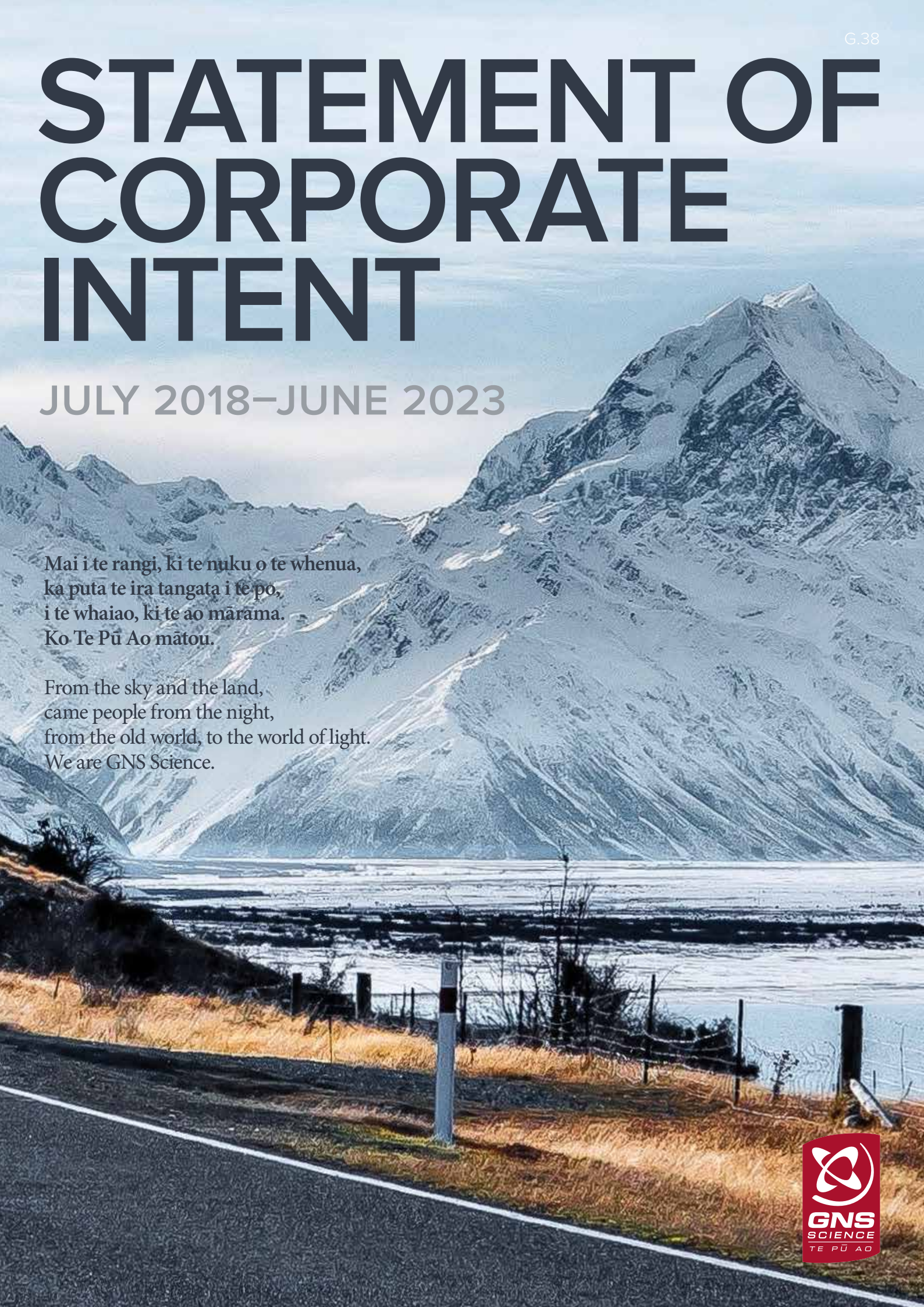
STATEMENT OF CORPORATE INTENT

JULY 2018–JUNE 2023



Mai i te rangi, ki te nuku o te whenua,
ka puta te ira tangata i te pō,
i te whaiao, ki te ao mārama.
Ko Te Pū Ao mātou.

From the sky and the land,
came people from the night,
from the old world, to the world of light.
We are GNS Science.

GNS SCIENCE
TE PŪ AO

UPCOMING MILESTONES

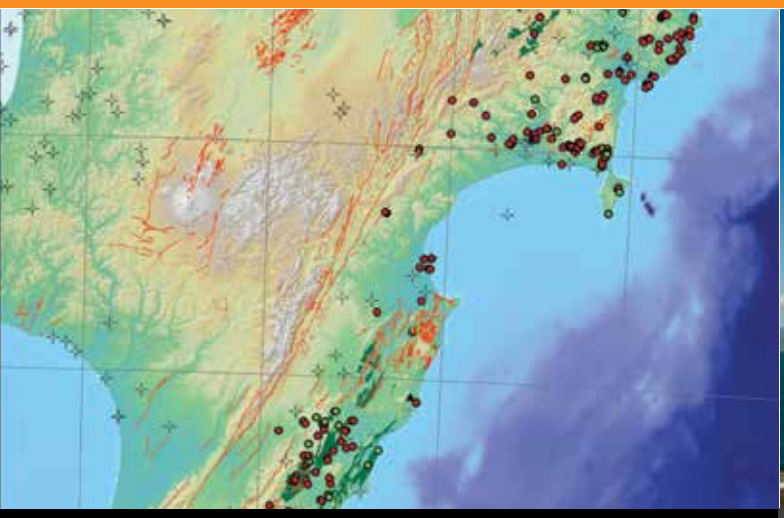
AUCKLAND'S CARBON EMISSIONS

We are leading a project to determine Auckland's first full carbon budget. The project uses atmospheric measurements to determine not only Auckland's fossil fuel carbon emissions but also account for Auckland's 'land carbon sink'—the exchange of carbon with the urban biosphere. We believe that Auckland's land carbon sink could remove a substantial amount of carbon from the atmosphere. Our study will collect the first city-scale evidence as to whether this is occurring, and if so, how much carbon is being removed. Findings will inform Auckland Council's carbon emission mitigation strategy and will be incorporated into New Zealand's Paris Climate Agreement commitments.

GEONET ENHANCEMENTS

The GeoNet system is undergoing major enhancements, including the establishment of a dedicated 24/7 operations centre by December 2018. It will mean increased capability to provide fast and accurate information on earthquakes, volcanic unrest, tsunamis, and landslides. The upgrades will provide new decision support tools and visualisation software that will enable duty officers to make faster and more accurate assessments of geological hazards. Faster detection of threats and more specific advice will ultimately lead to reduced risk to life and property.

JULY 2018–JUNE 2019



SHINING A LIGHT ON SUBDUCTION

Together with international research teams we are collecting a large amount of seismic data to better understand the hazard posed by Hikurangi subduction zone, which lies off the eastern coastline of the North Island. Advances in seismic hazard assessment depend on a better understanding of the physical environment and mechanisms that control the earthquake, slow-slip, and creeping behaviours that occur on this subduction zone. Detailed 3D images of the subduction zone will help define the potential for great subduction earthquakes and tsunamis at the Hikurangi margin.

PROBING ZEALANDIA

New Zealand's largest ever Earth science endeavour is underway with the 23-nation International Ocean Discovery Program (IODP) completing six expeditions to Zealandia, the largely submerged continent of New Zealand, and the Ross Sea. GNS Science is a key player in this initiative, which is acquiring seabed cores to better understand the forces that generate earthquakes and drive plate tectonics, the workings of a seafloor volcano, and probe the mechanisms of submarine landslides. The research is also delivering insights on how a warmer climate impacted the South Pacific and West Antarctica in the geological past.

PROFILING OUR SUPER-VOLCANOES

We are planning to publish a landmark geological map of the entire Taupo Volcanic Zone. The first comprehensive map of its type, it will cover all active volcanoes from Ruapehu to White Island and include Earth's most-productive super-volcano system. The well-illustrated book and accompanying map will detail the volcanic geology and evolution of the zone. It will incorporate advances over the past decade from our 1:250,000 scale geological mapping (QMAP) programme, including the evolution of the Taupo-Okataina super-volcano system.

OUR RISING TIDES

We are working with our partners to provide accurate projections of sea-level rise and its impact on New Zealand. Parts of the Antarctic Ice Sheets are particularly sensitive to the warming oceans and could add over a metre to global sea level by the end of the century and 10-20 metres in the longer term. Our ice core and sedimentary programmes will provide accurate projections of sea-level rise and assess the impact on our shores. These projections will help to improve New Zealand's resilience to sea-level rise, and will inform adaptation and mitigation strategies.

JULY 2019–JUNE 2020

PROTECTING OUR GROUNDWATER

We are leading the development of a range of new computer modelling tools to help with the management of New Zealand aquifers. There are about 200 known aquifers in New Zealand and groundwater currently accounts for about a third of all freshwater usage. The novel, world-leading toolbox includes components for risk assessment and uncertainty analysis to support decision-making. The modelling tools will be much faster and more powerful than those currently in use. When fully available, it is expected the new models will deliver benefits worth about $350 million a year to New Zealand.

SMARTER BUILDINGS

We are developing a new system for measuring the inter-storey movement of buildings during earthquakes. This movement is a key measure in assessing the potential damage to a building, helping engineers decide whether a building can be quickly and safely re-entered. The technology is easily retrofitted and helps to ensure business continuity by reducing the time it takes to re-enter a workplace and restart cashflow. We are working with Kiwinet, a government-supported network of research providers, and private sector companies, to determine its commercial potential.

GNS SCIENCE PROFILE

Institute of Geological and Nuclear Sciences Limited	Trading as GNS Science
Head Office	1 Fairway Drive, Avalon, Lower Hutt 5010
Other Locations	National Isotope Centre, 30 Gracefield Road, Lower Hutt 5010 Dunedin Research Centre, 764 Cumberland Street, Dunedin 9016 Wairakei Research Centre, 114 Karetoto Road, RD4, Taupō 3384
Postal Address	PO Box 30368, Lower Hutt 5040
Web Address	www.gns.cri.nz
Ownership	Crown-owned entity, established under the Crown Research Institutes Act 1992
Board	Chairman, Dr Nicola Crauford Deputy Chair, Ms Sarah Haydon Director, Prof. Steve Weaver Director, Mr Chris Bush Director, Dr John Sharpe Director, Mr Paul White
Chief Executive	Mr Ian Simpson
	General Manager, Strategy, Prof. Tim Naish
	General Manager, Stakeholder Relations, Dr Justine Daw
	General Manager, Science, Dr Peter Benfell
	General Manager, Business Services, Mr Allan Frost
	General Manager, People & Culture, Ms Rose MacFarlane

CONTENTS

DELIVERING ON OUR VISION

This Statement of Corporate Intent (SCI) outlines our priorities and goals for the period July 2018 to June 2023 to deliver on our vision of a cleaner, safer, more prosperous New Zealand, and meet the expectations of our Shareholding Ministers. The Government's expectations are clear: GNS Science's purpose is to undertake research that drives innovation and economic growth in New Zealand's geologically-based energy and minerals industries, develops industrial and environmental applications of nuclear science, increases New Zealand's resilience to natural hazards, and enhances understanding of geological and Earth-system processes.

