clarifying understanding of significant figures http://www.astro.yale.edu/astro120/SigFig.pdf – comparing data from different sources to describe as quantitative, qualitative.
Scientific information can be presented using different types of symbols and representations. • Select, use, and interpret appropriate representations, including: – mathematical relationships, such as ratios – diagrams – equations to explain concepts, solve problems, and make predictions.	Class activities to develop skills could include: – drawing and labelling diagrams – constructing flow diagrams. – recording images – writing chemical formulae and equations – interpreting satellite images – construction of maps and cross-sections.
The analysis of the results of investigations allows them to be interpreted in a meaningful way. • Analyse data, including: – identification and discussion of trends, patterns, and relationships	Class activities to develop skills could include: – analysing data sets to identify trends and patterns – determining relationships between independent and dependent

Science Inquiry Skills	Possible Strategies, Contexts, and Activities
– interpolation/extrapolation where appropriate – selection and use of evidence and scientific understanding to make and justify conclusions.	variables – using graphs from different sources, e.g. CSIRO, BOM or ABS, to predict values other than plotted points – calculating mean values and rates of reaction, where appropriate.
Critical evaluation of procedures and outcomes can determine the meaningfulness of conclusions. • Evaluate the procedures and results to identify sources of uncertainty, including: – random and systematic errors – replication – sample size – accuracy – precision – validity – reliability – effective control of variables. • Discuss the impact that sources of uncertainty have on experimental results. • Recognise the limitations of conclusions	Students could evaluate procedures and data sets provided by the teacher to determine and hence comment on the limitations of possible conclusions. Use an example of an investigation report to develop report-writing skills, for example: www.biologyjunction.com/ap_sample_lab_12_dissolved_oxyge.htm
Effective scientific communication is clear and concise. • Communicate to specific audiences and for specific purposes using: – appropriate language – terminology – conventions.	Class activities could include: – reviewing scientific articles or presentations to recognise conventions – developing skills in referencing and/or footnoting – distinguishing between reference lists and bibliographies – opportunities to practise scientific communication in written, oral, and multimedia formats.

Science as a Human Endeavour

Through science, we seek to improve our understanding and explanations of the natural world. The *Science as a Human Endeavour* strand highlights the development of science as a way of knowing and doing, and explores the use and influence of science in society.

The development of science concepts, models, and theories is a dynamic process that involves analysis of evidence and sometimes produces ambiguity and uncertainty. Science concepts, models, and theories are continually reviewed and reassessed as new evidence is obtained and as new technologies enable different avenues of investigation. Scientific advancement involves a diverse range of individual scientists and teams of scientists working within an increasingly global community of practice, using international conventions and activities such as peer review.

Scientific progress and discoveries are influenced and shaped by a wide range of social, economic, ethical, and cultural factors. The application of science may provide great benefits to individuals, the community, and the environment, but may also pose risks and have unexpected outcomes. As a result, decision-making about socio-scientific issues often involves consideration of multiple lines of evidence and a range of needs and values. As an ever-evolving body of knowledge, science frequently informs public debate, but is not always able to provide definitive answers.

Through the exploration of *Science as a Human Endeavour*, students increase their understanding of the complex ways in which science interacts with society.

The understanding of *Science as a Human Endeavour* encompasses:

1. Communication and Collaboration

- Science is a global enterprise that relies on clear communication, international conventions, and review and verification of results.
- International collaboration is often required in scientific investigation.

2. Development

- Development of complex scientific models and/or theories often requires a wide range of evidence from many sources and across disciplines.
- New technologies improve the efficiency of scientific procedures and data collection and analysis; this can reveal new evidence that may modify or replace models, theories, and processes.

3. Influence

- Advances in scientific understanding in one field can influence and be influenced by other areas of science, technology, engineering, and mathematics.
- The acceptance and use of scientific knowledge can be influenced by social, economic, cultural, and ethical considerations.

4. Application and Limitation

- Scientific knowledge, understanding, and inquiry can enable scientists to develop solutions, make discoveries, design action for sustainability, evaluate economic, social, and environmental impacts, offer valid explanations, and make reliable predictions.

- The use of scientific knowledge may have beneficial or unexpected consequences; this requires monitoring, assessment, and evaluation of risk and provides opportunities for innovation.

- Science informs public debate and is in turn influenced by public debate; at times, there may be complex, unanticipated variables or insufficient data that may limit possible conclusions.

Science as a Human Endeavour underpins the content, strategies, contexts, and activities for all topics that are detailed in this subject outline, and the understandings should be integrated and used as points of reference for student learning.

The symbols in the right hand column of each topic, under the heading *Possible Strategies, Contexts, and Activities*, are provided as a guide to the possible contexts that teachers may use to develop student understanding of science as a human endeavour. They are neither comprehensive nor exclusive. Teachers may select from them and/or choose to use others.

