"This provisional draft version (not yet official or final) senior secondary Australian Curriculum has been provided to the Tasmanian Qualifications Authority for use with teachers for the purposes of mapping against student needs and current Tasmanian courses and for the development of criteria and standards for assessment from the draft achievement standards"
DRAFT SENIOR SECONDARY CURRICULUM – EARTH AND ENVIRONMENTAL SCIENCE

Organisation

1. Overview of senior secondary Australian Curriculum

ACARA has developed senior secondary Australian Curriculum in agreed subjects for English, Mathematics, Science and History according to a set of design specifications (see http://www.acara.edu.au/curriculum/development_of_the_australian_curriculum.html). The ACARA Board approved these specifications following consultation with state and territory curriculum, assessment and certification authorities.

The design specifications for the senior secondary Australian Curriculum provide that the senior secondary Australian Curriculum will specify content and achievement standards for a senior secondary subject. Content refers to the knowledge, understanding and skills to be taught and learned within a given subject. Achievement standards refer to the quality of learning (the depth of understanding, extent of knowledge and sophistication of skill) demonstrated by students within a given subject.

The senior secondary Australian Curriculum for each subject has been organised into four units. The last two units are developmentally more challenging than the first two units. Each unit is designed to be taught in about half a ‘school year’ (approximately 50–60 hours duration including assessment and examinations) of senior secondary studies. However, the senior secondary units have also been designed so that they may be studied singly, in pairs (that is, year-long), or as four units over two years. State and territory curriculum, assessment and certification authorities will determine how they will package and integrate the content and standards into their courses and the permitted entry and exit points and credit for completed study, in line with their certification requirements. A school implements the course for a subject by providing students with programs of learning that meet the requirements for content, scope and sequence set out in the approved course.

States and territories, through relevant curriculum, assessment and certification authorities will continue to be responsible for implementation of the senior secondary curriculum, including assessment, certification and the attendant quality assurance mechanisms. Each of these authorities acts in accordance with its respective legislation and the policy framework of its state government and Board. They will determine the assessment and certification specifications for local courses that incorporate the Australian Curriculum content and achievement standards and any additional information, guidelines and rules to satisfy local requirements.
2. Senior Secondary Science Subjects

The Australian Curriculum Senior Science subjects build on student learning in the Foundation to Year 10 Science curriculum and include:

- Biology
- Chemistry
- Earth and Environmental Science
- Physics.

3. Structure of Earth and Environmental Science

Units

In Earth and Environmental Science, students develop their understanding of the Earth system model, and the ways in which interactions between the Earth spheres and interactions between Earth processes, environments and resources are related within the Earth system. There are four units:

Unit 1: Introduction to Earth systems

Unit 2: Earth Processes - Energy Transfers and Transformations

Unit 3: Living on Earth - Extracting, Using and Managing Earth Resources

Unit 4: The Changing Earth - the Cause and Impact of Earth Hazards.

In Units 1 and 2, students are introduced to the Earth system model and how the ways in which the Earth spheres interact are related by transfers and transformations of energy. In Unit 1, students examine the evidence underpinning theories of the development of the Earth spheres, their interactions and their components. In Unit 2, students investigate how Earth processes involve interactions of the Earth spheres and are inter-related through transfers and transformations of energy within the Earth system.

In Units 3 and 4, students use the Earth system model, and an understanding of Earth processes, to examine Earth resources and environments, and the factors that impact the Earth system at a range of spatial and temporal scales. In Unit 3, students examine renewable and non-renewable resources, the implications of extracting, using and consuming these resources, and associated management approaches. In Unit 4, students consider how Earth processes and human activity can cause Earth hazards, and the ways in which these hazards can be predicted, managed and mitigated to reduce their impact on Earth environments.
Each unit includes:

- **Unit descriptions** – A short description of the purpose and rationale for each unit
- **Learning outcomes** – Six to eight statements describing the expected learning as a result of studying the unit
- **Content descriptions** – Content descriptions describe the core content to be taught and learned and are organised in three strands:
  - **Science Inquiry Skills** content descriptions are written for the entire unit; based on the generic science inquiry skills
  - **Science Understanding** and **Science as a Human Endeavour** content descriptions are written for each sub-section within the unit.

**Organisation of content**

**Science strand descriptions**

The Australian Curriculum: Science has three interrelated strands: **Science Understanding**, **Science as a Human Endeavour** and **Science Inquiry Skills**. These strands are used to organise the Science learning area from Foundation to Year 12. In the practice of science, the three strands are closely integrated; the work of scientists reflects the nature and development of science, is built around scientific inquiry and seeks to respond to and influence society’s needs. Students’ experiences of school science should mirror and connect to this multifaceted view of science.

To achieve this, the three strands of the Australian Curriculum: Science should be taught in an integrated way. The content descriptions of the three strands have been written so that this integration is possible in each unit.

In the Senior Secondary Science subjects, the three strands of **Science Understanding**, **Science as a Human Endeavour** and **Science Inquiry Skills** build on students’ learning in the F:10 Australian Curriculum: Science.

**Science Understanding**

Science understanding is evident when a person selects and integrates appropriate science concepts, models and theories to explain and predict phenomena, and applies those concepts and models to new situations. Conceptual models in science can include diagrams, physical replicas, mathematical representations, word-based analogies (including laws and principles) and computer simulations. All models involve selection of the aspects of the system to be included in the model, and thus have underpinning approximations, assumptions and limitations.

The **Science Understanding** content in each unit develops students’ understanding of the key concepts, models and theories that underpin the subject, and the strengths and limitations of different models and theories for explaining and predicting complex phenomena.
Science as a Human Endeavour

Through science, humans seek to improve their understanding and explanations of, and ability to predict phenomena in, the natural world. Since science involves the construction of explanations based on evidence, science concepts, models and theories can be changed as new evidence becomes available, often through the application of new technologies. Science influences society by posing, and responding to, social and ethical questions, and scientific research is itself influenced by the needs and priorities of society.

This strand highlights the development of science as a unique way of knowing and doing, and the role of science in decision making and problem solving. In particular, this strand develops both students’ understanding of science as a community of practice and appreciation that science knowledge is generated from consensus within a group of scientists and is therefore dynamic and involves critique and uncertainty. It acknowledges that in making decisions about science practices and applications, ethical and social implications must be taken into account.

Science Inquiry Skills

Science inquiry involves identifying and posing questions; planning, conducting and reflecting on investigations; processing, analysing and interpreting evidence; and communicating findings. This strand is concerned with evaluating claims, investigating ideas, solving problems, reasoning, drawing valid conclusions and developing evidence-based arguments.

Science investigations are activities in which ideas, predictions or hypotheses are tested and conclusions are drawn in response to a question or problem. Investigations can involve a range of activities, including experimental testing, field work, locating and using information sources, conducting surveys, and using modelling and simulations. The choice of the approach taken will depend on the context and subject of the investigation.