Aligned with the Government's National Statement of Science Investment (NSSI) and priorities for Research, Science and Innovation, we will invest our resources to deliver excellent science and profound impact that addresses the six Outcome Statements identified in our Statement of Core Purpose (SCP). Our research, across four Core Science Areas (CSAs) and 12 Themes, is supported by a mix of funding from the Crown (Strategic Science Investment Fund - SSIF, and contestable), EQC (support for GeoNet), and domestic and international commercial clients.

Strategic review

In March 2017, a strategic review, involving wide stakeholder consultation, was initiated to create a clearer, shared view of our role and purpose, and improve internal systems and processes, and collaboration.

Five themes emerged:

1. Investing for and with purpose—linking our role, purpose and activities with New Zealand's strategic needs;

2. From 'decision taker' to 'decision maker'—improving our connections with officials and government;

3. Culture change—organisational before individual activity, where our strategic direction drives our funding;

4. Deep partnering—enhancing our ability to partner with other CRIs and organisations; and

5. Awareness—improving stakeholder engagement and upweighting communications.

This SCI is indicative of the planned changes in leadership, operational structure, and science investment. As such, it is transitional in nature, overemphasising some aspects of GNS Science operation, which will be de-emphasised in future SCIs when the new strategy is fully implemented.

A review of our science programmes has led to a shift in emphasis of our SSIF investment towards:

- exploring the continent of Zealandia;
- understanding hazards and risks;
- understanding New Zealand's groundwater resource;
- enhancing support for Vision Mātauranga research; and
- developing a strategy for managing 'big data'.

To allow for this shift in emphasis we are reducing investment in petroleum, minerals, and geothermal research. We are retaining science capability in these fields so that New Zealand's science needs are met while enabling effective SSIF investment for long-term impact.

Major science initiatives

We are working with officials at MBIE and MCDEM to expand New Zealand's capacity for monitoring and assessing geohazard risk. The Government investment of $19.5 million over 4 years for Enhanced Geohazard Monitoring (EGM), will see the establishment of a 24/7 operations centre by December 2018, providing timely information to inform both quick response to events and long-term planning. Priority is being placed on awake monitoring and improved earthquake and tsunami advice.

We are also playing a leading role in a multi-national IODP geoscientific drilling programme taking place in New Zealand waters in 2017-19. IODP membership, via the Australia-New Zealand ANZIC consortium, allows us to use scientific drilling ships to answer important questions relating to geological hazards, climate change, and the hidden continent of Zealandia, bringing more than 150 scientists into the region to undertake collaborative research that will continue for many years.

We are hosts to both the Resilience Challenge and the Natural Hazards Research Platform (NHRP). The second five-year phase of the Resilience Challenge involves integration of key areas of the NHRP, as we look to the future needs of the New Zealand natural hazards science eco-system.

Implementing Te Rautaki Māori

Our Māori strategy (Te Rautaki Māori) will continue to guide our efforts to support Māori-relevant science and innovation and to incorporate Vision Mātauranga into our research. We will endeavour to take all opportunities to unlock the potential of GNS Science-Māori relationships through the use of Māori advisory panels that help inform our science and Māori relationship development.

Public Good Science Delivery

After more than 150 years of service to New Zealand, GNS Science will continue its evolution as a national science provider. In setting our new direction for future research and development, we are taking the opportunity to sharpen our focus, grow our partnerships and capability, improve our internal corporate culture, and enhance our national and international reputation. We remain optimistic that the current downturn in geoscience consultancy activity within New Zealand will reverse, and that our recent success in securing MBIE (Endeavour) and Royal Society of New Zealand (Marsden) research contracts will continue, allowing us to deliver on the research described herein, and the array of impacts and benefits they promise.

Dr Nicola Crauford,
Chairman

Ian Simpson,
Chief Executive

STATEMENT OF CORE PURPOSE

GNS Science's Purpose is to undertake research that:

- drives innovation and economic growth in New Zealand's geologically-based energy and minerals industries;
- develops industrial and environmental applications of nuclear science;
- increases New Zealand's resilience to natural hazards; and
- enhances understanding of geological and earth-system processes.

GNS Science will fulfil its Purpose through the provision of research and transfer of technology and knowledge in partnership with key stakeholders, including industry, Government and Māori, to:

OS1: Increase resource security and economic benefit from the development and diversification of New Zealand's oil, gas, geothermal energy and minerals industries

OS2: Increase New Zealand's resilience to natural hazards and reduce risk from earthquakes, volcanoes, landslides and tsunamis

OS3: Improve the sustainable management of and increase economic returns from groundwater resources

OS4: Create value for New Zealand industry through the use of isotope and ion beam technologies

OS5: Increase understanding of the geology and past climates of New Zealand, the Ross Dependency and Antarctica

OS6: Enhance the geotechnical engineering that underpins New Zealand's transport and energy infrastructure

To achieve these Outcome Statements (OS), GNS Science is the lead Crown Research Institute in:

» geothermal energy, oil, gas, gas hydrates;

» mineral resources;

» geological hazards, risk mitigation and societal impacts of natural hazards;

» earth-system processes and landscape evolution;

» groundwater processes and quality;

» the geological component of global environmental processes and climate change; and

» application of nuclear technology and isotope science and ion beam technology.

GNS Science will work with other research providers and end-users to contribute to the development of:

- high-value manufacturing
- freshwater management
- hazards management
- ocean floor exploration
- climate change adaptation and mitigation
- Antarctica

GNS Science will:

- operate in accordance with a Statement of Corporate Intent and business plan that describes how GNS Science will deliver against this Statement of Core Purpose, and describes what the shareholders will receive for their investment;
- meet its obligations as a Crown Company and remain financially viable, delivering an appropriate rate of return on equity;
- develop strong, long-term partnerships with key stakeholders, including industry, government and Māori, and work with them to set research priorities that are well linked to the needs and potential of its end-users;
- maintain a balance of research that both provides for the near-term requirements of its sectors and demonstrates vision for their longer-term benefit;
- transfer technology and knowledge from domestic and international sources to key New Zealand stakeholders, including industry, government and Māori;
- develop collaborative relationships with other CRIs, universities and other research institutions (within New Zealand and internationally) to form the best teams to deliver its Core Purpose;
- provide advice on matters of its expertise to the Crown;
- represent New Zealand's interests on behalf of the Crown through contribution to science diplomacy, international scientific issues and/or bodies as required;
- seek advice from scientific and user advisory panels to help ensure the quality and relevance of its research;
- establish policies, practices and culture that optimise talent recruitment and retention;
- enable the innovation potential of Māori knowledge, resources and people;
- maintain its databases, collections and infrastructure and manage the scientific and research data it generates in a sustainable manner, providing appropriate access and maximising the reusability of data sets; and
- seek shareholder consent for significant activity beyond its scope of operation.

OPERATING ENVIRONMENT

In setting our investment priorities as laid out in this SCI, we take guidance from the NSSI 2015-25, and other Government drivers (see pages 14 and 15). We will meet the shareholders' expectation that investment in science be relevant to stakeholder needs and contribute to New Zealand's economic, social, cultural, and environmental well-being. Emerging opportunities and challenges for New Zealand's use of its natural capital will increasingly demand the application of research carried out by GNS Science. Important is the increasing role of Māori in the management and economic use of geological resources, and the mitigation of natural hazards.

Evolution of the New Zealand science system, particularly the impact of the National Science Challenges Phase 2 strategies, and expectations around the use of SSIF with respect to the Programmes Investment Contract and pending Impact Evaluation process, are factors in the constrained fiscal environment in which we will operate over the next five years.

Although Treasury has forecasted positive economic growth over the next three years, peaking at 3.6% in 2018-19, we expect the spending of central and local government, and our New Zealand commercial clients, to be constrained. Low oil prices and flat domestic electricity demand persist, and this, together with a tailing-off of Canterbury and Kaikoura earthquakes recovery work, is having a direct impact on our ability to earn New Zealand commercial revenue.

Countering this, we expect some modest revenue growth from the National Science Challenges as well as continued incremental growth in international commercial contracts. These tend to be larger in size and longer term than domestic contracts, but timing is uncertain and there are additional risks involved in operating in foreign jurisdictions, as well as potential risks to our staff. We have a process for mitigating these risks, or declining to participate, as appropriate. This increased focus on the offshore allows us to continue to work with the Government to Government (G2G) initiative to seek new offshore clients, and promotion of New Zealand Crown-funded intellectual property (IP) and expertise.

We have budgeted accordingly, with a forecast of modest revenue growth from $94.4 million in 2018-19 to $95.5 million in 2019-20. Expenditure will remain under tight control throughout this period.

In setting our priorities we consider the research and service needs of the main sectors we serve, and key Government strategies, to deliver maximum impact and, ultimately, outcome benefit for the nation. Maintaining our strong tradition of collaboration and stakeholder engagement will ensure that we will tackle only the highest priority research. The research needs of Government, industry, and community partners are determined by various means, including advice from our Strategic Science and User Advisory Panel, programme-specific advisory groups, and sector-based strategic groups, such as Straterra,

PEPANZ, the Land and Water Forum, and the New Zealand Geothermal Association. We also obtain input to our research plans via regular engagement with government organisations and clients, such as EQC, Contact Energy, and Mercury NZ.

We maintain cutting-edge research through regular participation at international conferences and membership of major international forums, such as the Global Earthquake Model (GEM), International Ocean Discovery Programme (IODP), the International Partnership for Geothermal Technology (IPGT), the International Energy Agency-Geothermal Implementing Agreement (IEA-GIA), and the Intergovernmental Panel on Climate Change (IPCC). These interfaces also help to ensure that we collaborate widely with the national and international research community to form 'best teams' to provide comprehensive and effective science solutions.

On page 30 we outline strategies for building deeper relationships and collaborations with key stakeholders, such as EQC, to secure longer-term funding streams. We are also seeking to develop new sources of revenue such as commercialisation of IP via engagement with Callaghan Innovation-initiated technology incubators.