Topic 1: Earth Systems

This topic lays the foundation of scientific inquiry skills that students will use in planning and implementing the earth systems study. The purpose of the study is to enable students to examine in detail the interaction between and within at least two Earth systems; the atmosphere, hydrosphere, geosphere, and biosphere. In addition, students link their study to at least one aspect of human endeavour so the findings of their study can lead to recommendations to appropriate groups and enable students to make informed decisions about their personal action.

Science Understanding	**Possible Strategies, Contexts, and Activities**
The four Earth systems are the geosphere, atmosphere, hydrosphere, and biosphere. • Investigate the components of each of the four spheres. • Identify visible and 'hidden' system components and processes. • Identify interactions among system components. • Describe dynamic relations in a system and among systems. • Organise components and processes in a web of interactions.	Examine an overview of Earth systems and their interconnections, including numerous teaching resources and student activities in Earth Labs – Earth system science unit and field study. http://serc.carleton.edu/earthlabs/climate/index.html Investigate the interaction of the four Earth systems in the local area and construct a table to show how the four Earth systems can interact. www.ucmp.berkeley.edu/education/dynamic/session4/index.html Investigate a case study, for example *Cleaning up an oil spill* http://response.restoration.noaa.gov/training-and-education/education-students-and-teachers Discuss an infographic about the systems of the Earth. www.visual.ly/fifty-unbelievable-facts-about-earth
A change in any one 'sphere' can impact others at a range of temporal and spatial scales. • Explain how changes in systems can be caused by natural or human-induced factors. • Describe that changes in a system and between systems can occur over a variety of timescales. • Identify patterns and changes over a variety of time scales. • Discuss how a change in Earth systems can influence conditions in a range of spatial scales from the local area to globally. • Explain that changes in systems may have cyclic or unpredictable patterns. • Examine changes that have happened in interactions among Earth systems in the past. • Predict future changes within and among Earth systems in a given area.	Conduct a field activity in which students participate in a whole class Earth systems study to develop appropriate science inquiry skills and make connections with science as a human endeavour. • Observe interactions among the systems in a local area. • Identify and record these interactions. • Analyse this primary data. • Identify an environmental issue, concern, initiative, or successful undertaking. • Hypothesise, control variables, predict, and gather new data. • Gather background information, such as from maps and satellite imagery, and/or research the outcomes of prior studies. • Provide recommendations for further work. Explore use of fieldwork apps, such as: Fieldmove Clino – free app for field notes, photos, map of sites, and recording dip and strike measurements. Suitable for iPhones and android devices. www.mve.com/digital-mapping Evernote skitch – a sketching app to complement field notes and photos. https://evernote.com/skitch/?var=c

Topic 2: Earth's Resources

For thousands of years, humans have made use of the Earth's resources to sustain life and provide infrastructure for living. New technologies have made possible the discovery of the larger quantities of resources needed in a technological society and have led to new extraction processes. There are, however, environmental consequences of the extraction, processing, and use of non-renewable mineral and energy resources. The sustainability of resources is now a topic for public debate – a debate that can be informed by the work of scientists.

Students learn about the formation of non-renewable mineral and energy resources; techniques used for their discovery; identification and extraction, and effects of the extraction; and use of these resources on ecosystems. They develop skills in the selection, graphing, analysis, and evaluation of data on use and discovery of non-renewable resources, and draw conclusions about the environmental impacts of current practices.

Science Understanding	Possible Strategies, Contexts, and Activities
People use the geological resources of the Earth to help satisfy their needs and wants. • Compare the use of geological resources in various lifestyles. • Discuss, using examples from a variety of cultures, ways in which geological resources are used.	Compile a list of all the resources that one person uses in a day. Explore ways in which Indigenous Australians, or Indigenous peoples in other countries, used geological resources before colonisation.
Non-renewable mineral and energy resources are formed in various ways over geological timescales, so are not readily replenished. • Discuss the sustainability of reserves of fossil fuels, and metallic and non-metallic resources.	Collect data on global consumption and the rate of new discoveries of conventional petroleum during the 20th and early 21st Centuries. ('Peak Oil'). Construct graphs to illustrate the findings. Construct a table to display non-renewable fuel resources, including unconventional petroleum and uranium, and the approximate known global reserves of each resource, and critically evaluate this information in terms of sustainability. Collect and graph data on global reserves and current rate of use of a range of metallic resources, including iron ore and copper, and critically evaluate this information in terms of sustainability.
The formation of non-renewable energy resources, including fossil fuels and unconventional gas, is related to their geological setting. • Explain the processes by which coal is formed. • Describe the processes by which petroleum and coal-seam gas are formed and are trapped. • Describe structures within which petroleum may be trapped.	Explore the benefits and risks of the extraction and use of unconventional gas. www.csiro.au/en/Research/Energy/Hydraulic-fracturing/What-is-unconventional-gas Use diagrams to explain the formation of a placer deposit in a stream bed. Draw labelled diagrams of common petroleum traps to help explain how petroleum and coal-seam gas is formed and are trapped. Identify hand specimens of various ranks of coal.