In science investigations, collection and analysis of data and evidence play a major role. This can involve collecting or extracting information and reorganising data in the form of tables, graphs, flow charts, diagrams, prose, keys, spreadsheets and databases. The analysis of data to identify and select evidence, and communication of findings, involve selection, construction and use of specific representations, including mathematical relationships, symbols and diagrams.

Through the Senior Secondary Science subjects, students will continue to develop generic science inquiry skills, building on the skills acquired in the F-10 Australian Curriculum: Science. These generic skills are described below and will be explicitly taught and assessed in each unit. In addition, each unit provides specific skills to be taught within the broader generic science inquiry skills; these specific skills align with the Science Understanding and Science as a Human Endeavour content of the unit. The generic science inquiry skills are:

- Identify, research and construct questions for investigation, proposing hypotheses and predicting possible outcomes
• Design investigations, including: making decisions about the procedure to be followed, the materials required and the type and amount of primary and/or secondary data to be collected; conducting risk assessments; and considering ethical research.

• Conduct investigations, including using equipment and techniques safely, competently and methodically, for valid and reliable collection of data.

• Represent data in meaningful and useful ways; organise and analyse data to identify trends, patterns and relationships, and recognise uncertainty and limitations in data; and select, synthesise and use evidence to construct and justify conclusions.

• Evaluate processes, claims and conclusions by considering the quality of available evidence; and use reasoning to construct scientific arguments.

• Select, construct and use appropriate representations to communicate conceptual understanding, solve problems and make predictions.

• Communicate information or findings to specific audiences and for specific purposes using appropriate language, nomenclature, text types and modes.

The Senior Secondary Science subjects have been designed to accommodate, if appropriate, an extended scientific investigation with each pair of units. States and territories will determine whether there are any requirements related to an extended scientific investigation as part of their course materials.

**Organisation of achievement standards**

The Earth and Environmental Science achievement standards are organised by two dimensions; ‘Earth and Environmental Science Concepts, Models and Applications’ and ‘Earth and Environmental Science Inquiry Skills’. They describe five levels of student achievement.

‘Earth and Environmental Science Concepts, Models and Applications’ describes the knowledge and understanding students demonstrate with reference to the content of the *Science Understanding* and *Science as a Human Endeavour* strands of the curriculum. ‘Earth and Environmental Science Inquiry Skills’ describes the skills students demonstrate when investigating the content developed through the *Science Understanding* and *Science as a Human Endeavour* strands.

**4. Links to F-10**

**Progression from the F-10 Australian Curriculum: Science**

The Senior Secondary Earth and Environmental Science curriculum continues to develop student understanding and skills from across the three strands of the F-10 Australian Curriculum: Science.

In the *Science Understanding* strand, the Earth and Environmental Science curriculum draws on knowledge and understanding from across the four sub-strands of Biological, Physical, Chemical and Earth and Space Sciences. In particular, the Earth and Environmental Science curriculum continues to develop the key concepts introduced in the Biological Sciences and Earth and Space Sciences sub-strands, that is, that a diverse range of living things have evolved on Earth over hundreds of millions
of years; that living things are interdependent and interact with each other and with their environment; and that the Earth is subject to change within and on its surface, over a range of timescales as a result of natural processes and human use of resources.

**Mathematical skills expected of students studying Earth and Environmental Science**

The Earth and Environmental Science curriculum requires students to use the mathematical skills they have developed through the F-10 Australian Curriculum: Mathematics, in addition to the numeracy skills they have developed through the *Science Inquiry Skills* strand of the Australian Curriculum: Science.

Within the *Science Inquiry Skills* strand, students are required to gather, represent and analyse numerical data to identify the evidence that forms the basis of their scientific conclusions, claims or arguments. In gathering and recording numerical data, students are required to make measurements with an appropriate degree of accuracy and to represent measurements using appropriate units, and, as appropriate, to specify confidence intervals to indicate accuracy.

Students are required to represent numerical data so that trends, patterns and relationships can be identified. This includes representing data in tables and selecting appropriate graphical forms to identify or demonstrate relationships. Students analyse graphical representations of data to identify and describe linear and non-linear relationships between variables.

**5. Representation of General Capabilities**

General capabilities that are specifically covered in Earth and Environmental Science include Literacy, Numeracy, Information and Communication Technology (ICT) Capability, Critical and Creative Thinking and Ethical Behaviour.

**Literacy** is of fundamental importance in students’ development of *Science Inquiry Skills*. Students will be taught to read, understand and gather information presented in a wide range of genres, modes and representations (including text, flow diagrams, symbols, graphs and tables). They are taught how to communicate processes and ideas logically and fluently and to structure evidence-based arguments.

**Numeracy** is key to students’ ability to make and record observations, order, represent and analyse data and interpret trends and relationships. Earth and Environmental Science requires students to engage in statistical analysis of data, including issues relating to reliability and probability, and to manipulate linear mathematical relationships to calculate and predict values.

**Critical and Creative Thinking** is particularly inherent in the science inquiry process, which requires the ability to construct questions and hypotheses; develop investigation methods, interpret and evaluate data; interrogate, select and cross reference evidence; and analyse interpretations, conclusions and claims.
Ethical Behaviour involves students exploring the ethics of their own and other others’ actions. Students are required to evaluate the ethics of experimental science, codes of practice, and the use of scientific information and science applications. They explore what integrity means in science, and explore and apply ethical guidelines in their investigations. They consider the implications of their investigations on others, the environment and living organisms. They use scientific information to evaluate claims and to inform ethical decisions about a range of social, environmental and personal issues and applications of science.

Information and Communication Technology (ICT) Capability is a key part of Earth and Environmental Science Inquiry Skills. Students develop ICT capability when they research science concepts and applications, investigate scientific phenomena, and communicate their scientific understandings. In particular, they employ their ICT capability to access information; collect, analyse and represent data; model and interpret concepts and relationships; and communicate science ideas, processes and information.

There are also opportunities within Earth and Environmental Science to develop the general capabilities of Intercultural Understanding and Personal and Social Capability, with an appropriate choice of activities by the teacher.

6. Representation of Cross-curriculum Priorities

The Sustainability, Aboriginal and Torres Strait Islander histories and cultures and Asia and Australia’s engagement with Asia cross curriculum priorities are specifically addressed in Earth and Environmental Science.

In Earth and Environmental Science, the priority of sustainability provides authentic contexts for exploring, investigating and understanding the function and interactions of Earth systems. Earth and Environmental Science explores a wide range of systems that operate at different time and spatial scales. By investigating the relationships between systems and system components and how systems respond to change, students develop an appreciation for the interconnectedness of Earth’s biosphere, geosphere, hydrosphere and atmosphere. Relationships including cycles and cause and effect are explored, and students develop observation and analysis skills to examine these relationships in the world around them.