Our vision of a cleaner, safer, more prosperous New Zealand translates into three applied Core Science Areas (CSAs), underpinned by a fourth. Twelve themes describe the research undertaken across the CSAs, and these relate to 20 Impact Statements (see pages 37 to 65). Collectively, these statements encompass our full research capability, and underline our ability to deliver on our six SCP Outcome Statements (OS).

CSA1: Science for a Cleaner NZ – providing critical information for more-effective management of climate and sea-level change, groundwater, air quality, and land use [relates to OS3 and OS5]

CSA2: Science for a Safer NZ – enhancing the nation's ability to understand, mitigate, and communicate the effects of earthquakes, volcanic eruptions, tsunami, and landslides [OS2 and OS6]

CSA3: Science for a More Prosperous NZ – developing new knowledge and tools to optimise discovery and sustainable use of our geothermal energy, petroleum, and mineral resources, and developing new materials for high-value manufacturing [OS1 and OS4]

CSA4: Underpinning Geoscience Knowledge – generating, managing and communicating geoscience information, data and collections to underpin applied research, policy development, and decision making [OS1 to OS6]

CORE SCIENCE AREAS	THEMES	IMPACTS
SCIENCE FOR A CLEANER NZ	Past, Present & Future Climates	1. Towards a low-carbon economy
	Air, Water & Land	2. Improved water management 3. More-realistic air quality regulations
SCIENCE FOR A SAFER NZ	Hazard Monitoring	4. Effective response to hazard events 5. Timely response to hazard events
	Understanding Hazards	6. Better mitigation planning 7. Enhanced global research presence
	Assessing Risk	8. Enhanced risk analysis and uptake 9. National Seismic Hazard Risk Model
	Societal & Economic Resilience	10. Better-informed policy development 11. Enhanced preparedness, response, and recovery 12. Improved infrastructure design
SCIENCE FOR A MORE PROSPEROUS NZ	Renewable Geothermal Energy	13. Enhanced operational efficiency 14. Greater socio-economic benefit
	Petroleum Resources	15. Improved resource management
	Mineral Resources	16. Enhanced mineral prospectivity
	New Materials & Processes	17. More energy-efficient products
UNDERPINNING GEOSCIENCE KNOWLEDGE	Zealandia Revealed	18. Deeper understanding of crustal evolution 19. Deeper understanding of Earth deformation and plate boundary processes
	Geoscience Information	20. Enhanced database efficacy

Relative Investment  **>$4M**  **$0.5-$4M**  **<$500K**

SCP OUTCOME STATEMENTS

OS1	OS2	OS3	OS4	OS5	OS6
					
					
					
					
					
					
					
					
					
					
					
					
23%	53%	7%	6%	9%	2%

GOVERNMENT PRIORITIES

The NSSI confirms the dual importance of science excellence—peer-reviewed research of international quality—and impact—strong line of sight via end-users to eventual benefits for individuals, businesses or society.

NSSI Goals	Our Actions
A better-performing science system that is larger, more agile and more responsive, investing effectively for long-term impact on our health, economy, environment, and society.	We will focus our activities on our vision of a cleaner, safer, more prosperous New Zealand, and apportion our resources appropriately. We will balance our activities to achieve immediate benefit and longer-term impact: 44% of revenue will be directed towards leverage of proven ideas (time to impact 1-2 years), 43% towards development of emerging ideas (time to impact 3-5 years), and 13% towards generation of new ideas (time to impact 6-15 years). This revenue will be derived from an appropriate mix of core, contestable, and commercial projects (see bar graph, page 32). We will review and, where necessary, redirect our research to ensure responsiveness to New Zealand's changing needs, with stakeholder input obtained through close alignment of our research activities with our commercial contracts. We will support innovation and agility (discovery science) by directing a proportion of our SSIF towards short-term (1-2 year) strategic development initiatives.
Growth in Business Expenditure on R&D to well above 1% of GDP, driving a thriving independent research sector that is a major pillar of the New Zealand science system.	We will transfer our scientific knowledge and expertise to end-users, thereby assisting them to undertake in-house R&D. This will occur through our commercial contracts with businesses, government agencies and foreign companies, joint research programmes with businesses, and on-going partnership with the University of Auckland Product Accelerator and membership of KiwiNet and Return on Science.
Reduced complexity and increased transparency in the public science system.	We will ensure that our research outputs are accessible and comply with the Open Government Information and Data Programme. Our Nationally Significant Databases, together with several other key datasets, are already publicly accessible through web sites or application programming interfaces (APIs).

NSSI Goals	Our Actions
Continuous improvement in New Zealand's international standing as a high-quality R&D destination, resulting in the attraction, development and retention of talented scientists, and direct investment by multinational organisations.	We will contribute to New Zealand's high standing in the global scientific community through participation in high-profile international collaborations such as the Thwaites Glacier project (see page 36), and IODP drilling of our submarine territories (see pages 2, 7 and 62), the latter representing an investment of c. $120 million in New Zealand science, c. $30 for every dollar invested by New Zealand in the researchand impact indicators, such as the 'Nature Index'. We will attract, develop and retain talented scientists by strengthening leadership, direction, and delivery, and initiating a culture change programme redefining who we are, how we behave, and the way we work (see page 30). We will actively work to maintain our reputation for science excellence, as reflected in our consistently top performance in Endeavour and Marsden fund bidding and delivery, and in international science quality and impact indicators, such as the 'Nature Index'
Comprehensive evaluation and monitoring of performance, underpinned by easily available, reliable data on the science system, to measure our progress towards these goals.	We will enhance our own performance evaluation and monitoring by implementing improved systems for integrated administration and reporting, document management, research reporting, and stakeholder engagement (see page 31).

The Government priorities for Research, Science and Innovation Investments, as expressed in the Annual Letter of Owner's expectation (February 2018), cover two broad areas.

Sustaining economic development and supporting the regions

The need to diversify the economy by investing in new industries, creating new businesses, and new ways of doing business requires priority research to assist in the transition to a low-carbon economy by 2050 and to develop innovative, knowledge-intensive technologies that could disrupt existing industries or create new ones, leverage regional strengths (both existing and potential), and create resilience to natural hazards. Our continued research to support renewable geothermal power generation and low-enthalpy geothermal development is aimed at driving New Zealand towards a zero-carbon, renewable energy-based economy (the goal of '100% renewable power generation by 2035').

Our research into natural gas and gas-hydrate resources recognises the need for a low-carbon transition option to reduce dependency on petroleum and coal as we approach that target, and thus assist the Government to meet Paris Agreement pledges.

Our materials science research into magnets and sensors, backed up by investigation into domestic supply of strategic metals to support green-technologies, will provide niche support for New Zealand's emerging high-technology industries. But, for this economic transformation to be possible, geohazard risk assessment and the development of mitigation strategies, supported by rapid hazard forecasting, is vital to protect our assets.

Supporting a rich and protected environment

The Government understands that a healthy economy depends on a healthy environment, so sustainable economic development is an overarching priority. There is thus a dual emphasis on understanding climate change, its drivers, and its possible effects on New Zealand, and improving the quality of New Zealand's freshwater. These priorities are reflected strongly in the two themes within the Science for a Cleaner NZ CSA, in which we focus on developing understanding and effective tools for air, land and freshwater (groundwater) management, and for adapting to climate change impacts.

SECTOR PRIORITIES

GNS Science's dual geoscience and industrial research focus have led us to develop and maintain close relationships with a large number of end-user groups within diverse stakeholder sectors. Engagement has taken place through contracts, secondments, and joint projects, with many of our commercial clients also being the targeted end-users for our SSIF and contestable research programmes. This has ensured that we have a good understanding of their research strategies and needs.

SCIENCE FOR A CLEANER NZ

Fresh water, clean air and sustainable environmental practice are vital to our social, cultural and economic well-being (cf. SCP Output Statement 3; OS3). Those charged with managing the quality of water and air—principally the regional councils, territorial authorities, and Ministry for the Environment, MFE)—require high quality, independent analysis on which to base their decisions. Climate change mitigation and adaptation have also become critically important global and regional environmental issues, requiring sound strategy and policy development (cf. OS5).

Climate Change response

Much of the scientific advice currently offered on climate change is underscored by numerical modelling, which seeks to quantify impacts based exclusively on historical and current instrumental records. Such models fail to account for the evidence contained in ice and sediment archives extending back into geological time. These offer the only avenue to observe and examine Earth's longer-term environmental and biological variability. They also allow us to determine the rate and magnitude of the change that can occur beyond the relatively stable historical period monitored by instruments. Data gleaned from geological archives has, uniquely, shown that mean sea level can vary by more than a few metres and mean surface temperature by as much as 6°C, in response to changes in atmospheric CO_2 concentration. Our internationally acclaimed paleoclimate research is, therefore, critical to refining and validating predictive climate-change models, providing essential observation-based data to identify the types and scale of change to which we will need to adapt in the future (see page 36).

Groundwater Management

There are about 200 mapped aquifers in New Zealand. Groundwater supplies 35% of the nation's water needs, supporting agriculture, city, and domestic supply and other uses, especially in dry periods. Regional authorities have a statutory responsibility to manage aquifers sustainably, and rely on the data and models provided though our active monitoring networks and aquifer case studies. At the national scale, 110 groundwater sites are monitored quarterly as part of the National Groundwater Monitoring Programme (NGMP), with each sample analysed for 25 parameters for long-term trends in water quality. The data provide a national baseline perspective on groundwater quality that differentiates between natural and human-induced change, and feeds into models and tools used to improve New Zealand's freshwater management (the free software for interpreting trends in groundwater quality is used in over 70 countries following its release in 2007. MFE compiles a national report on groundwater quality and quantity, which relies on NGMP data. Regional councils seek advice and reviews on the operation of their regional groundwater monitoring networks, and changes in water chemistry related to land use. This allows them to work out the most effective management strategies to ensure sustainability. There is an identified need for information on the source, flow paths and transit times of water and key contaminants through groundwater systems, and identification of recharge areas, flow paths, mixing of ground and surface waters, seawater intrusion, and aquifer structure. For this, we employ a range of chemical and isotopic tracing and dating techniques, in conjunction with numerical groundwater models. These tools and models also contribute directly to environmental management by, for example, determining the sources of nutrients that contribute to toxic algae growth in rivers, or variations in the geochemistry of soils, with their attendant health or agricultural implications (see also page 38).

Air Quality Assessment

Urban air pollution is thought to be responsible for about 1400 premature deaths in New Zealand and $5.5 billion in health costs and lost productivity, every year. Reducing particulate matter levels in the air will thus deliver major health benefits for local communities as well as the national economy, in terms of reduced respiratory disease. Using ion beam technology (IBT), particles trapped on air filters can be chemically analysed, and the relative contribution of different air-pollution sources determined, including vehicle, domestic heating, and industrial emissions, sea salt, and soil. Councils use the results to develop air-pollution mitigation measures and to track the effectiveness of these measures. IBT is also used to develop new materials and sensors, which are sought by New Zealand's manufacturing firms focused on environmental management (see also page 38).