Science Understanding	Possible Strategies, Contexts, and Activities
The formation of non-renewable metallic mineral resources is related to their geological setting. • Explain how metallic ores may be concentrated by gravity-settling and hydrothermal processes. • Explain how the processes of weathering, erosion, and deposition may concentrate metallic ores. • Explain how the formation of iron ore (banded iron formations) occurred in an anaerobic environment. • Identify metallic ores, using their physical and chemical properties.	Use step-by-step diagrams to explore the formation of ore bodies by the processes of gravity settling in a magma chamber, and by hydrothermal vein formation associated with igneous activity. Identify minerals such as chalcopyrite, haematite, magnetite, galena, sphalerite, rutile, gold, copper, uranium, bauxite, and graphite.
A variety of techniques can be used to discover deposits of mineral and energy resources and identify the extent and quality of these resources. • Discuss techniques for finding mineral resources, using magnetic and electromagnetic surveys, geochemical sampling, and drilling. • Explain how seismic and gravity surveys are used in petroleum exploration. • Discuss how the presence of a resource can affect the surrounding physical and chemical environment.	Evaluate discovery techniques such as satellite imaging, and geochemical and geophysical sampling to collect datasets, and direct sampling techniques such as drilling, and core soil, and rock sampling. www.earthsciencewa.com.au/mod/resource/-view.php?id=1149 Use a magnetometer (or a metal detector) over a measured grid to locate and map buried metal objects. Investigate the impacts of various steps used in mineral exploration on the environment. www.earthsciencewa.com.au/mod/resource/-view.php?id=1155 www.earthsciencewa.com.au/mod/resource-/view.php?id=1154
The depth, extent, and location of mineral and energy resources determine the method of extraction. • Describe the essential features of underground, open cut, and the *in situ* leaching method of extraction of mineral resources. • Explain how the size, shape, and depth of a mineral deposit influence the choice of extraction method. • Explain how petroleum, shale oil, coal, and coal-seam gas are extracted from the Earth in different locations.	Draw and label diagrams showing the essential features and environmental impact of each mining and extraction method. Discuss reasons for using underground mining or open cut mining in different scenarios. Explore the life cycle of a mine. www.minerals.org.au/resources/gold/-life_cycle_of_a_mine
The extraction and use of mineral and energy resources influences interactions between the abiotic and biotic components of ecosystems, including hydrologic systems. • Describe potential environmental impacts that can be associated with the extraction, use, and processing of mineral and energy resources.	Compare the environmental impacts associated with the extraction and use of coal and uranium for electricity generation. Investigate sources of methane (including natural sources such as bacterial action and methane hydrates, and anthropogenic sources such as livestock and fugitive emissions from coal seam gas extraction), its use as a fuel, and its action as a greenhouse gas. Investigate how the processing of sulfide

Science Understanding	Possible Strategies, Contexts, and Activities
	minerals can lead to the formation of acid rain or acid mine drainage, and the environmental impact of this. Use case histories and news reports to evaluate environmental impacts of mining. Examples include uranium and bauxite mining at Pocos de Caldas in Brazil, and at Brukunga in South Austraia.

Topic 3: Earth’s Sustainable Future

Increases in human life span and greater use of scientific and technological knowledge have increased the global demand for energy, water, and soil resources. The provision of quality fresh water and groundwater at local and global levels will continue to be of high importance into the future. Effective use of resources is constrained by factors such as waste disposal, and the efficiency of energy technologies. The desire to use more renewable sources to increase supply has generated discussion about the advantages and disadvantages of renewable and non-renewable resources, and changes in practice that might lead to a more sustainable future.

Students discuss various types of renewable energy resources, and factors affecting the sustainability of soil, water, and energy resources. They investigate a range of aspects of soil, water, and energy use, and develop and extend their skills in analysis and evaluation.