In Earth and Environmental Science, students appreciate that science provides the basis for decision making in many areas of society and that these decisions can impact on the Earth system. They understand the importance of using science to predict possible effects of human and other activity and to develop management plans or alternative technologies that minimise these effects.

Earth and Environmental Science values Aboriginal and Torres Strait Islander histories and cultures. It acknowledges that Aboriginal and Torres Strait Islander Peoples have longstanding scientific knowledge traditions. In exploring scientific knowledge and decision making about Earth processes, environments and resources, students will develop an understanding that Aboriginal and Torres Strait Islander Peoples have particular ways of knowing the world and continue to be innovative in providing significant contributions to development in science. They will investigate examples of
Aboriginal and Torres Strait Islander science and the ways traditional knowledge and western scientific knowledge can be complementary.

In addition, there are opportunities for teachers, with an appropriate choice of activities, to include *Asia and Australia’s engagement with Asia*.

### 7. Safety

Science learning experiences may involve the use of potentially hazardous substances and/or hazardous equipment. 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 *Workplace Health and Safety Act 2011*, in addition to relevant state or territory health and safety guidelines.

When state and territory curriculum authorities integrate the Australian Curriculum into local courses they will include more specific advice on safety.

For further information about relevant guidelines, contact your state or territory curriculum authority.

### 8. Animal ethics


When state and territory curriculum authorities integrate the Australian Curriculum into local courses they will include more specific advice on the care and use, or interaction with, animals.

For further information about relevant guidelines, contact your state or territory curriculum authority.
DRAFT SENIOR SECONDARY CURRICULUM – EARTH AND ENVIRONMENTAL SCIENCE

Rationale

Earth and Environmental Science is a multifaceted field of inquiry that focuses on interactions between the solid Earth, its water, its air and its living organisms, and on dynamic, interdependent relationships that have developed between these four components. Earth and environmental scientists consider how these interrelationships produce environmental change at a variety of timescales. To do this, they integrate knowledge, concepts, models and methods drawn from geology, biology, physics and chemistry in the study of Earth’s ancient and modern environments. Earth and environmental scientists strive to understand past and present processes so that reliable and scientifically-defensible predictions can be made about the future.

Earth and Environmental Science extends content presented in the Foundation to Year 10 Australian Curriculum: Science but focuses on the content presented in the Biological and Earth and Space Sciences sub-strands. In particular, it provides students with opportunities to explore the theories and evidence that frame our understanding of Earth’s origins and history; the dynamic and interdependent nature of Earth’s processes, environments and resources; and the ways in which these processes, environments and resources respond to change across 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 an Earth and Environmental Science focus rather than with a particular ecological, biological, physical or chemical focus. This subject emphasises the way Earth materials and processes generate environments including habitats where organisms live; the natural processes and human influences which induce changes in physical environments; and the ways in which organisms respond to those changes.

Students develop their investigative, analytical and communication skills and apply these to their understanding of Earth and environmental science issues in order to engage in public debate, solve problems and make evidence-based decisions about contemporary issues. The knowledge, understanding and skills introduced in this subject will encourage students to become confident, active citizens who can competently use diverse methods of inquiry, and will provide a foundation for further studies or employment in Earth and environmental science-related fields.
Aims

Earth and Environmental Science aims to develop students’:

- interest in Earth and environmental science and their appreciation of how this multidisciplinary knowledge can be used to understand contemporary issues
- understanding of Earth as a dynamic system consisting of four interacting systems: the solid Earth (geosphere); its near surface waters (hydrosphere); its gases (atmosphere); and its living organisms (biosphere)
- appreciation of the complex interactions, involving multiple parallel processes, that continually change Earth, its environments and its climate as well as the ways in which living organisms respond to these changes
- comprehension of the variety of timescales at which changes to Earth and its environments occur, and the ways in which scientists use existing knowledge to make predictions about the future
- evaluation of the relationship between Earth and environmental science and social, ethical, economic and political issues; and their realisation that Earth and environmental science is a changing and expanding body of ideas, facts and interpretations that has developed over time
- ability to conduct a variety of field and laboratory investigations involving collection, analysis and evaluation of qualitative and quantitative data from primary and secondary sources
- ability to critically evaluate Earth and environmental science concepts and interpretations using their own knowledge or observations, and to communicate their conclusions using appropriate language, nomenclature and representations.
Unit 1: Introduction to Earth Systems

Unit description

The Earth system involves four interacting systems: the geosphere, atmosphere, hydrosphere and biosphere. A change in any one ‘sphere’ can impact the others at a range of spatial and temporal scales. In this unit, students build on their existing knowledge of Earth by exploring the development of our understanding of Earth’s formation and its internal and surface structure. Students study the processes that formed the oceans and atmosphere. They review the origin and significance of water at Earth’s surface, how water moves through the hydrological cycle, and the environments influenced by water, in particular the oceans, the cryosphere and groundwater.

Students critically examine the scientific evidence for the origin of life, linking this with their understanding of the evolution of Earth’s hydrosphere and atmosphere. They 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, and they investigate how the distribution and viability of life on Earth is influenced by ecosystem diversity. Students use science inquiry skills that mirror the types of scientific inquiry conducted to establish our contemporary understanding of Earth systems: they engage in a range of investigations that develop the field and research skills used by geoscientists, atmospheric scientists, hydrologists and environmental scientists to interpret geological, historical and real-time scientific information.

Learning outcomes

By the end of this unit, students:

- understand the key features of Earth systems: the geosphere, atmosphere, hydrosphere and biosphere, how they are interrelated, and their shared 4.5 billion year history
- understand models and evidence for the formation and evolution of Earth, its internal structure, the hydrosphere, the atmosphere and the biosphere
- understand how scientists have compiled information from a range of sources to refine models for the evolution of Earth and its four spheres; and how understandings of the global system and geological time have informed decision making on the management and conservation of Earth resources and environments
- identify and classify rocks and minerals and use stratigraphy and radiometric dating data to interpret the age of rocks and fossils
- collect, analyse and communicate secondary data to describe the structure of the geosphere, atmosphere, hydrosphere and biosphere
- use field and research skills to collect data on Earth phenomena and use these as analogies to deduct and analyse events that occurred in the past.
Content descriptions

Science inquiry skills (Earth and Environmental Science Unit 1)