SCIENCE FOR A SAFER NZ

New Zealand's location on an active plate boundary means nature's forces can change our world dramatically at any time. As our population and cities grow, we become more at risk. Major geological hazard events have had, and continue to have, a significant impact on New Zealand's economy and social well-being. The total cost of the Canterbury earthquakes will likely exceed $40 billion (Treasury estimate in 2018 dollars). After the Boxing Day and Japanese tsunami, the Ministry of Civil Defence & Emergency Management (MCDEM) now rates tsunami alongside earthquakes in the 'potentially most dangerous' category. Volcanic eruptions are equally damaging, and the threat under our largest urban area, Auckland, is significant. The frequent eruptions from Tongariro are individually costly, causing disruption to air transport, agriculture and forestry over a wide area of central North Island. The threat of landslides is ever present across New Zealand, with damage to roading, such as that which recently occurred along the Manawatu Gorge and Kaikoura-Blenheim highways, being time-consuming and very costly to repair. The more we learn about such events, the better prepared we are to deal with them (cf. OS2).

Hazard Resilience

New Zealand is one of many countries that in 2016 signed up to a global agreement on disaster risk reduction that will guide actions to reduce risk from natural disasters through to 2030. The Sendai Framework is a non-binding agreement with seven clear targets and four priorities for action to prevent new, and reduce existing, disaster risks. Science is embedded throughout the Framework and there is strong recognition of the need for enhanced understanding of disaster risk and risk-informed decision making especially at government level. The Framework aims to achieve a substantial reduction of disaster risk and losses in lives, livelihoods, and health and in the economic, physical, social, cultural, and environmental assets of persons, businesses, communities, and countries. The key stakeholders charged with delivering on the Sendai Framework—MCDEM, EQC, and regional CDEM and lifelines groups—will require research information to inform the development of a national strategy for disaster risk reduction and resilience to support the Government's obligations. The Ministerial Review on Better Responses to Natural Disasters and Other Emergencies, released in January 2018, has also signalled ways in which science should be better integrated into response and recovery planning, There is a need to reduce the economic and social costs of natural hazards, through a robust evidence-base for determining priorities for action across the full range of disaster-risk management options. These will involve land-use planning, engineering standards, emergency response planning, and risk transfer through insurance. Important research input will include improved understanding of the processes that cause earthquakes, tsunami, volcanic eruptions, and landslides, and estimation of the size, frequency and potential impacts of each of these geological hazards.

Hazard Monitoring

High demand from civil defence agencies, the commercial sector and the public for the data it generates amply demonstrates the important role GeoNet plays in this country. Over the past 17 years, GeoNet has become a household name, and an international exemplar of how to monitor geological hazards and provide timely information to the people who need it. New Zealanders can now see where an earthquake occurs, and the magnitude of the shaking in their neighbourhood, within seconds on their mobile devices. Continuing and increased support from its sponsor, EQC, as well as additional funding via SSIF infrastructure for Enhanced Geohazards Monitoring, will ensure that GeoNet continues to improve its delivery and range of services (see also pages 30 and 42).

Understanding Earthquakes

Determining the rupture history of earthquakes on important fault systems such as the Alpine Fault (the South Island's main source of earthquake hazard) and the Hikurangi subduction zone (the North Island's greatest risk), is the key to understanding where and when future earthquakes will occur, and what their impacts are likely to be. Modelling the likelihood of future seismic activity and the effects of ground shaking provides important information for the development of hazard mitigation strategies. Earthquake engineering research feeds into structural design standards, enabling infrastructure to be built to withstand earthquake shaking for a given location, leading to a safer built environment and faster recovery in the event of a natural disaster, (see also page 44).

Tsunami Modelling

Propagation models showing how tsunamis travel across the Pacific Ocean and impact on our coast help authorities to prepare coastal communities. When a large sub-seafloor earthquake occurs in the Pacific the best-matching model is quickly found to obtain a first approximation of what the likely impacts will be in New Zealand. This is communicated to the MCDEM and other agencies, as every minute of advance warning can make a difference in terms of public safety. As fresh information comes to hand on the size, location, depth and style of an earthquake, the model can be refined to give updated information on tsunami arrival times and likely effects. Given our long coastline and growth in coastal communities, increasing the sophistication of such models becomes ever more important.

Understanding Volcanism

New Zealand has twelve volcanoes that are considered active, and they present a range of potential hazards. Taupo is the world's most dangerous volcano in terms of the size of its historical eruptions, so the threat must be taken very seriously. There is permanent surveillance operating at the active volcanoes to detect early signs of volcanic unrest. Research focused on sub-surface processes and plumbing systems, and the impacts of eruptions on infrastructure and people, is necessary for the development of eruption scenarios for emergency management and risk assessment.

Understanding Mass Movement

Unstable geological conditions, heavy rain, earthquakes, and human-induced landscape changes can trigger landslides. Expertise in geomorphology and engineering geology enables strategies for reducing the impacts of slope failures and landslides to be developed. As well, there is a need to identify and quantify landslides and their triggers, design safer slopes, assess risk, monitor unstable slopes, understand landslide movement mechanisms, and consider social impacts.

Hazard Loss Modelling

Loss modelling helps to quantify the impact of natural disasters on infrastructure and people, providing quantitative estimates of likely damage and loss of assets and casualties, critical for risk management, hazard planning, and insurance assessment. Disaster risk reduction and resilience can only be achieved through understanding how society interacts with natural hazards and disasters. It is important to understand what contributes to effective land-use planning for natural hazards, how agencies and the public understand and respond to threats, and the attributes of an effective recovery (see also page 48).

SCIENCE FOR A MORE PROSPEROUS NZ

New Zealand is relatively well endowed with natural energy and mineral resources, which collectively are important contributors to the wealth and energy security we expect as a first-world nation. The knowledge base and intellectual capacity within the resource sector is critical to support the goal, espoused in the New Zealand Energy Strategy 2011–2021, to grow our economy to deliver greater prosperity, security and opportunities for all New Zealanders (cf. OS1 and OS4).

Geothermal Energy

Renewable geothermal energy is a critical component of New Zealand's electricity generating capacity at 16%; behind hydro, and well ahead of wind. Geothermal energy is reliable, clean and cost-effective and provides a consistent energy flow day and night, in any season and in any weather. Research is essential to maintaining the viability of the industry, and increasing investor/developer confidence by reducing technical risks of exploration. Examples include field and laboratory investigations that shed light on rock permeability and sub-surface fluid flow pathways, making drilling targets more likely to be successful, and finding new ways to modify the internal surfaces of geothermal pipes to prevent the build-up of minerals that reduces operational efficiencies at power plants. Investigation of hotter and deeper geothermal sources, up to 5 km deep, is the key to developing more-sustainable resources for the future. The abundance of high-temperature geothermal resources in the central North Island means geothermal is the lowest-cost electricity generation option to build and operate. With well-targeted research, geothermal energy is on course to help achieve the Government goal of 100% renewable electricity generation by 2035 (see also page 52).

Petroleum Resources

In April 2018 the Government announced that they would issue no more exploration 'block offers' for petroleum in New Zealand's EEZ, confining new permits to onshore Taranaki. Although oil and gas production is seen by many as a sunset industry, there is an acknowledgement that the transition to 100% renewables would take some decades, and that New Zealand's needs for natural gas, in particular, would continue for some time. Existing exploration and mining rights via 31 active permits (9 onshore and 22 offshore) would be honoured, some relating to the 27 producing fields in Taranaki extend through to 2030. Thus, there remains a need for geoscientific research to support the industry, for as long as it is active in New Zealand.

Currently, the New Zealand economy benefits significantly through royalties and income tax from oil and gas production, oil exports. Natural gas is an important peak-load fuel (replacing coal) for electricity generation as we transition to a low-carbon economy. In addition to domestic residential supply, gas is used by Methanex NZ, as a chemical feedstock to produce methanol, an increasingly important, clean transport fuel. Ballance Agri-nutrients also uses gas to manufacture ammonia and then urea for use domestically as farm fertiliser and feedstock. These, and other commodities such as floating Liquified Natural Gas (LNG), are key export avenues for any significant future gas discovery.

Gas Hydrates

Gas hydrates (methane-rich icy deposits beneath the seafloor) off the North Island's east coast, present an unconventional energy resource for the country. New Zealand has some of the most extensive and highly concentrated deposits of hydrates in the world, the nature of which is still being determined. If only a small fraction of the potentially huge resource can be commercially recovered, it would prove a major boost to our economy and energy security (see also page 54).

Mineral Resources

Onshore mineral extraction is an essential industry for New Zealand, providing aggregate for roads and construction, limestone for agriculture, and iron sands, clay, zeolite, gold and silver for internal use and export. Combined, the production value of mining and quarrying is more than $2 billion a year, generating substantial near-term impact to both national and local economies through royalties, taxes and jobs. As well as improving knowledge of the location and quality of 'industrial minerals', there is a need to better understand the geological processes that result in large, high-value precious metal deposits, and to use these in exploration. Digital map products remain important for promoting knowledge and understanding of mineral accumulations and their host regions.

The realisation that New Zealand is the 'above water' component of the world's eighth continent Zealandia provides a fresh context for understanding and researching into ore deposit formation and will play a key role in facilitating new important mineral discoveries. An understanding of deposit-forming processes within our Exclusive Economic Zone (EEZ) and extended continental shelf (ECS), underpins longer-term resource appraisal, and policy development for low-footprint extraction. Seafloor deposits, yet to be commercially extracted, include phosphorite and iron sands, both of which are the subject of current mining license applications. Massive sulphides (metal-rich accumulations associated with sea-floor hydrothermal vents), which occur along the chain of submarine volcanoes extending 1500 km northeast from the Bay of Plenty, are seen as a new frontier in mineral exploration. Since the mid-1990s, these deposits have been systematically explored and mapped, with the research shedding light on the processes of mineral deposit formation. This information is critical for assessing economic potential, and making informed decisions on whether a deposit could, or indeed should, be harvested (see also page 56).

Reflecting New Zealand's drive towards 100% renewable energy, and 'green' technologies, increasing emphasis is being placed on 'critical metals', such as copper, lithium, tin, tungsten, vanadium, and rare earth elements. These are also essential commodities for high-tech manufacturing. New Zealand currently imports over $200 million of such metals annually, a figure that is expected to grow rapidly as we drive towards a low-carbon economy. Dwindling reserves globally, and political instability of the main producers, threatens security of supply, making a broad-based search for domestic sources (including mineralised fluids, landfills, mine dumps, and effluents) imperative.