Science Understanding	Possible Strategies, Contexts, and Activities
Renewable resources include some that are available regularly and others that are replenished at time scales from years to millennia. • Discuss the need for, and limitations of, renewable sources of energy, including biofuels, solar, wind, and geothermal energy. • Determine whether a renewable resource is either diminished or sustained over time given the abundance of the resource, and how readily it can be replenished. • Investigate how the timescale required to replenish a large groundwater system, such as the Great Artesian Basin, is influenced by the rate of depletion of the system. • Discuss the sustainability of soil and water at local, regional, and global scales.	Research the development of wind farms in a chosen location (region, state, or territory) and/or arrange a local visit to report on current and proposed electricity generation, costs of construction and ongoing maintenance needs. www.earthsciencewa.com.au/mod/resource/-view.php?id=1104 Explore geothermal energy and the amount of energy it produces. www.earthsciencewa.com.au/mod/resource/-view.php?id=1103 Investigate the drains/bores in use in areas that recycle stormwater run-off. www.salisbury.sa.gov.au/Live/Environment_and_Sustainability-/Wetlands_and_Water/Wetlands www.charlessturt.sa.gov.au/wpw http://bhkcstormwater.com.au/ Collect, sieve, and microscopically view soil samples to compare and report on two or more soil types in a local district. Sketch or photograph examples of dry-land salinity or erosion to illustrate a negative impact of human activity on sustainability of resources. Investigate how stormwater run-off affects the sand budget from the coast.
The availability and quality of fresh water can be influenced by human activities, and natural processes at local and regional scales. • Discuss how stormwater run-off in urban areas may be recycled for community use so that it is not wasted and does not pollute waterways. • Explain how overextraction of groundwater from near coastal aquifers may cause inflow of sea water. • Explain how pollution of groundwater can result from a variety of rural, urban, and industrial activities.	Discuss how urbanisation, overextraction, pollution, siltation, drought, and algal blooms affect the availability and quality of fresh water. www.researchgate.net/publication/-225600623_Eutrophication_in_Australian_Rivers_-Reservoirs_and_Estuaries_-_A_Southern_Hemisphere_Perspective_on_-the_Science_and_Its_Implications www.mdba.gov.au/managing-water/water-quality/blue-green-algae www.water.nsw.gov.au/_data/assets/pdf/file/0008/548621/algal_murray_stage_1_final_report.pdf Visit, or investigate online, a water desalination plant, to research and report on aspects of production, including the energy used and cost. Undertake research to design a comparative table of soil types found across a local district or region,

Science Understanding	Possible Strategies, Contexts, and Activities
	to compare soil fertilities, mineral source rock types, and past and current land use. Investigate and report on the sources and costs of water for domestic use at students' own locality, and how these may have changed over time. Obtain data to calculate and report on the volume of rainwater that falls annually on a typical house roof in a local district. Evaluate the benefits and limitations of using desalination of sea water to provide a viable water resource.
The effective use of energy resources is constrained by factors including waste disposal, and the efficiency of available technologies to collect, store, and transfer the energy. • Compare the advantages and disadvantages of using renewable and non-renewable energy resources.	Use different carbon calculators to estimate individual carbon footprints and investigate why different calculators give different results. Compare the operations at the hydroelectricity plant in the Italian Alps, which is well-managed, with those at the plant São Paulo, which has developed a black foam issue. Investigate the cost and efficiency of solar panels over the past decade.

Topic 4: Climate Change

Climate variables have changed over geological time, due to natural processes occurring in the Earth's atmosphere, outside the atmosphere and within the Earth. Significant variation in the Earth's climate has the potential to produce a major effect on Earth systems.

Students investigate geological, prehistorical, historical, and contemporary records that provide evidence of past changes in climate. They also explore the impact that human activities have had on recent changes in the Earth's climate and how changes in oceanic circulation can affect weather systems. Students consider different interpretations of the scientific evidence for climate change models, and the reliability of these models in predicting future climate change. They develop and extend their skills in communicating scientific information by analysing and presenting evidence, and drawing and justifying conclusions.

Science Understanding	**Possible Strategies, Contexts, and Activities**
Natural processes in the Earth's atmosphere affect climate change over geological time. • Discuss the evolution of the Earth's atmosphere. • Explain how the composition of the Earth's atmosphere changes over time. • Discuss the greenhouse effect. • Explain how the lifespans of greenhouse gases and their ability to absorb infrared radiation contribute to their warming potentials. • Discuss how solar energy is absorbed, re-emitted, and reflected by atmospheric gases and the Earth's surface, including the albedo effect.	Watch the SciShow YouTube video – *A History of the Earth's Climate* (includes natural and anthropogenic factors). https://youtu.be/dC_2WXyORGA Watch and discuss *Australia: A Time Traveller's Guide* about the evolution of the Australian continent. www.abc.net.au/tv/timetravellers/#/-Great_Bombardment Investigate how the composition of the atmosphere has changed over time, including greenhouse gases, water vapour, carbon dioxide, ozone, methane, and nitrous oxide, using: - the Earthlearningidea website*: Earth's Atmosphere – A step by step Evolution* www.earthlearningidea.com/PDF/-103_Evolution_atmosphere.pdf - *Phet: The Greenhouse effect* https://phet.colorado.edu/en/simulation-/greenhouse - *Earth System Science Education Alliance: Water Vapour: Feedback or Forcing*? http://esseacourses.strategies.org/-module.php?module_id=172 Explore the Earth's energy budget with EarthLabs. http://serc.carleton.edu/eslabs/weather/2b.html Investigate the Earth's energy budget through the EarthLabs activity http://d32ogoqmya1dw8.cloudfront.net-/files/eslabs/weather/energy_balance_instructions.pdf
Natural processes outside of the Earth's atmosphere affect climate change over geological time. • Explain how astronomical cycles affect natural climate variability. • Explain how variations in solar energy due to sunspot activity can contribute to natural climate change.	Investigate how the Milankovitch cycles and solar cycles affect natural climate variability.
Natural processes within the Earth affect	Investigate how plate tectonics has influenced climate change over geological