- Identify, research and construct questions for investigation, proposing hypotheses and predicting possible outcomes
- Design field and research investigations including: the procedure to be followed, the information required and the type and amount of primary and/or secondary data to be collected, conducting risk assessments and considering research ethics
- Conduct field and research investigations, including using field mapping and location equipment, rock and soil sampling and identification equipment and spatial analysis techniques, safely, competently and methodically for valid and reliable collection of data
- Represent data in meaningful and useful ways; organise and analyse data to identify trends, patterns and relationships, and recognise uncertainty and limitations in data; and select, synthesise and use evidence to make and justify conclusions
- Evaluate models, processes, claims and conclusions by considering the quality of available evidence and use reasoning to construct scientific arguments
- Select, construct and use appropriate representations, including maps and cross sections to describe and analyse spatial relationships, and stratigraphy and the radioactive decay equation to interpret the age of rocks and fossils, to communicate conceptual understanding, solve problems and make predictions
- Communicate to specific audiences and for specific purposes using appropriate language, text types and modes, including compilations of field data and research reports

Development of the geosphere

Science Understanding

- Application of the Principle of Uniformitarianism involves the use of knowledge and understanding of present day processes to infer past events and processes
- Past Earth events can be placed in sequential order using a relative geological timescale or assigned specific ages on absolute time scale
- Earth formed as a result of planetary accretion approximately 4.5 billion years ago and has changed continually since this time
- As a result of cooling and consolidation Earth has internally differentiated into a layered structure, each with a characteristic mineralogy and chemistry: a solid inner core, a liquid outer core, a mantle, an asthenosphere and a lithosphere
- Plate tectonics is the unifying theory that explains past and current movements of Earth’s crustal rocks and provides a framework for understanding its geological history
• Complex geological processes lead to the formation of sedimentary, igneous and metamorphic rocks over a range of time scales as part of the rock cycle; rocks are composed of assemblages of mineral crystals or grains

• Sequences of sedimentary rocks record the consequences and products of interactions between the atmosphere, hydrosphere, biosphere, and geosphere including weathering events and past surface environments

Science as a Human Endeavour

• Theories and models are revised and refined as new technologies and associated techniques enable collection of new data (e.g. the relative geological timescale was based on geometric principles including superposition and cross-cutting relationships; radiometric dating techniques enabled these events to be assigned specific ages on an absolute time scale)

• Investigations of Earth’s formation, structure and development are commonly carried out by multiple independent teams of scientists who share and critically review ideas through science communication networks and publications

• Understanding geological timescales enables decision making that takes into account both immediate and much longer term implications of environmental change (e.g. changes to landscapes, extraction and use of non-renewable resources)

Development of the atmosphere and hydrosphere

Science Understanding

• The atmosphere was derived from volcanic outgassing during cooling and consolidation of Earth and its composition has been significantly modified by the action of photosynthesising organisms

• The modern atmosphere has a layered structure characterised by changes in temperature: the troposphere, mesosphere, stratosphere and thermosphere

• Water is present on the surface of Earth as a result of volcanic outgassing and impact by icy bodies from space

• Water’s unique properties (e.g. water dissolves many substances, water increases volume on freezing causing solid ice to float on liquid water) and its abundance at the surface of Earth make it an important component of Earth and biological systems and processes

• Water is generally conserved in the global system and changes state through the processes of the hydrologic cycle

Science as a Human Endeavour

• The discovery of new phenomena can be associated with the development of new technologies and associated techniques (e.g. identification and investigation of the layered structure of the atmosphere required developments in remote measurement technologies)
• Recognition of the relatively small amounts of fresh water available for biological processes informs community decision making about investment in infrastructure and technologies to increase access to high quality water (e.g. dams, desalination plants)

Development of the Biosphere

Science Understanding

• Interactions of the hydrosphere, atmosphere and geosphere enabled life to first appear on Earth approximately 4 billion years ago

• Ecosystems involve complex interactions (including flows of matter and energy) between organisms and the atmosphere, geosphere and hydrosphere; the unique nature of these interactions in different environments underpins ecosystem diversity

• The fossil record provides evidence for both the diversification and proliferation of living organisms over time (e.g. increases in marine animals in the Cambrian, terrestrial vertebrates in the Devonian and mammals in the Tertiary), and the catastrophic collapse of ecosystems (e.g. the mass extinction event at the end of the Cretaceous)

• The theory of evolution by natural selection provides an explanation for the changing diversity of life on Earth, including speciation in response to changes in the environment

Science as a Human Endeavour

• Advances in science knowledge and understanding can prompt re-evaluation and interpretation of previously collected evidence (e.g. advances in microbiology have provided new ways to analyse and interpret the evidence for evolution in the fossil record and to model the conditions for the origin of life)

• Development of new models and theories often requires integration of evidence from a wide range of previous studies across multiple fields (e.g. improved understanding of complex events in Earth’s history requires integration of concepts and evidence from fields such as chemistry, ecology and palaeontology)

• Understanding of the interconnection between ecosystems within the biosphere, enables more reliable predictions of the environmental consequences of natural events and human activities at local, regional and global scales (e.g. habitat destruction, changes in nutrient availability, local species loss)
Unit 2: Earth Processes – Energy Transfers and Transformations

Unit description

Earth system processes require energy. In this unit, students explore how the transfer and transformation of energy from the sun and Earth’s interior enable and control processes within and between the geosphere, atmosphere, hydrosphere and biosphere. Students analyse how the transfer of solar energy to Earth is influenced by the structure of the atmosphere; how air masses and ocean water move as a result of solar energy transfer and transformation to cause global weather patterns; and how changes in these atmospheric and oceanic processes can result in anomalous weather patterns. Students examine how transfer and transformation of heat and gravitational energy in Earth’s interior drive plate movements.

Students use their knowledge of the photosynthetic process to understand the transformation of sunlight into other energy forms that are useful for living things. Students’ study how energy transfer and transformation in ecosystems are modelled and they review how biogeochemical cycling of matter in environmental systems involves energy use. Students critically review how an understanding of the drivers of Earth processes informs infrastructure design, policy development and environmental decision making.

Learning outcomes

By the end of this unit, students:

- understand how energy is transferred, transformed and conserved in Earth systems and the factors that influence transfers and transformations of energy
- understand how energy transfers and transformations drive plate tectonic movements and influence Earth’s surface structure, weather patterns and ocean currents
- understand how the major biogeochemical cycles interact with atmospheric, geological and biological systems at different spatial and temporal scales
- understand how scientific knowledge about atmospheric and oceanic processes allows us to predict systematic global and regional weather patterns, identify anomalous weather systems and to make decisions about the use of resources to mitigate weather effects
- collect and analyse secondary data to develop, analyse and apply models for energy transfers and transformations and cycling of matter in the geosphere, hydrosphere, atmosphere and biosphere
- use field and research skills, including systematic observation or monitoring of a natural system, to make inferences about the factors causing changes to movements of energy and matter in Earth systems.
Content descriptions

Science inquiry skills (Earth and Environmental Science Unit 2)