Isotope Labelling

Niche capability in isotope and ion beam technologies (cf. OS4) has the capacity to create value for New Zealand industries. This includes building competitive export commodities in the primary sector. An example is the use of isotope methods to authenticate the source of high-value food or beverage products such as mānuka honey and orange juice, to check they are 'true to label' and meet export criteria.

New Materials for Industry

Ion beam techniques can also be used to develop new materials with characteristics such as increased hardness and wear resistance, hydrophobicity, or magnetic properties. The New Zealand manufacturing sector makes use of such new materials in, for example, high-value products for harvesting waste heat, improving the energy efficiency of heating and cooling processes, and developing new sensors and sensor systems (see also page 58).

NATIONAL SCIENCE CHALLENGES

Appreciating their important roles in underpinning the Government's socio-environmental and economic agenda, we are a collaborating partner to seven of the eleven National Science Challenges. We host Resilience to Nature's Challenges due to our wide knowledge of natural hazards and their societal risks and impacts.

Our understanding of the soil-groundwater interface and past ecosystems are germane to Our Land & Water and New Zealand's Biological Heritage; and our carbon-cycle research and analysis of past climate, benefits Deep South by enhancing predictive models of future climate.

Resilience Challenge

Resilience to Nature's Challenges, Kia Manaweroa – Ngā Ākino o Te Ao Tūroa (Resilience Challenge), was launched in June 2015, with research programme aimed at improving New Zealand's preparation, response and adaptation to a range of geological and weather hazards. Departing from traditional single-risk models, the Resilience Challenge is focused on building broad-spectrum resilience for our unique rural, urban and Māori communities to multi-hazards, including weather and rural fire exacerbated by climate change. There is a special emphasis on extreme-risk communities at coastal margins and other vulnerable locations. The overarching mission of the Resilience Challenge is to: "Partner with multiple stakeholders to generate new co-created research solutions to inform how New Zealand builds a transformative pathway toward natural hazard resilience".

The Resilience Challenge formal partnership involves six universities – Auckland, Canterbury, Lincoln, Massey, Otago, and Victoria – three CRIs – GNS Science, NIWA, and Scion – and two research associations – BRANZ and Opus. The research is conducted by more than 80 scientists from these and several other organisations, including Manaaki Whenua Landcare Research, University of Waikato, Market Economics, and Resilient Organisations. The science teams encompass a multi-disciplinary mix of physical science, Māori, engineering, social science, economics, and business and enterprise.

The Challenge received $19.6 million in Government funding for its first four years (supported by an additional $0.6 million in co-funding), which it invested in developing new science-backed approaches to resilience, and fast tracking their implementation. This extends beyond defensive and adaptive approaches to making New Zealand a safer place to live

in and a more attractive, lower risk investment opportunity. The research is headlined by four 'Co-creation Laboratory' programmes, where end-users partner with researchers to devise resilience solutions in the Rural, Urban, Māori, and Edge (Coastal) environments. Six 'Resilience Toolbox' programmes are developing resilience-specific technical solutions to be applied across the highest-priority areas within the Co-creation Laboratory programmes

Co-creation Laboratory programmes

- *Resilient Rural Backbone:* Finding innovative solutions to better protect vulnerable rural communities, and enable them to thrive in the face of natural hazard risks.
- *Urban Resilience:* Integrating and implementing tools that enable our towns and cities to adapt and transform with urban change, whilst building resilience to natural hazards.
- *Better Understanding and Implementation of Mātauranga Māori and Tikanga to Build Resilience*: Integrating local, traditional, and iwi knowledge with Te Reo and Māori values into improved natural hazard resilience strategies for all New Zealand communities.
- *Living at the Edge - Transforming the Margins*: Finding support solutions for communities living in highly-vulnerable, dynamic settings such as coastal margins and flood plains.

Resilience Toolbox' programmes

- *Resilient Governance:* Addressing the role played by governance, policies, and institutional and societal relationships that underpin enduring community resilience.
- *Infrastructure and Built-Environment Solutions:* Developing tools to assess the performance of spatially-distributed infrastructure networks subject to extreme natural hazards.
- *Creating an Economically Resilient New Zealand:* Developing economic decision support tools that enable New Zealanders to transition effectively and quickly to a more-resilient nation.
- *Cultural Resilience:* Working to understand the social norms that underpin a resilient culture in New Zealand, harnessing and building on them to improve our national resilience.
- *Resilience to New Zealand's Hazard Spectrum:* Generating a set of fit-for-purpose hazard tools and solutions for nationally consistent delivery of risk information.
- *Resilience Trajectories for a Future Proof New Zealand:* Harnessing data to accelerate progress toward the vision of a resilient New Zealand and to inform policy makers and practitioners where to spend our resilience 'dollar' most effectively.

The Resilience Challenge is an important vehicle for building the next generation of researchers in natural hazard resilience, with over 20 doctoral students included in its first phase of operation.

As host of the Resilience Challenge, GNS Science has responsibility for providing financial management and infrastructure support is provided by the Challenge office to deliver on the Challenge mission against a series of outcome-based key performance indicators. Supported by a full formal collaboration agreement among the eleven formal partners. The challenge's management team is responsible for operations and supporting a governance group of experienced independent members who drive the strategic direction.

Over the next two years the Resilience Challenge scientists will continue to produce research results that communities, organisations, and agencies can use in real time to improve New Zealand's natural hazard resilience. The research will enable more-resilient design of New Zealand's electricity, transport and communications sectors. Agencies responsible for these networks will be better able to collaborate and exchange information on resilience. The Challenge will be able to measure some of the diverse capabilities of a resilient community, helping New Zealand's authorities and land-use planners to implement strategies for adaptation to hazards in New Zealand's cities, coasts and farms.

The Resilience Challenge, and its stakeholders, are now planning the next five-year phase of operation across resilience themes of critical importance to New Zealand.

NATURAL HAZARDS RESEARCH PLATFORM

GNS Science is host of the Natural Hazards Research Platform, a consortium of Government-funded science providers dedicated to increasing New Zealand's resilience to natural hazards. Established in 2009, the Platform brings together integrated hazard and risk expertise from GNS Science, NIWA, University of Canterbury, University of Auckland, Massey University, and Opus. Several other universities, consultancies, and international partners are also involved as subcontractors or through aligned research programmes.

The aim of the Platform is to contribute directly to improved economic, infrastructural and societal resilience to natural hazards in New Zealand, through research that aligns with the strategies of Government agencies responsible for reduction, readiness, response and recovery. The Platform is charged with providing the best scientific advice possible in the national interest. Following the Canterbury earthquake sequence and the Kaikoura earthquake, the Government provided additional funding to support high need, short-term research that informed decision-making during critical periods.

UC UNIVERSITY OF CANTERBURY Te Whare Wananga o Waitaha CHRISTCHURCH NEW ZEALAND

THE UNIVERSITY OF AUCKLAND NEW ZEALAND

NIWA Taihoro Nukurangi

OPUS

MASSEY UNIVERSITY TE KUNENGA KI PŪREHUROA UNIVERSITY OF NEW ZEALAND

GNS SCIENCE TE PŪ AO

The programmes of research are underpinned by aligned SSIF at GNS Science and NIWA, and by six long-term (2015-19) research programmes led by the non-CRI Partners, covering a range of hazard and engineering topics. These projects and the lead organisations are:

- Climate change impacts on weather-related hazards (University of Auckland).
- Tools and knowledge to improve New Zealand's long-term resilience to wind storms (Opus).
- Volcanic risk: from hazards to impacts (Massey University).
- Building quake and people: a serious game platform for informing life-saving strategies (University of Auckland; completed in October 2017).
- Research-informed advancements in guidelines and standards of engineering practice for natural hazards (University of Canterbury).
- Building to recover: quantifying and predicting the role of the built environment in social and economic recovery (Opus).

In addition, the Platform has 11 projects under contract via its contestable process (2017-19), covering a range of hazard, engineering, and economics topics. These projects and the lead organisations are:

- Pre-historic earthquakes on Kaikoura's earthquake faults and implications for seismic hazard (GNS Science).
- Paleo-coastal uplift along the Kaikoura coastline—Detecting multi-fault rupture and implications for the southern Hikurangi margin (GNS Science).
- Stability of buckling-restrained braced frame (BRBF) connections using a simplified notional load yield line method (University of Auckland).
- Adaptive and interactive futures—A 'serious game' for decision-making and coastal hazards (NIWA).
- Improved medium-term earthquake forecasting (GNS Science).
- Too big to fail? —A multi-disciplinary approach to predict collapse and debris flow hazards from Mt Ruapehu (Massey University).
- Towards robust decision-making in natural hazard risk management: Uncertainty quantification for RiskScape-MERIT modelling (Market Economics).
- Indicators of vulnerable populations to natural hazards—A case study of flooding in the Porirua City Council area (Massey University).
- Enhanced probabilistic flood forecasting using optimally designed numerical weather prediction ensembles (NIWA).
- Improving the seismic performance of glazing and windows (University of Canterbury).
- Quicker and safer tsunami evacuations through agent-based modelling (GNS Science).

The Platform is set to merge with the Resilience Challenge; in 2018, a series of workshops with researchers and stakeholders will be held to plan the new research programme, which will be initiated in late 2019.

IMPLEMENTING VISION MĀTAURANGA

GNS Science is committed to developing partnerships with Māori to identify iwi aspirations, and to undertake joint research projects to realise those aspirations.

The GNS Science Māori Strategy, Te Rautaki, was launched in September 2016, and has been successful in forging new relationships with Māori researchers, organisations, individuals, iwi, and businesses. Te Rautaki's vision is to 'Create mutual value by unlocking the potential of GNS Science-Māori relationships', which is as much about unlocking our own potential as it is about deepening our existing relationships with Māori.

We will achieve this vision by:

» mana enhancing relationships and the reciprocal sharing of information (Manākitanga);

» strengthening our internal processes (Tikanga) and policies to improve our service delivery, research, responsiveness to Māori, and legal responsibilities and obligations;

» being more visible to Māori, with Māori knowing who we are and what we do and by promoting research and GNS Science capability within Māori communities;

» strengthening our people (Whakapakari tāngata) and knowledge of Te Ao Māori and

» ensuring that the R & D GNS Science is involved with are available to support Māori development and resilience.

Te Rautaki is forward looking and aligns with Vision Mātauranga, the National Science Challenges, He Kai Kei Aku Ringa, iwi research planning documents, and GNS Science strategy. Our staff work closely with Māori trusts, iwi, and businesses to help address Māori needs and aspirations, test innovation and to develop research that has real impact on Māori aspirations by jointly developing our research projects with Māori.