Science Understanding	Possible Strategies, Contexts, and Activities
climate change over geological time. • Explain how the plate tectonic supercycle has contributed to global climatic changes throughout the Earth's history.	time.
Oceans absorb large amounts of solar radiation. • Explain the effect of water's large specific heat capacity on changes in ocean temperature.	Investigate the specific heat capacity of various substances including water.
Changes in oceanic circulation may impact on weather systems • Explain the difference between surface and deep water ocean currents. • Explain the relationship between the world's wind belts and the world's surface ocean currents. • Explain the relationship between the thermohaline circulation and deep water ocean currents.	Examine how continental distribution influences ocean currents. Discuss the impact of mountain building on elevation and hence climatic conditions. Watch and discuss *Australia: A Time Traveller's Guide* about the evolution of the Australian continent. www.abc.net.au/tv/timetravellers/#/-Great_Bombardment Investigate ocean currents and how they influence climate. http://oceanservice.noaa.gov/education-/tutorial_currents/welcome.html
Anthropogenic activities affect climate conditions. • Explain the enhanced Greenhouse effect. • Describe anthropogenic activities that are changing the levels of greenhouse gases • Compare how local, national, and global policies can affect the levels of these gases. • Explain how carbon is stored in Earth's systems over a variety of time scales.	Explore the Global Warming Potential (GWP) of carbon dioxide, methane, nitrous oxide, and hydrofluorocarbons. Explore how land clearing and fossil fuel consumption can increase levels of greenhouse gases. Investigate state, territory, and/or national government policies related to climate change. http://dfat.gov.au/international-relations/themes/climate-change/pages/climate-change.aspx Explore how the global policies about chlorofluorocarbon (CFC) use brought a change to the levels of these gases in the atmosphere through the No Zone of Ozone activity. Examine the storage of carbon in the carbonate-silicate geochemical cycle. Examine evidence of past glaciations, interglacial periods, and atmospheric parameters to find a period in Earth's history that can be used as an analogue for a future with an enhanced Greenhouse effect. Watch and discuss a TED talk, such as *Climate Change is Happening. Here's How We Adapt* www.ted.com/talks/alice_bows_larkin_-we_re_too_late_to_prevent_climate_change_-here_s_how_we_adapt/transcript?language=en
Climate change affects Earth systems. • Discuss the effects of climate change on	Investigate clathrate deposits on the ocean floor.

Science Understanding	Possible Strategies, Contexts, and Activities
Earth systems.	https://en.wikipedia.org/wiki/Methane_clathrate Discuss whether the melting of sea-ice will raise sea levels in the same way as the melting of continental ice sheets. Explore the impacts of climate change on: - the biosphere, e.g. species distribution and crop productivity - atmosphere, e.g. rainfall patterns and surface air temperatures - hydrosphere, e.g. sea levels, ocean acidification, extent of ice sheets Explain how climate analogues can be used to explore the impact of climate change. Explore the interactions between the spheres that occur during the melting of permafrost. Discuss effects of climate change on natural carbon sequestration in the carbon cycle. Explore how geo-sequestration could reduce atmospheric levels of carbon dioxide. http://australianmuseum.net.au/blogpost/lifelong-learning-geosequestration-sweeping-co2-under-the-rug www.co2crc.com/au/dls/factsheets/CO2CRC_FactSheet-_01.pdf
Geological, prehistorical, historical, and contemporary records provide evidence that climate change has affected different regions and species differently over time. • Investigate how contemporary levels of CO_2 and temperature are monitored, and provide evidence of contemporary climate change. • Explore how climate proxies are used to provide evidence of climate change.	Explore NOAA Paleo proxy data – What is it? www.ncdc.noaa.gov/paleo/primer_proxy.html www.serc.carleton.edu/microbelife/topics/proxies/-paleoclimate.html Explore the evidence for the 'Medieval' Warm Period. Explore how historical and archaeological records such as cave paintings can be used to determine past climates. Investigate a range of proxy data that can be used to determine past climatic conditions, include isotopic ratios, ice core data, palaeo-botany, and the fossil record with EarthLabs. http://serc.carleton.edu/eslabs/climatedetectives/-index.html Investigate climate change using foraminifera. www.ucmp.berkeley.edu/fosrec/Olson2.html Investigate the evidence for 'the Little Ice Age'- understanding climate and climate change using this CLEAN activity. http://cleanet.org/resources/41810.html
Models for predicting climate change are based on past climate data and are continually changing. • Explain how General Circulation Models can be used to predict future climate change.	Evaluate the usefulness of General Circulation Models. www.ipcc-data.org/guidelines/pages/gcm_guide.html Investigate NASA Global Climate modelling. www.giss.nasa.gov/projects/gcm/ Review and comment on discussions of the Intergovernmental Panel on Climate Change (IPCC). Explore how Global Climate Models are used

Science Understanding	Possible Strategies, Contexts, and Activities
	to predict future climate, through watching and discussing '*Modelling our Climate' – Brown University* https:youtube/SuZHngxltKo Explain how the El Niño/ La Niña events in the ocean-atmosphere system of the tropical Pacific Ocean can be predicted using climate models. Bureau of Meteorology: *What is El Nino and what might it mean for Australia*. www.born.gov.au/climate/updates/articles/a008-el-nino-and-australia-shtml

ASSESSMENT SCOPE AND REQUIREMENTS

All Stage 2 subjects have a school assessment component and an external assessment component.