- Identify, research and construct questions for investigation, proposing hypotheses and predicting possible outcomes
- Design field and research investigations including: the procedure to be followed, the information required and the type and amount of primary and/or secondary data to be collected, conducting risk assessments and considering research ethics
- Conduct field and research investigations, including using field mapping and location equipment, environmental sampling techniques and spatial analysis techniques, safely, competently and methodically for valid and reliable collection of data
- Represent data in meaningful and useful ways; organise and analyse data to identify trends, patterns and relationships, and recognise uncertainty and limitations in data; and select, synthesise and use evidence to make and justify conclusions
- Evaluate models, processes, claims and conclusions by considering the quality of available evidence; and using reasoning to construct scientific arguments
- Select, construct and use appropriate representations, including maps and other spatial representations, food webs and biomass pyramids, to communicate conceptual understanding, make predictions and solve problems
- Communicate to specific audiences and for specific purposes using appropriate language, text types and modes, including use of conceptual models and schematic diagrams, and compilations of field data and research reports

Energy for Earth processes

Science Understanding

- Energy is required to do work; energy can be transformed between multiple forms (e.g. kinetic, gravitational, thermal, light)
- Processes within and between Earth systems require energy that originates either from the Sun or the interior of Earth
- Thermal and light energy from the Sun drives important Earth processes including evaporation and photosynthesis
- Transfers and transformations of heat and gravitational energy in the Earth’s interior drive plate movement through processes including mantle convection, plume formation and slab sinking
**Science as a Human Endeavour**

- Multiple models and theories are often required to explain, describe and predict complex phenomena (e.g. models of the origin and maintenance of Earth’s internal heat are important to models and theories of the origin of igneous rocks and volcanoes, the age of Earth and plate tectonics)

- Sophisticated physical and computer based models of the dynamics and mechanics of plate motion and collision enable prediction of future plate tectonic movements and provide evidence for local evidence-based decision making (e.g. investment in infrastructure, location of geothermal resources)

- Decisions to invest in alternative energy technologies that harness Earth’s internal heat (e.g. geothermal electricity generators in volcanically active regions, geothermal power plants that harvest energy from near surface hot, dry rocks in non-volcanic regions) are informed by environmental, economic and political considerations

**Energy for atmospheric and hydrologic processes**

**Science Understanding**

- The net transfer of solar energy to Earth’s surface is influenced by its passage through the atmosphere (e.g. the greenhouse effect) and the physical characteristics of Earth’s surface (e.g. albedo)

- The transfer of solar energy to Earth’s surface, the behaviour of the global oceans as a heat sink, and Earth’s rotation and revolution, cause weather patterns and systematic ocean currents

- The interaction between Earth’s atmosphere and oceans changes through time and can result in anomalous global weather patterns, including El Nino and La Nina

**Science as a Human Endeavour**

- The discovery of new phenomena can be associated with the systematic collection of data over larger spatial or temporal scales (e.g. identification of cyclic changes in the atmosphere and hydrosphere required collection and analysis of air pressure and sea-surface temperature data to reveal patterns that are not evident at small spatial or short temporal scales)

- Energy efficient design of buildings and other structures (e.g. use of materials to maximise or minimise passive solar heating) uses understanding of the transfer of energy to Earth’s surface and the physical characteristics of Earth’s surface (e.g. slope, aspect) to reduce resource use and improve the environmental efficiency of structures

- Communities rely on reliable meteorological forecasting to prepare for extreme weather events and to inform decisions about investment in infrastructure requirements and development
Energy for biogeochemical processes

Science Understanding

• Photosynthesis is the principal mechanism for transformation of energy from the sun into energy forms that are useful for living things; net primary production is a description of the rate at which new biomass is generated, mainly through photosynthesis

• Food webs and biomass pyramids model movement of matter and energy through biotic components of ecosystems

• The availability of energy and matter determines ecosystem carrying capacity: the number of organisms that can be supported in an ecosystem

• Biogeochemical cycling of matter (e.g. carbon, nitrogen, phosphorus) involves transfer and transformation of energy and matter between the biosphere and the geosphere, atmosphere and hydrosphere

Science as a Human Endeavour

• Satellite technologies have enabled the estimation, comparison and monitoring of primary production (i.e. biomass production due to photosynthesis) globally and in a range of different ecosystems

• Understanding of biogeochemical cycles informs prediction of the effects of natural or human induced changes to biogeochemical processes or reservoirs and improves resource management decision-making and policy development

• Monitoring of ecosystems, including indicators of changes in carrying capacity, food web interactions and biogeochemical cycling, leads to more effective management of ecosystems and mitigation of disruptive events or factors
Achievement Standards Unit 1 and 2

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<th>EES Concepts, Models and Applications</th>
<th>EES Inquiry Skills</th>
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<td>For the Earth and environmental science contexts studied, the student:</td>
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<td>- analyses how the components of the Earth system have changed over time, and how these changes have been shaped by interactions between the Earth spheres</td>
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<td>- analyses how matter flows and energy transfers and transformations shape and are shaped by interactions between Earth spheres, processes and environments across a range of temporal and spatial scales</td>
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<td>• explains how energy transfers and transformations occur between and within Earth spheres</td>
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| D | For the Earth and environmental systems studied, the student:  
• identifies components of Earth spheres  
• identifies processes that cause change in Earth spheres  
• describes key aspects of a theory used to describe a system process  
• identifies phenomena that can be explained by Earth processes  
For the Earth and environmental science contexts studied, the student:  
• follows procedures to conduct safe, ethical investigations and collects required data  
• analyses data to identify simple trends and relationships  
• presents simple conclusions based on selected data  
• considers processes and claims from a personal perspective  
• communicates using key representations in a range of modes and genres (including simple scientific reports) |
|---|---|
| E | For the Earth and environmental systems studied, the student:  
• identifies some parts of the Earth system  
• describes observable Earth phenomena and Earth processes  
For the Earth and environmental science contexts studied, the student:  
• identifies that Earth and environmental science ideas have changed over time  
• describes ways in which Earth and environmental science has been used in society  
For the Earth and environmental science contexts studied, the student:  
• follows procedures to make and record observations  
• identifies simple trends in data and presents basic conclusions  
• considers claims from a personal perspective  
• communicates using some scientific terms in a range of modes and genres |
Unit 3: Living on Earth - Extracting, Using and Managing Earth Resources

Unit description

Earth resources are required to sustain life and provide infrastructure for living (for example, food, shelter, medicines, transport, communication), ensuring ongoing demand for plant, animal, mineral and energy resources. In this unit, students explore renewable and non-renewable resources and analyse the effects that resource extraction, use and consumption have on the Earth systems and human communities.

Students contextualise the occurrence of non-renewable mineral and energy resources with respect to tectonic setting and review how Earth and environmental science processes guide resource exploration and extraction. They investigate how the rate of extraction and other environmental factors impact on the availability of renewable resources, including water, energy and biota, and the importance of monitoring and modelling to manage the availability of these resources at local, regional and global scales.