We are placing an increasing emphasis on Whakapakari tangata (staff development), providing in-house courses in Te Reo, Treaty awareness, Māori pronunciation, marae protocol, and waiata training. This has been extended to the Board of Directors and the Executive, as well as research and support staff who engage regularly with Māori. GNS Science has made a commitment to allocate SSIF specifically to better support Māori engagement, Vision Mātauranga, and relationship management with Māori.

Building on the success of our Te Kura Whenua initiative with Ngāti Kahungunu Iwi Incorporated (2014-17), we plan to organise more marae- and field-based wānanga to help bridge the gap between science and Mātauranga Māori, and to foster dialogue on important geoscience issues such as climate change, hazard resilience and resource management.

Four MBIE-funded Vision Mātauranga Capability Fund projects are demonstrating effective research partnerships with iwi, and possible pathways to enduring scientific engagement.

Te haurehu waikawa pungatara e pa ana te kaimahi Māori – Impact of hydrogen sulphide on the Māori workforce

GNS Science and Whakarewarewa Village Charitable Trust are working together to demonstrate a framework for integrating related scientific data and Mātauranga-a-iwi (traditional knowledge of the tribe and its land base) to better understand hydrogen sulphide behaviour surrounding the Whakarewarewa Village, and the possible impact on human health.

The research team contains experts who share an interest in exploring synergies between these two knowledge systems. Whakarewarewa, The Living Māori Village, provides guides and other staff for tourism businesses, and this project targets improvements in the workforce to realise opportunities in growing the business and ensuring the health of the Māori workforce.

The research has two mutual benefits: 1. to improve Māori understanding of the science of hydrogen sulphide and the possible risk to human health when exposed to high concentrations of it, and 2. corroboration of historical and current events concerning hydrogen sulphide and its possible health effects. Data from the world-first fine and coarse air particulate matter database from the sampling campaign from November 2014 to June 2017 at Whakarewarewa Village will be integrated into the research.

Incorporating environmental and indigenous knowledge for future management of freshwater resources in the Piako Catchment

We are working with Ngāti Hauā Iwi Trust to improve the health and vitality of the Piako River, to ensure the mauri of the waterways is sustained for future generations through a merger of scientific knowledge with Mātauranga Māori (indigenous knowledge), Mātauranga-ā-iwi, and cultural values. By gaining a clearer picture of the current knowledge around freshwater resources in the Piako Catchment, Ngāti Hauā will acquire the knowledge to make informed decisions regarding future management of water resources, both for the health of the environment and for the iwi. Scientific, Mātauranga, and policy information is being collected, and stored on an interactive user portal (website). Additional knowledge and perspectives are being gathered from iwi members through hands-on engagement at their marae. Collectively, the information resource will allow for Ngāti Hauā to store information, assess changes in water resources over time, and have information on-hand for improved decision making. The project is supported by Waikato Regional Council.

Kaitiaki flows and baseflow-dominated stream systems

The increasing role of iwi in environmental management, associated with treaty settlements and newly-legislated co-management arrangements, requires iwi to develop skills in water resource management. In partnership with Ngāti Rangiwewehi, we are setting out to identify kaitiaki flow regimes for Awahou Stream using a mixture of science and wananga. This is a new concept to water resource management because it is being developed by iwi to meet iwi criteria, including the amenity of spring-fed baseflow-dominated streams, and groundwater resource sustainability of the spring catchments. Kaitiaki flows are being considered by Ngāti Rangiwewehi and the Rotorua Lakes Council with regard to an up-coming consent renewal for municipal drinking water supply from Awahou Stream. These two organisations are joint holders of the consent and the renewal will govern water management in the area for many years to come. The project is also developing a water resources capability plan for Ngāti Rangiwewehi, outlining their aims and tasks over the next 20 years in terms of staff capability, training requirements, and strategic projects at local, catchment and regional scales.

Hei koha tū hei kura huna a papa
A resource characterisation and ancestry of minerals for Ngāti Hako

In partnership with Ngāti Hako, web are integrating scientific data and Mātauranga-a-iwi to attain a better understanding of the mineral resources within the Ngāti Hako rohe (region). The research interweaves oral histories, for example ngā mōteatea (songs) of past traditional mineral resource use, with the mineral resource potential now recognised as vital for a modern society. The collaboration is providing Ngāti Hako with an understanding of the geology of the Hauraki Region that has shaped the land and resulted in the formation of different minerals resources. The project brings together portions of Mātauranga Māori, with a recognition of the needs of modern society in developing a pathway to realise and unlock mineral potential as well as economic opportunities. The findings are providing a balance between mineral development and environmental protection with Ngāti Hako as kaitiaki (guardians to maintain, protect and enhance).

A Royal Society of New Zealand Marsden-funded project is helping to reconnect taonga (treasures) with their Māori owners.

Track the Black – the whakapapa of paru

Intricately woven kakahu (Māori cloaks) are extant exemplars showcasing traditional black iron-tannate dyes derived from iron-rich paru (muds) that were applied to New Zealand flax fibre (muka) during the manufacturing process. Paru-dye residues are essentially the only physical remnant left that could track unprovenanced heritage objects or textiles to their origins. By coupling indigenous studies and modern forensic techniques, GNS Science and Te Papa staff are revealing and restoring human-environmental linkages and whakapapa (historical relationships) to 'disconnected' paru-dyed taonga held in museums and private collections. Reconnection methods include a strong component of Mātauranga Maori. This is being gained through knowledge sharing and semi-structured interviews with key community and iwi (tribe) knowledge holders around traditional paru use to reveal their past significance, curation and location. A database of diagnostic geochemical properties of paru from sites across New Zealand is being created, and geochemical correlations between individual paru pits and heritage textiles revealed. This is allowing reconnection of unprovenanced taonga back to iwi, empowering iwi to protect, restore and acknowledge the cultural importance of paru for the provision of black dye in the marae setting.

OPERATIONAL INITIATIVES

Our review of executive and corporate functions carried out in early-mid 2018 was aimed at ensuring that GNS Science has the capability and capacity to support its science teams in the future, so positioning it better to achieve its vision.

Creating the future—our people

Our organisational culture and capabilities underpin our ability to deliver on our strategic direction. The changes outlined herein call for a workplace culture that is smart, strategic and responsive. We want all New Zealanders to recognise the value we bring both domestically and globally, and to do this we need an organisation with outstanding people and effective systems and processes.

Our focus will be on:

- Ensuring we have the structure, capability, and capacity to create globally influential science;
- Strengthening leadership, direction, and delivery through changes to the way we operate;
- Initiating a significant culture change programme redefining who we are, how we behave and the way we work, linked to our strategic review;
- Investing in improving our health, safety, and wellbeing culture through increased communication, education and participation;
- Developing cultural capability to meet our commitments under Vision Mātauranga and enhancing our partnerships with Māori;
- Updating our internal systems and processes to ensure they are fit for purpose, flexible, and responsive to our needs; and
- Implementing key recommendations and priority outcomes from our Pay and Employment Equity Review (PEER) project, in partnership with the PSA, to resolve gender pay gaps.

Enhancing external relations and collaboration

By creating value through close engagement, and linking our business with our stakeholders, we should see increased revenue and profits from research, commercial and commercialisation activities, and greater awareness and appreciation of our science by all New Zealanders. We will incorporate more outreach activities into our research, building on our success with MBIE-funded Unlocking Curious Minds projects. Positive outcomes include being widely respected by stakeholders as a trusted advisor and the first port of call for solving their problems, and being regarded as an innovative company.

EQC has committed to ongoing support of GeoNet, with funding increasing from $12.7 million in 2018-19 to $13.2 million in 2020–21, enabling us to enhance our stewardship of the project. We will use the additional investment to continue to move

GeoNet forward by streamlining our current operations and updating our monitoring network. Work has started on our longer-term goal to accurately and automatically detect eruptions at New Zealand's most active volcanoes (see page 42). This includes development of forecasting tools that will assist decision-making once an eruptive sequence is under way. The establishment of a 24/7 geological hazard monitoring centre for New Zealand will have the benefit of reducing the time taken to provide critical information to stakeholders on natural hazard events (see also page 2 and 7).

Through participation in Centres of Research Excellence ('MacDiarmid Institute', and 'QuakeCore'), University of Auckland's Product Accelerator, and the National Science Challenges (see page 22), we will make further progress in removing barriers to science and technology partnerships.

Maintaining research funding

We will maintain research funding at a level that fully supports our SCP. We will continue to make effective use of SSIF and contestable funding, aligned with commercial funding, to address issues of national importance. By streamlining our project management and reporting systems for greater efficiency, we will ensure a robust and enduring skill-base to underpin our commercial capability. A stage-gate process, linked to strategic drivers will further improve bid quality and reduce administration costs.

Enhancing information services

The business of GNS Science is data driven and our goal is to improve operational practices to increase efficiency and data management maturity, through high-performance, robust systems that are usable, connected and interoperable to well-targeted and managed dataset collection and use.

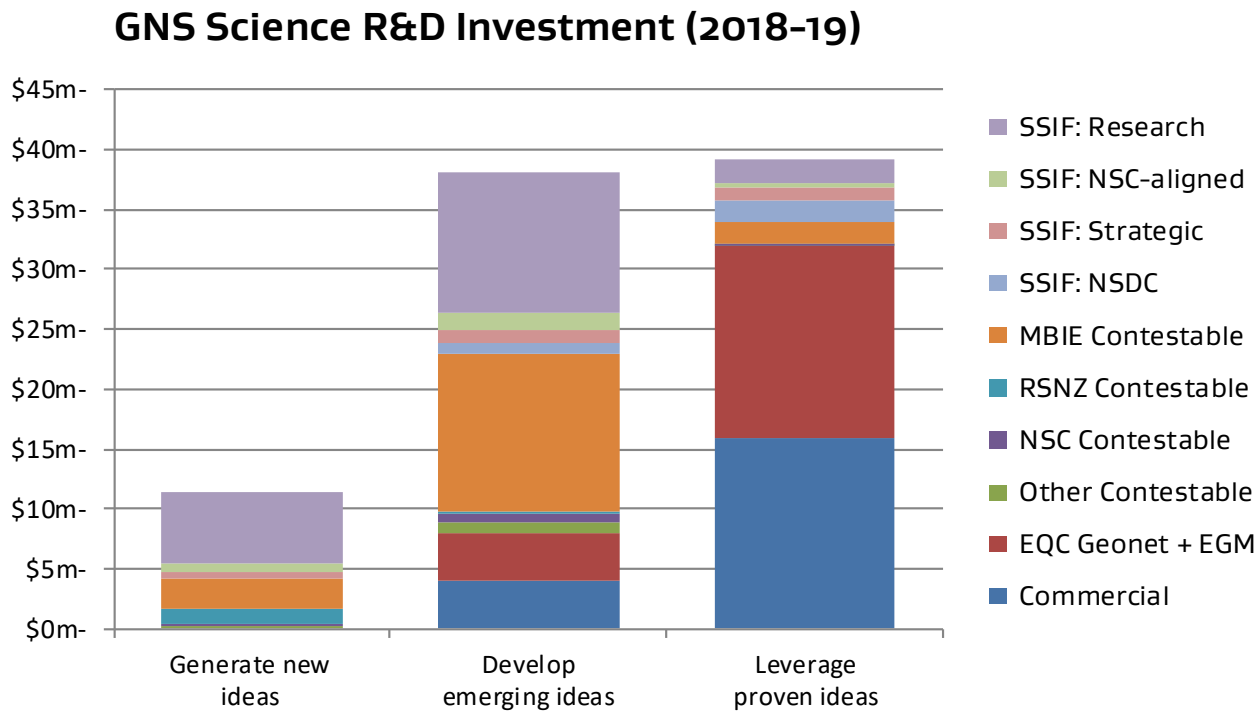
In 2018-19 we will be developing a business case for an Electronic Content Management System (ECMS) to improve our level of document control and external collaboration ability, and utilising a technology roadmap to guide our IT hardware and service procurement decisions. This will enable us to achieve improved scalability, efficiency, and availability of information services in the medium to long term.