Teachers design a set of school assessments that enable students to demonstrate the knowledge, skills, and understanding they have developed to meet the learning requirements of the subject. These assessments provide students' evidence of learning in the school assessment component.

EVIDENCE OF LEARNING

The following assessment types enable students to demonstrate their learning in Stage 2 Earth and Environmental Science:

School Assessment (70%)
- Assessment Type 1: Investigations Folio (30%)
- Assessment Type 2: Skills and Applications Tasks (40%)

External Assessment (30%)
- Assessment Type 3: Earth Systems Study (30%).

Students provide evidence of their learning through eight assessments, including the external assessment component. Students complete:
- at least two practical investigations, and one investigation with a focus on science as a human endeavour
- at least three skills and applications tasks
- one earth systems study.

At least one investigation or skills and applications task should involve collaborative work.

It is anticipated that from 2018 all school assessments will be submitted electronically.

ASSESSMENT DESIGN CRITERIA

The assessment design criteria are based on the learning requirements and are used by:
- teachers to clarify for the student what he or she needs to learn
- teachers and assessors to design opportunities for the student to provide evidence of his or her learning at the highest possible level of achievement.

The assessment design criteria consist of specific features that:
- students should demonstrate in their learning
- teachers and assessors look for as evidence that students have met the learning requirements.

For this subject, the assessment design criteria are:
- investigation, analysis, and evaluation
- knowledge and application.

The specific features of these criteria are described in the list below.

The set of assessments, as a whole, give students opportunities to demonstrate each of the specific features by the completion of study of the subject.

Investigation, Analysis, and Evaluation

The specific features are as follows:

IAE1 Design of a safe investigation

IAE2 Obtaining, recording, and representation of data, using appropriate conventions and formats

IAE3 Analysis of data and other evidence to formulate and justify conclusions

IAE4 Evaluation of procedures and their effect on data.

Knowledge and Application

The specific features are as follows:

KA1 Demonstration of knowledge and understanding of earth and environmental science concepts

KA2 Application of earth and environmental science concepts in new and familiar contexts

KA3 Demonstration of understanding of the development of earth and environmental science and its social, ethical, and environmental impact

KA4 Communication of knowledge and understanding of earth and environmental science concepts and information, using appropriate terms, conventions, and representations.

SCHOOL ASSESSMENT

Assessment Type 1: Investigations Folio (30%)

Students undertake at least two practical investigations and one investigation with a focus on science as a human endeavour. They inquire into aspects of earth and environmental science through practical discovery and data analysis, and/or by selecting, analysing, and interpreting information.

Practical/Field Investigations

As students design and carry out investigations, they develop and extend their science inquiry skills by formulating questions and hypotheses, selecting and using appropriate equipment, apparatus, and techniques, identifying variables, collecting, representing, analysing, and interpreting data, evaluating procedures and considering their impact on results, drawing conclusions, and communicating their knowledge and understanding of concepts.

Practical/field investigations may be conducted individually or collaboratively, but each student presents an individual report. At least one practical/field investigation must give students the opportunity to design the method. Students should be given the opportunity to investigate a question or hypothesis for which the outcome is uncertain.

A practical/field report should include:

- introduction with a hypothesis, variables, and relevant earth and environmental concepts
- materials/apparatus, method/procedure outlining any trials and steps to be taken*
- identification and management of safety and/or ethical risks*
- results*
- analysis of results, identifying trends, and linking results to concepts
- evaluation of data and procedures, and identifying sources of uncertainty
- conclusion.

The report should be a maximum of 1500 words or the equivalent in multimodal form.

Suggested formats for presentation of a practical/field investigation report include:
- a written report
- a multimodal product.

Science as a Human Endeavour Investigation

Students investigate an aspect of earth and environmental science with an emphasis on science as a human endeavour. This investigation focuses on at least one aspect of science as a human endeavour described on pages 36 and 37, and may draw on a context suggested in the topics being studied or explore a new context.

Students consider, for example:
- how humans seek to improve their understanding and explanation of the natural world
- how working scientifically is a way of obtaining knowledge allows for the analysis of scientific claims, but also allows for change in scientific theory in the light of new evidence, possibly due to technological advances
- the role of social, ethical, and environmental factors in advancing scientific research and debate
- how scientific theories have developed historically and hence speculate on how theory and technology may continue to advance understanding and endeavour
- links between advances in science and their impact and influence on society.

Students access information from different sources, select relevant information, analyse their findings, and develop and explain their own conclusions from the investigation.