Students explore the opportunities for changing patterns of non-renewable and renewable resource use to ensure ongoing supply and more sustainable resource use in future. Students apply their knowledge, understanding and skills to critically analyse contemporary resource extraction, use and consumption issues in the context of social, ethical, economic and political settings.

Learning outcomes

By the end of this unit, students:

- understand the processes of resource discovery and extraction and the social and environmental impacts of these processes
- understand the difference between renewable and non-renewable Earth resources and how their extraction, use and consumption have different impacts on Earth systems
- understand the impacts of human activities and Earth processes on fresh water and biotic resources and the factors that influence the scale of this impact
- understand the importance of new technologies and comprehensive scientific data in designing and evaluating resource discovery, extraction, use and consumption models, and the role of science in influencing decisions about resource extraction, landscape remediation and resource use
- collect and analyse primary and secondary data sets to infer the spatial and temporal impact of resource extraction activities on the geosphere, hydrosphere, atmosphere or biosphere
• evaluate and communicate the scientific, economic, cultural and political arguments and evidence that underpin arguments for and against strategies for more sustainable renewable and non-renewable resource use
Content descriptions

**Science inquiry skills (Earth and Environmental Science Unit 3)**

- Identify, research and construct questions for investigation, proposing hypotheses and predicting possible outcomes
- Design field and research investigations including: the procedure to be followed, the information required and the type and amount of primary and/or secondary data to be collected, conducting risk assessments and considering research ethics
- Conduct field and research investigations, including using field mapping and location equipment, environmental sampling techniques, water sampling techniques and spatial analysis techniques, safely, competently and methodically for valid and reliable collection of data
- Represent data in meaningful and useful ways, organise and analyse data to identify trends, patterns and relationships, and recognise uncertainty and limitations in data; and select, synthesise and use evidence to make and justify conclusions
- Evaluate models, processes, claims and conclusions by considering the quality of available evidence; and using reasoning to construct scientific arguments
- Select, construct and use appropriate representations, including maps and other spatial representations, to communicate conceptual understanding, make predictions and solve problems
- Communicate to specific audiences and for specific purposes using appropriate language, text types and modes, including compilations of field data and research reports

**Use of non-renewable Earth resources**

**Science Understanding**

- Non-renewable mineral and energy resources are formed over geological time scales so are not readily replenished
- The location of non-renewable mineral and energy resources, including fossil fuels, iron ore and gold, is related to their geological setting (e.g. sedimentary basins, igneous terrains)
- Mineral and energy resources are discovered using a variety of spatial analysis techniques (e.g. based on satellite images, aerial photographs and geophysical datasets) and direct sampling techniques (e.g. drilling, core sampling, soil and rock sampling) to identify the spatial extent of the deposit and quality of the resource
- The type, volume and location of mineral and energy resources influences the methods of extraction (e.g. underground, open pit, onshore and offshore drilling and completion)
- Mineral and energy resource extraction impacts on the biophysical interactions between the abiotic and biotic components of ecosystems, including hydrologic systems
**Science as a Human Endeavour**

- Development of new measurement techniques often requires integration of concepts, technologies and techniques from across multiple fields (e.g. use of magnetic fields or electromagnetic induction and remote sensing technologies have increased the rate of identification of mineral and energy resources and improved estimates of their size and value made prior to extraction)

- Decisions about whether to and how to extract a resource depends on the value, location and volume of the resource and the impacts on and costs to the environment and community, including those of the local custodians, of removing the resource; consultation and negotiation with local communities is required

- When the rate of exploitation of a non-renewable resource (e.g. coal, oil) exceeds the discovery or existence of new reserves then this consumption cannot be sustained (e.g. concept of ‘peak oil’); this can have economic and social implications for communities reliant on the resource

**Use of renewable Earth resources**

**Science Understanding**

- Renewable resources, including water, biota and some energy resources, are those that are typically replenished at time scales of years to decades

- The abundance of the renewable resource and how readily it can be replenished influences the rate at which it can be sustainably used at local, regional and global scales

- The cost-effective use of renewable energy resources is constrained by the efficiency of available technologies to collect, store and transfer the energy

- The availability and quality of fresh water can be influenced by human activities (e.g. urbanisation, over-extraction, pollution) and natural processes (e.g. siltation, drought, algal blooms) at local and regional scales

- Overharvesting can directly reduce populations of biota beneath the threshold of population viability at local, regional and global scales; the concept of maximum sustainable yield aims to enable sustainable harvesting

- Any human activities that impact ecosystems (e.g. species removal, habitat destruction, pest introduction, dryland salinity) can directly or indirectly reduce populations of living things beneath the threshold of population viability at local, regional and global scales

- Harvesting, transport and processing of resources for consumption creates an ‘ecological footprint’ as it typically involves the use of other resources
Science as a Human Endeavour

- Development of complex models requires integration of evidence from a wide range of previous studies across multiple fields, often collected across wide spatial and temporal scales (e.g., models of environmentally sustainable development rely on multiple studies of human impact on the atmosphere, hydrologic systems and ecosystems from across a range of scientific disciplines)

- Models are subject to debate and revision as new data cause scientists to question the underpinning assumptions and limitations of the model (e.g., models of maximum sustainable yield for fisheries and agriculture have changed as new data becomes available)

- Indigenous models of land management have developed from extended interactions with the land and can complement science-based models of resource management

- Harnessing and extracting renewable resources can have an impact on local and regional communities (e.g., wind farm noise; impact of sustainable practice on cultural activities; management of logging practices); decision making requires balancing local, regional and global values and priorities
Unit 4: The Changing Earth - the Cause and Impact of Earth Hazards

Unit description

Earth hazards occur over a range of time scales and have significant impacts on Earth systems across a wide range of spatial scales. Investigation of naturally occurring and human-induced Earth hazards enables prediction of their impacts and the development of management and mitigation strategies. In this unit, students examine the cause and effects of naturally occurring Earth hazards including volcanic eruptions, earthquakes and tsunami. They examine ways in which human activities can contribute to the frequency, magnitude and intensity of Earth hazards such as fire and drought. This unit focuses on the timescales at which the effects of natural and human-induced change are apparent and the ways in which scientific data are used to provide strategic direction for the mitigation of Earth hazards and environmental management decisions.

Students interrogate the scientific evidence for climate change models, including examination of evidence from the geological record and explore the tensions associated with differing interpretations of the same evidence. They consider the reliability of these models for predicting future climate change, and the implications of future climate change events, including changing weather patterns globally and in Australia, (for example, changes in flooding patterns or aridity, and changes to vegetation distribution, river structure and groundwater recharge). Students consider how local, regional and global decision making takes into account the findings from Earth and environmental science and reflects social, ethical, economic, political and environmental concerns.