We will also be refreshing our Information Services Strategic Plan to support the Strategic Review outcomes, and establishing a new roadmap of projects to support its delivery. Our principles in developing this roadmap are:

- Big Data and analytics are key drivers of future science and technology advances;
- services are digital by default;
- information is managed as an asset;
- investment and capability are shared; and
- improved systems assurance.

OUR RESEARCH

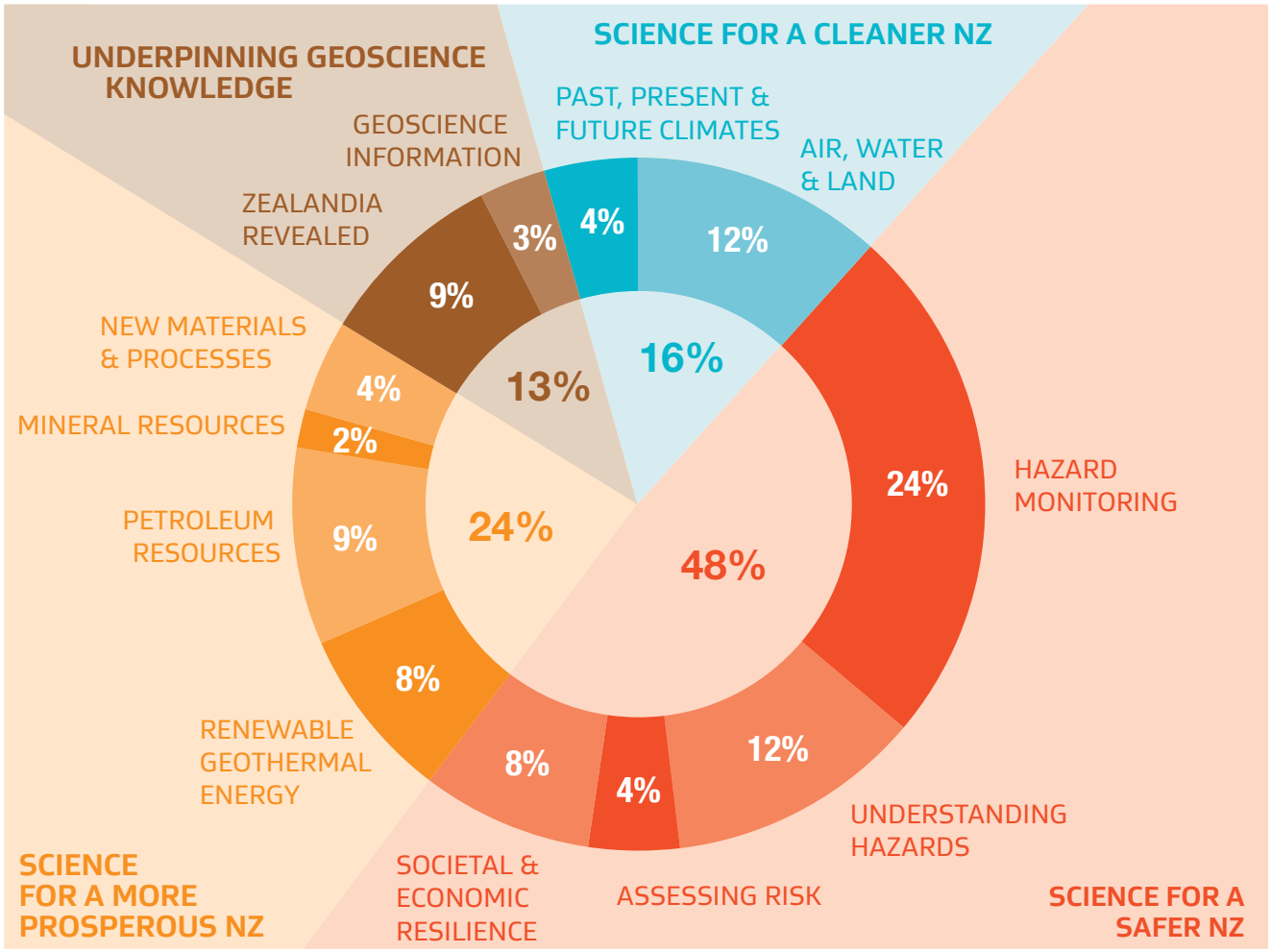
Over the next five years, we will undertake wide ranging research designed to deliver on our vision. This will be suppported by a variety of revenue sources: SSIF–Research Programmes, Nationally Significant Databases and Collections, and Enhanced Geohazard Monitoring (EGM); external contestable (MBIE-administered Endeavour, Vision Mātauranga, National Hazard Research Platform (NHRP), National Science Challenges (NSC), Catalyst, and Unlocking Curious Minds funds; RSNZ-administered Marsden, and Catalyst funds; EQC Biennial Fund; Centres of Research Excellence (MacDiarmid Institute and QuakeCore funds; EQC funding of GeoNet; and commercial service and consultancy.



Basic ('generate new ideas') research in regional geology, tectonics, biostratigraphy and materials science (13%), provides the fundamental understandings for more applied ('develop emerging ideas') research in environmental science, economic geology, and high-value manufacturing (43%). In combination, these generate the capability and understandings to undertake effective problem solving ('leverage proven ideas') (44%).

Our total R&D investment of $88.6 million—based on the 2018-19 budget forecast less NHRP Partner Payments and Resilience Challenge funds—is made up of 31% SSIF, 24% contestable, 22.5% EQC GeoNet + EGM, and 22.5% commercial.

The investment is deployed across four Core Science Areas and 12 underlying Research Themes.



Translating the Themes (outer ring, above) to the appropriate SCP Outcome Statements (see pages 12 & 13) reveals that the greatest amount of effort (58%) is directed towards OS2—natural hazard risk and resilience. OS1—wealth from resources (21%), and OS5—geology and past climates (11%), OS3—groundwater quality (4%); OS4—nuclear & isotope applications (5%), and OS6—enhanced geotechnical engineering (1%) make up the remainder.

In the detailed explanation of our research that follows (see pages 34-65), we address four questions in relation to the science outlook associated with each of the 12 Themes:

- What are our research aims over the next 1-5 years?
- Who are the key end-users we are targeting to take up our research results and put them to good use?
- What impacts, and ultimate benefits, do we expect to achieve?
- How will we measure success?

SCIENCE FOR A CLEANER NZ

Our role is to enhance the nation's ability to understand and responsibly manage changes in climate, sea level, air and water quality, and land use.

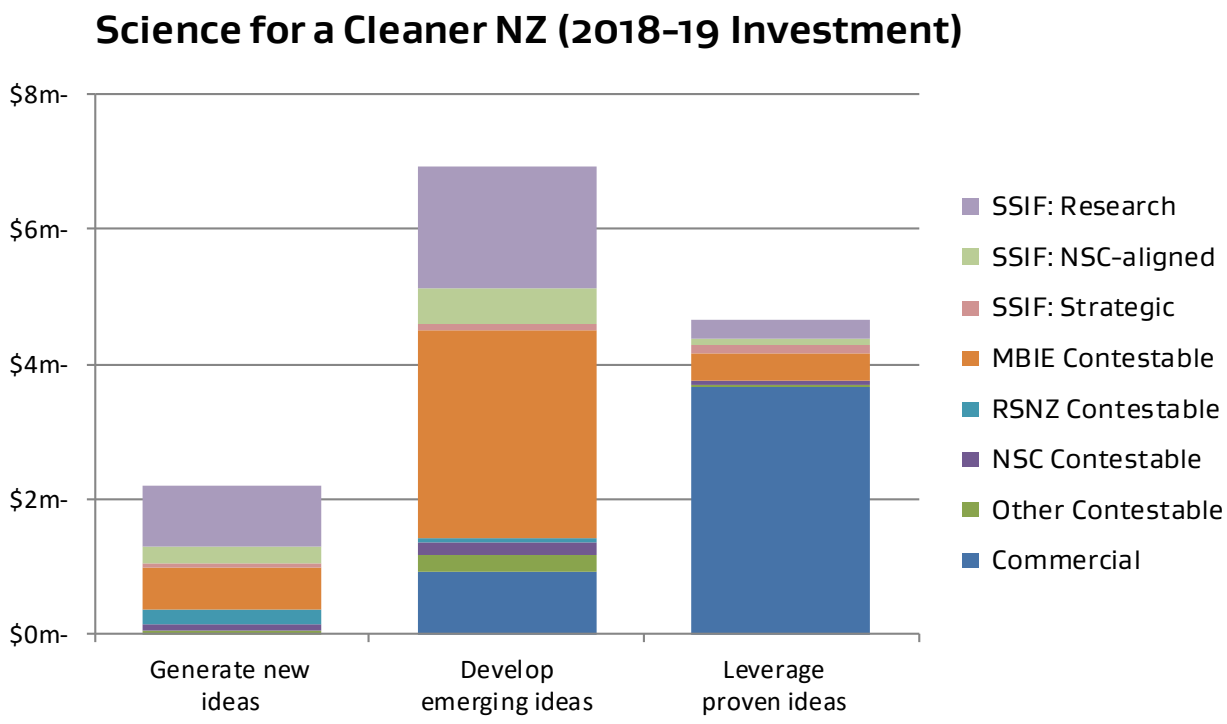
Our research findings contribute to improved environmental assessment by developing better networks for real-time monitoring, and effective mechanisms for dissemination to, and engagement with, the public, iwi, and other stakeholders. The desired outcome for New Zealand is effective kaitiakitanga (environmental stewardship), leading to social, cultural, health and economic benefits. To achieve this, we investigate ancient and modern environmental systems and processes, and determine the impacts of human activity and changing climate, empowering environmental stewardshop.