Possible starting points for the investigation could include, for example:
- an article from a scientific journal (e.g. Cosmos, New Scientist)
- a blog, an infographic or TED talk based on an aspect of earth and environmental science
- an advertisement or a film clip in which an earth and environmental science concept is misconstrued
- an expert's point of view on an aspect of earth and environmental science
- a new development in the field of earth and environmental science endeavour
- the impact of a technique used in an earth and environmental science context, and its historical development
- concern about an issue that has environmental, social, economic, or political implications
- emerging earth and environmental science-related careers and pathways
- changes in government funding for earth and environmental science-related purposes, e.g. for scientific research into aerial and satellite imagery to model resource distribution, suitable extraction methods, social impacts of resource extraction, environmental impacts on landscapes and aquifers, maximum sustainable yield in fisheries, economic value of ecosystem services, identification of reliable earthquake precursor phenomena, reduction of greenhouse gas emission.

Based on their investigation, students prepare a scientific communication, which must include the use of scientific terminology and:
- an introduction to identify the focus of the investigation and how it links to science as a human endeavour
- relevant earth and environmental science concepts or background
- an explanation of the impact or significance of the focus of the investigation, e.g. potential of new development, effect on quality of life, environmental implications, economic impact, intrinsic interest
- a conclusion with justification
- citations and referencing.

The communication should be a maximum of 1500 words if written or a maximum of 10 minutes for an oral presentation, or the equivalent in multimodal form.

This communication could take the form of, for example:

- an article for a scientific journal
- a letter to the editor
- a report.

For this assessment type, students provide evidence of their learning in relation to the following assessment design criteria:

- investigation, analysis, and evaluation
- knowledge and application.

Assessment Type 2: Skills and Applications Tasks (40%)

Skills and applications tasks require students to use their knowledge and understanding of relevant earth and environmental ideas, facts, and relationships in a range of tasks that may be:

- routine, analytical, and/or interpretative
- posed in new and familiar contexts
- individual or collaborative assessments, depending on the design of the assessment.

Students undertake at least three skills and applications tasks. Students may undertake more than three skills and applications tasks within the maximum number of tasks allowed in the school assessment component, but at least two should be under the direct supervision of the teacher. The supervised setting should be appropriate to the task. Each task should be a maximum of 90 minutes of class time, excluding reading time.

A skills and applications task may require student to, for example: use earth and environmental terms, conventions, and notations; demonstrate understanding; apply knowledge; graph or tabulate data; analyse data; evaluate procedures; formulate conclusions; represent information diagrammatically; design an investigation to test a hypothesis or investigable question.

Skills and applications tasks should be designed to enable students to demonstrate knowledge and understanding of the key earth and environmental concepts and learning covered in the program, and to apply this knowledge to solve problems. Some of these problems could be defined in a practical, social, or environmental context. Tasks should also enable students to demonstrate science inquiry skills. Students use appropriate earth and environmental terms and conventions to explain links between earth and environmental concepts, and demonstrate an understanding of science as a human endeavour

Skills and applications tasks may include:

- modelling or simulation
- a data interpretation exercise
- a multimodal product
- a practical assessment such as a ‘completion practical’ with associated questions
- an oral presentation
- an extended response
- a written assignment
- multiple-choice questions in combination with other question types
- short-answer questions.

For this assessment type, students provide evidence of their learning in relation to the following assessment design criteria:

- investigation, analysis, and evaluation
- knowledge and application.

EXTERNAL ASSESSMENT

Assessment Type 3: Earth Systems Study (30%)

Students undertake one fieldwork investigation into a particular local environmental issue, concern, initiative, or successful undertaking that can be linked to topics studied in Stage 2 Earth and Environmental Science. Students develop a research question, then design, plan, undertake, and report on a field-based extended investigation to answer the question. Students analyse the information gathered in terms of the interactions of two or more Earth systems.

The investigation must include collection and analysis of primary data. It may include secondary data, and may also include:

- gathering background information, such as from maps and satellite imagery, and/or researching the outcomes of previous studies
- hypothesising, controlling variables, predicting, and gathering new data
- discussing science as a human endeavour as it relates to the findings
- making recommendations for further work.

Each student designs an investigation proposal. The proposal must include:

- a statement of an investigable question or hypothesis
- an outline of the proposed research approach and method
- a list of equipment required
- the type of data that will be collected
- a risk assessment that addresses safety, ethical, and legal considerations

Students trial their methods and make modifications to their design accordingly. Teacher feedback is used to modify the proposal before students undertake the approved investigation.

The report must use scientific terminology, and include:

- an introduction to identify the purpose, and relevant background or previous research into the topic
- the procedure followed, including an explanation of the final design
- appropriate presentation of data, e.g. tables, graphs, maps, charts, photographs, or other illustrations
- analysis of the information gathered in terms of the interactions of two or more Earth systems
- a conclusion, which includes predictions or advice based on findings
- evaluation of methods, with recommendations for improvement.

Students work individually in their data collection and field or laboratory analysis, and preparation of reports for external assessment. However, fieldwork excursions may be undertaken in class groups.