Learning outcomes

By the end of this unit, students:

• understand how natural Earth hazards occur and the ways in which they impact the geosphere, hydrosphere, atmosphere and biosphere, including human communities
• understand that Earth hazards have a variety of causes, (both human and non-human), and consequences which are apparent over a range of temporal and spatial scales
• understand how environmental change is modelled, and how the reliability of these models influences predictions of future events and changes
• understand the cumulative data collection that underlies development of environmental change models and the processes by which predictive and explanatory models inform environmental management policies and practice, as well as and the other social considerations that inform these policies and practice
• analyse and interpret temporal and spatial trends evident in primary and secondary Earth and environmental science data in order to evaluate environmental change models
• evaluate and communicate the scientific, economic, environmental and political arguments and evidence that underpin arguments for and against environmental change models and mitigation strategies, and identify alternative interpretations
Content descriptions

Science inquiry skills (Earth and Environmental Science Unit 4)

- Identify, research and construct questions for investigation, proposing hypotheses and predicting possible outcomes
- Design field and research investigations including: the procedure to be followed, the information required and the type and amount of primary and/or secondary data to be collected, conducting risk assessments and considering research ethics
- Conduct field and research investigations, including using field mapping and location equipment, environmental sampling techniques, field metering equipment and spatial analysis techniques, safely, competently and methodically for valid and reliable collection of data
- Represent data in meaningful and useful ways; organise and analyse data to identify trends, patterns and relationships, and recognise uncertainty and limitations in data; and select, synthesise and use evidence to make and justify conclusions
- Evaluate models, processes, claims and conclusions, by considering the quality of available evidence; and using reasoning to construct scientific arguments
- Select, construct and use appropriate representations, including maps and other spatial representations, to communicate conceptual understanding, make predictions and solve problems
- Communicate to specific audiences and for specific purposes using appropriate language, text types and modes, including compilations of field data and research reports

Earth hazards

Science Understanding

- Earth hazards result from interactions of Earth systems and can threaten life, health, property, or environment; their occurrence may not be prevented but their effect can be mitigated
- Plate tectonic processes generate earthquakes, volcanic eruptions and tsunami; and the occurrence of these events impacts on other Earth processes and interactions (e.g. ash clouds influencing global weather)
- Monitoring and analysis of data, including earthquake location and frequency data and ground motion monitoring, enables prediction of the location and probability of repeat occurrences of hazardous Earth events, including volcanic eruptions, earthquakes and tsunami
• Major weather systems generate cyclones, flood events and drought; and the occurrence of these events impacts other Earth processes and interactions (e.g. habitat destruction, ecosystem regeneration)

• Human activities, including land clearing, can contribute to the frequency, magnitude and intensity of some natural hazards (e.g. drought, flooding, bushfire, landslides) at local and regional scales

• The impact of Earth hazards on life, health, property, or environment depends on the location, magnitude and intensity of the hazard, and the configuration of Earth materials influencing the hazard (e.g. biomass, substrate)

Science as a Human Endeavour

• Indigenous people may have a longer term oral histories of environmental phenomena that enables clearer understanding of the nature of natural hazards in particular locations

• Advances in knowledge and understanding of seismic processes have led to improved design of ground-shake resistant structures and identification of areas likely to be affected by earthquakes

• Disaster management plans are developed based on scientific understanding but are customised according to the social and economic needs and values of the community

• Some ecosystems rely on episodic earth hazard events to rejuvenate and maintain their long-term viability (e.g. flood plain fertility, bushfire and seed germination); management of these events needs to balance short term, local priorities with longer term, regional priorities

Global climate change

Science Understanding

• Natural processes (e.g. oceanic circulation, orbitally-induced solar radiation fluctuations, the plate tectonic supercycle) and human activities contribute to global climate changes that are evident at a variety of time-scales

• Human activities, particularly land-clearing and fossil fuel consumption, produce gases and particulate materials that change the composition of the atmosphere and climatic conditions (e.g. the enhanced greenhouse effect)

• Climate change impacts the biosphere, atmosphere, geosphere and hydrosphere; climate change has been linked to changes in sea level, rainfall patterns, surface temperature and ice sheet extent

• The geological, prehistorical and historical records provide evidence (e.g. fossils, pollen grains, ice core data, isotopic ratios, indigenous art sites) that climate change has impacted different regions and species differently over time
• Climate change models are developed through analysis of past and current climate data and enable prediction of the likelihood of future climate

**Science as a Human Endeavour**

• Models are subject to debate and revision based on the availability of supporting evidence and review of the underpinning assumptions and limitations (e.g. as more data for long term climatic trends becomes available, this can prompt revision of climate change models)

• Although forecasting the consequences of environmental change is crucial to society, it involves so many complex phenomena that predictions have inherent uncertainties; this has implications for the willingness of individuals, communities and governments to commit significant resources to mitigation strategies

• Social responses to acid rain and ozone depletion provide examples of the capacity for social change in order to manage a global environmental issue, and reflect the importance of communication of science understandings to individuals, communities and governments
### Achievement Standards Level 3 and 4

<table>
<thead>
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For the Earth and environmental science contexts studied, the student:

- evaluates the origins and significance of key findings and the role of technologies, debate and review in the development of Earth and environmental science concepts, theories and models
- evaluates how Earth and environmental science has been used in concert with other sciences to meet diverse needs and inform decision making; and the social, economic and ethical implications of these applications

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- communicates clearly and accurately in a wide range of modes, styles and genres (including scientific reports) for specific audiences and purposes
### B

For the Earth and environmental systems studied, the student:

- explains how human activities and Earth processes affect interactions between Earth spheres, environments and resources
- explains how interactions between Earth spheres, processes, resources and environments change, and how these changes are monitored and managed
- explains the theories and models used to describe Earth and environmental systems and processes; the phenomena they can be applied to, and their limitations
- applies theories and models of systems and processes to make plausible predictions, explain phenomena and solve problems

For the Earth and environmental science contexts studied, the student:

- designs and conducts safe, ethical investigations to collect valid, reliable data in response to a specific question, hypothesis or problem
- analyses data sets to identify causal and correlational relationships between variables
- represents data accurately, selects data as evidence and provides evidence for conclusions
- evaluates processes and claims; provides a critique with reference to evidence and identifies possible improvements or alternatives
- selects, constructs and uses appropriate representations to communicate ideas, solve problems and make predictions
- communicates clearly and accurately in a range of modes, styles and genres (including scientific reports) for specific audiences and purposes

### C

For the Earth and environmental systems studied, the student:

- explains how human activities affect interactions between Earth processes, environments and resources
- explains how resources and environments are changed as a result of Earth processes and human activities
- describes the theories and models used to describe Earth and environmental processes
- applies a theory or model of a system or process to explain phenomena

For the Earth and environmental science contexts studied, the student:

- designs and conducts safe, ethical investigations which enable collection of valid data in response to a specific question, hypothesis or problem
- analyses data to identify relationships between variables
- selects and represents data to demonstrate relationships and constructs conclusions based on data
- assesses processes and claims and suggests improvements or alternatives
- selects and uses appropriate representations to communicate ideas, solve problems and make predictions
- communicates accurately in a range of modes, styles and genres (including scientific reports) for specific purposes
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**Glossary**

**Analyse**
Consider in detail for the purpose of finding meaning or relationships, and identifying patterns, similarities and differences.