The report should be a maximum of 2000 words, if written, or the equivalent in multimodal form.

Original field notes and/or data sheets are submitted as an appendix to the teacher, for verification.

For this assessment type, students provide evidence of their learning in relation to the following assessment design criteria:

- investigation, analysis, and evaluation
- knowledge and application.

PERFORMANCE STANDARDS

The performance standards describe five levels of achievement, A to E.

Each level of achievement describes the knowledge, skills, and understanding that teachers and assessors refer to in deciding how well a student has demonstrated his or her learning on the basis of the evidence provided.

During the teaching and learning program the teacher gives students feedback on their learning, with reference to the performance standards.

At the student's completion of study of each school assessment type, the teacher makes a decision about the quality of the student's leaning by:

- referring to the performance standards
- assigning a grade between A+ and E- for the assessment type.

The student's school assessment and external assessment are combined for a final result, which is reported as a grade between A+ and E-.

Performance Standards for Stage 2 Earth and Environmental Science

	Investigation, Analysis and Evaluation	Knowledge and Application
A	Designs a logical, coherent, and detailed earth and environmental science investigation. Obtains records, and represents data, using appropriate conventions and formats accurately and highly effectively. Systematically analyses data and evidence to formulate logical conclusions with detailed justification. Critically and logically evaluates procedures and their effects on data.	Demonstrates deep and broad knowledge and understanding of a range of earth and environmental science concepts. Applies earth and environmental science concepts highly effectively in new and familiar contexts. Demonstrates a comprehensive understanding of science as a human endeavour. Communicates knowledge and understanding of earth and environmental science coherently, with highly effective use of appropriate terms, conventions, and representations.
B	Designs a well-considered and clear earth and environmental science investigation. Obtains, records, and displays findings of investigations, using appropriate conventions and formats mostly accurately and effectively. Logically analyses data and evidence to formulate suitable conclusions with reasonable justification. Logically evaluates procedures and their effects on data.	Demonstrates some depth and breadth of knowledge and understanding of a range of earth and environmental science concepts. Applies earth and environmental science concepts mostly effectively in new and familiar contexts. Demonstrates some depth of understanding of science as a human endeavour. Communicates knowledge and understanding of earth and environmental science mostly coherently, with effective use of appropriate terms, conventions, and representations.
C	Designs a considered and generally clear earth and environmental science investigation. Obtains, records, and displays findings of investigations, using generally appropriate conventions and formats with some errors, but generally accurately and effectively. Makes some analysis of data and evidence to formulate generally appropriate conclusions with some justification. Evaluates some procedures and some of their effects on data.	Demonstrates knowledge and understanding of a general range of earth and environmental science concepts. Applies earth and environmental science concepts generally effectively in new or familiar contexts. Describes some aspect of science as a human endeavour. Communicates knowledge and understanding of earth and environmental science generally effectively, using some appropriate terms, conventions, and representations.
D	Prepares the outline of a earth and environmental science investigation. Obtains, records, and displays findings of investigations, using conventions and formats inconsistently, with occasional accuracy and effectiveness. Describes data and formulates a simple conclusion. Attempts to evaluate procedures or suggest an effect on data.	Demonstrates some basic knowledge and partial understanding of earth and environmental science concepts. Applies some earth and environmental science concepts in familiar contexts. Identifies some aspect of science as a human endeavour. Communicates basic earth and environmental science information, using some appropriate terms, conventions, and/or representations.
E	Identifies a simple procedure for a earth and environmental science investigation. Attempts to record and display some descriptive results of an investigation, with limited accuracy or effectiveness. Attempts to describe results and/or attempts to formulate a conclusion. Acknowledges that procedures affect data.	Demonstrates limited recognition and awareness of earth and environmental science concepts. Attempts to apply earth and environmental science concepts in familiar contexts. Shows some recognition of science as a human endeavour. Attempts to communicate information about earth and environmental science.

ASSESSMENT INTEGRITY

The SACE Assuring Assessment Integrity Policy outlines the principles and processes that teachers and assessors follow to assure the integrity of student assessments. This policy is available on the SACE website (www.sace.sa.edu.au) as part of the SACE Policy Framework.

The SACE Board uses a range of quality assurance processes so that the grades awarded for student achievement, in both the school assessment and the external assessment, are applied consistently and fairly against the performance standards for a subject, and are comparable across all schools.

Information and guidelines on quality assurance in assessment at Stage 2 are available on the SACE website (www.sace.sa.gov.au).

SUPPORT MATERIALS

SUBJECT-SPECIFIC ADVICE

Online support materials are provided for each subject and updated regularly on the SACE website (www.sace.sa.edu.au). Examples of support materials are sample learning and assessment plans, annotated assessment tasks, annotated student responses, and recommended resource materials.

ADVICE ON ETHICAL STUDY AND RESEARCH

Advice for students and teachers on ethical study and research practices is available in the guidelines on the ethical conduct of research in the SACE on the SACE website (www.sace.sa.edu.au).