**Biogeochemical cycles**
Pathways by which chemical substances move through the biosphere, lithosphere, atmosphere, and hydrosphere.

**Biomass**
The mass of living matter (microbial, plant and animal) in a given environmental area.

**Biomass Pyramid**
A representation of the total biomass at each trophic level within a system.

**Biophysical interactions**
Interaction between the biotic and abiotic elements of the atmosphere, hydrosphere, lithosphere and biosphere.

**Carrying capacity**
The largest number of individuals (within populations) that can be supported by the ecosystem.

**Conclusion**
A judgement based on evidence.

**Contemporary science**
New and emerging science research and issues of current relevance and interest.

**Conventions**
Agreed methods of representing concepts, information and behaviours.

**Cryosphere**
The portions of the Earth where water is in solid form and temperatures are cold enough for water to freeze.

**Data**
The plural of datum; the measurement of an attribute, e.g. the volume of gas or the type of rubber. This does not necessarily mean a single measurement: it may be the result of averaging several repeated measurements and these could be quantitative or qualitative.
El Nino

Extensive warming of the central and eastern Pacific occurring roughly every 3 to 8 years, that leads to a major shift in weather patterns across the Pacific, in eastern Australia giving rise to an increased probability of drier conditions. Intervals between successive El Nino events are referred to as La Nina events.

Environment

All of the surroundings, both living (biotic) and non-living (abiotic).

Environmental sampling techniques

Techniques used to survey, measure, quantify, assess and monitor biotic and abiotic components of the environment and their interactions; techniques used depend on the subject and purpose of the study and may include: random quadrats, transects, grid arrays, netting, trapping, aerial surveys and rock, soil, air and water sampling.

Evaluate

Examine and judge the merit or significance of something, including processes, events, descriptions, relationships or data.

Evidence

In science, evidence is data that are considered reliable and valid and which can be used to support a particular idea, conclusion or decision. Evidence gives weight or value to data by considering its credibility, acceptance, bias, status, appropriateness and reasonableness.

Field metering equipment

Tools used in the field to measure and record environmental parameters including light meters, weather stations, electromagnetic induction (EMI) meters, magnetometers and radioactivity sensors.

Field work

Observational research undertaken in the normal environment of the subject of the study.

Food webs

Representation of the complex of interrelated feeding relationships in an ecological community.

Greenhouse effect

Trapping of heat radiated from the Earth’s surface by the gasses of the atmosphere.

Hot dry rock

Impermeable homogeneous crystalline rock at a temperature that can provide useful amounts of energy found at drilling depths below the Earth’s surface.

Hypothesis

A tentative idea, based on observation that can be supported or refuted by experiment.
Investigation
A scientific process of answering a question, exploring an idea or solving a problem that requires activities such as planning a course of action, collecting data, interpreting data, reaching a conclusion and communicating these activities.

Isotopic ratios
Proportions of isotopes of radioactive elements that vary over time, or stable isotopes that vary as a result of biological processes.

Law
Statement of a relationship based on available evidence.

Mapping and location equipment
Tools used in the field to describe the field location and to measure and record data and field observations, including global positioning system (GPS), compasses and electronic devices with geopositioning capacity (e.g. cameras).

Model
A representation that describes, simplifies, clarifies or provides an explanation of the workings, structure or relationships within an object, system or idea.

Multi-modal text
Text that combines two or more communication modes e.g. print text, image and spoken word as in film or computer presentations.

Outgassing (volcanic)
The release of gases including steam, from the deep interior of the Earth to the surface from a magma source (volcanism).

Population
A group of organisms of one species that interbreed and live in the same place at the same time.

Primary source
In science, a primary source is information created by the person or persons directly involved in a study or observing an event.

Principle of Uniformitarianism
The theory that all geologic phenomena may be explained as the result of existing forces having operated similarly from the origin of the Earth to the present time.

Qualitative data
Information that is not numerical in nature.

Quantitative data
Numerical information.
Radiometric dating
Determination of the age of objects or rocks by measuring relative proportions of parent and daughter isotopes in them and calculating the time taken to achieve this ratio using experimentally determined decay rates.

Reliable data
Data that have been judged to have a high level of reliability; reliability is the degree to which an assessment instrument or protocol consistently and repeatedly measures an attribute achieving similar results for the same population.

Report
A written account of an investigation.

Representation
Diagrams, illustrations, models, mathematical equations and graphs used to explain or communicate ideas and conclusions.

Research
To locate, gather, record and analyse information in order to develop understanding and create new knowledge.

Rock and soil sampling and identification equipment
Tools used in the field to enable rock and soil sampling including classification charts, geological hammer, hand lens, soil auger, soil pH kit and other soil testing chemicals (e.g. dilute acid)

Scientific language
Terminology that has specific meaning in a scientific context.

Secondary source
Information that has been compiled from primary sources by a person or persons not directly involved in the original study or event.

Simulation
A representation of a process, event or system which imitates the real situation.

Spatial analysis techniques
The range of techniques used to examine imagery and datasets covering large spatial areas and commonly compiled in geographical information systems (GIS) including maps, satellite imagery, aerial photographs, geophysical data sets and other remotely sensed imagery

Stratigraphy
Study of rock layers and layering of materials such as sediments including ash, meteoritic impact ejecta layers, and soils.
Supercycle (tectonic)
The cycling of the Earth over a period of 400 to 600 million years from a single continent and ocean with an inferred icehouse climate to many continents and oceans with a moderate to warm climate.

Sustainable
Supports the needs of the present without compromising the ability of future generations to support their needs.

System
A group of interacting objects, materials or processes that form an integrated whole.

Technology
The development of products, services, systems and environments, using various types of knowledge, to meet human needs and wants.

Theory
An explanation of a set of observations that is based on one or more proven hypotheses which has been accepted through consensus by a group of scientists.

Trend
General direction in which something is changing.

Uncertainty (in data)
A range of measured values in collected data.

Validity
The extent to which tests measure what was intended; the extent to which data, inferences and actions produced from tests and other processes are accurate.

Water sampling techniques
The range of sampling and measurement techniques used to collect data on the chemical and physical properties of water, (e.g. measurement of solute concentrations, electroconductivity, pH, temperature, salinity, total suspended solids, turbidity, flow rates) and biological components (e.g. biosurveys, bioassays).