In partnership with central government, regional authorities, iwi, industry, universities, and the public. Improving the accuracy, reliability, and coverage of paleo-environment proxies, and environmental monitoring networks will provide stakeholders with authoritative, unbiased data and advice to support the development of informed policies, plans and strategies for climate-change and environmental management.

The 2018–19 investment of $13.8 million is made up of 30% SSIF, 37% contestable, and 33% commercial. 24% supports the Past, Present and Future Climates Theme, and supports 76% Air, Water & Land.

Research to 'develop emerging ideas' involves physical and geochemical characterisation of our air, land, and water environments; whereas research to 'generate new ideas' relates to obtaining a better understanding of the drivers and impacts of climate change through paleoclimate and carbon-cycle research, and sub-crustal fluid flow into and out of aquifers. Commercial projects, which mainly 'leverage proven ideas' provide practical support to the land and water sectors for improved environmental management.

Increasing demand for groundwater consultancy services has seen the horizon profile skew slightly towards 'leverage proven ideas', relative to the 2016-17 profile; the strategic move to invest more SSIF into groundwater systems modelling capability, leading to the creation of a 'hydrological QMap of New Zealand', will see the profile shift back over the next two years more towards 'generate new ideas'.


Science for a Cleaner NZ (2018-19 Investment)
$8m-
$6m-
$4m-
$2m-
$0m-
Generate new ideas
Develop emerging ideas
Leverage proven ideas
SSIF: Research
SSIF: NSC-aligned
SSIF: Strategic
MBIE Contestable
RSNZ Contestable
NSC Contestable
Other Contestable
Commercial

PAST, PRESENT & FUTURE CLIMATES

Science outlook

Our research on past climate and environments is essential for improving predictions of the rate, scale, and magnitude of future climate change and assessing the likely impacts of these changes on New Zealand and New Zealanders (see page 16). Knowledge of past environmental change is also key to understanding the evolution of Zealandia, the origins of its biota and the nature and distribution of its geological resources.

In collaboration with Victoria, Canterbury, and Otago universities, and NIWA, we will continue to contribute to international efforts to understand how climate has changed in the past and how these changes have affected the wider SW Pacific region, from Antarctica to the tropics.

For example, leadership of the multi-national Roosevelt Island Climate Evolution (RICE) project (2013-16) has allowed us to take the lead on the planning of the international Thwaites Glacier ice-core drilling project in West Antarctica. This highly-leveraged international research project aims to determine the stability of the West Antarctic Ice Sheet in a warming world, and improve estimates of its contributions to future sea-level rise. Thus supports New Zealand's efforts to be a good global citizen in understanding and mitigating the impacts of climate change and resultant environmental degradation.

Our focus on previous episodes of major climate shifts and intervals of warmer-than-present climate is aimed at quantifying ice-sheet contribution to sea level rise (see page 3, 'Our rising tides'), and informing longer-term (centuries to millennia) adaptation and mitigation strategies. We seek paleo-environmental evidence that extends the understanding of Earth-system behaviour beyond the short instrumental record, to times of global temperature and atmospheric carbon dioxide concentrations relevant to those projected for the next several decades. This is essential to any assessment of the impacts of climate change on New Zealand's environment, society, and prosperity. A quantitative understanding of the source and fate of key greenhouse gases is also critical to this assessment (see page 2, 'Auckland's carbon emissions').

Research aims

- Advance understanding of the regional impacts of global change at a range of spatial and temporal scales, by:
  - refining and developing isotopic methods for dating climate archives and deriving climate proxies;
  - using radiocarbon to determine the responses and dynamics of carbon stocks and flows in the biosphere, atmosphere, and ocean system relevant to New Zealand;
  - using ice and sediment cores to construct high-resolution climate records for the past 150,000 years, to reduce Southern Hemisphere climate model uncertainties;
  - refining future sea level projections for New Zealand and modelling local impacts;
  - using marine records to recognise the main drivers, mechanism, and patterns of climate change in the SW Pacific, with an emphasis on 'warmer world' intervals; and
  - identifying the global causes and regional consequences for biological and physical systems of extremely warm, high-CO_2 climatic events in the geologic past.
- Determine the effects of climate warming on Antarctica's ice sheets, simulating responses using models validated with prehistoric data to improve sea-level rise projections.
- Determine how the Southern Ocean carbon sink is evolving in response to climate change using atmospheric radiocarbon measurements.
- Determine the seasonality of Southern Ocean dynamics from Antarctic radiocarbon observations to improve the predictive capability of the New Zealand Earth System Model being constructed by the Deep South NSC.
- Devise probabilistic sea-level rise scenarios for New Zealand's coastline, and co-design impact assessment/risk programmes with local authorities, communities, and iwi/hapū.

Uptake and implementation

Paleoclimate-validated predictive models and associated climate-impact scenarios, documented in peer-reviewed high-impact scientific papers, provide important input into the globally-reported findings of the IPCC (International Panel on Climate Change), WEF (World Economic Forum), and WMO (World Meteorological Organisation). These organisations inform the Government through the Climate Change Minister, via regulators, strategists, and policy developers in government ministries, such as DOC (Conservation), MFE (Environment), MFAT (Foreign Affairs and Trade), MOH (Health), and MPI (Primary Industries), regional councils and territorial authorities. Iwi/Māori, for whom kaitiakitanga spans multiple generations into the future, and who therefore have a long-term perspective on environmental management, take a keen interest in the information gleaned from geological archives. In developing ever more-sophisticated and robust models, an effective interface with other researchers becomes a key element in the science value chain.

IMPACTS

1. Towards a low-carbon economy

New highly-resolved environmental data have been used to improve forecasts of climate and biological change for New Zealand, and pathways identified to a low-carbon economy that will support New Zealand's international commitments.

MEASURES OF SUCCESS

By June 2020, carbon source and sink data is included in New Zealand emissions reporting in relation to the Paris Agreement, and used to inform international advisory bodies such as IPCC, WEF, and WMO.

By June 2023, GNS scientists have been engaged in the production of the IPCC 6th Assessment Report, providing key paleoclimate information from the SW Pacific, Antarctica and New Zealand, published in high-impact international journals.

AIR, WATER & LAND

Science outlook

Our wide-ranging groundwater-related research helps to address the 'supply of fresh water' issue (see page 17), which is the major environmental and resource issue internationally. Specifically, we address the need to fully understand the structural characteristics of, and the fluxes of water into, out of, and through New Zealand aquifers, and improve our ability to predict the response of New Zealand aquifers to pressures such as climate change and land-use intensification. There is also a need to improve understanding of contaminant transfers between air, land, and water and the resulting environmental impacts. We see environmental stewardship as a collective responsibility. Enhanced engagement and knowledge exchange mechanisms that give the public and Iwi/Māori a more-active role (see page 28) will increase public awareness of environmental risks and help to provide tools for decision makers to address multi-faceted issues (see page 3, 'Protecting our groundwater').

We also make a contribution to the increasingly damaging problem of air pollution in New Zealand (see page 17), by applying our customised ion beam technology to determining the origins of particulate matter, and by creating smart environmental sensors. For example, joint research with Whakarewarewa Village Charitable Trust (see page 27) is developing strategies that makes their people more resilient to their environment, allowing them to derive even greater benefit from the natural assets of their rohe.

Research aims

- Provide new knowledge on the physical and chemical characteristics and responses of New Zealand's land and water systems and their response to future pressures, by:
  - determining the hydrogeological and structural characteristics of our aquifer systems;
  - developing fit-for-purpose chemical and isotopic tools for determining the dynamics of hydrologic systems;
  - applying tracers for biogeochemical processes that define the source, fate, and transport of nitrogen, carbon, and other pollutants; and
  - determining how human activities and climate change affect our groundwater resources,
- In partnership with industry and government develop environmental isotopes as a traceability tool to support product authentication and Country of Origin Labelling (CoOL), and as a biosecurity and forensic tool to protect New Zealand's unique flora and fauna.
- Develop and validate an improved method for quantifying the extent of denitrification in groundwater systems, based on the measurement of excess nitrogen.
- In collaboration with NIWA and ESR, develop, test and validate methods for simplifying large-scale groundwater models so that they can run quickly without introducing biases or inaccuracies.
- In collaboration with Cawthron, Matana, Victoria University and University of Otago, obtain a nation-wide overview of the health of our lakes using paleo-environmental reconstructions, to enable prioritisation for protection and achievable restoration
- In partnership with Whakarewarewa Trust, integrate environmental data and Mātauranga-a-iwi to determine the impact of hydrogen sulphide on local Māori communities.
- In partnership with Ngāti Hauā Iwi Trust, integrate environmental data and Mātauranga-a-iwi for water management in the Piako Catchment.
- In partnership with Ngāti Rangiwewehi, identify kaitiaki flow regimes for Awahou Stream using science and wananga.
- Develop new knowledge on outdoor and indoor air quality via source apportionment of air particulate matter, and sensor development.
- In collaboration with Te Papa, identify the unique geochemical fingerprints of paru from different locations used by Māori to dye flax fibre for weaving, and so allow unprovenanced taonga to be reconnected with their original owners.

IMPACTS

2. Improved water management

Tracer-validated numerical models and 'smart' tools for accurate, rapid and cost-effective characterisation, mapping, and modelling of key aquifers have led to a better understanding of aquifer systems and a demonstrable improvement in the management of groundwater and interconnected surface-water systems.

3. More-realistic air quality regulations

A better understanding of the drivers of air quality in New Zealand in relation to particulate matter has resulted in more-realistic pollution thresholds and regulations, leading to improved community health.

MEASURES OF SUCCESS

By June 2020, isotope tracer-based information, and simplified, reliable and integrated ('SMART') groundwater-surface water models are being used by industry and government agencies to inform policy and management decisions affecting and water resources and biological products.

By June 2022, air particulate source apportionment data is being used for setting new air-quality standards in New Zealand and, through to the IAEA-sponsored international air pollution programme, to set new air quality standards overseas.

By June 2023, regional councils have revised monitoring strategies for lakes within their catchments, and are amending plans to set and manage limits more effectively.

Uptake and implementation

The is a strong appetite amongst water regulators for 3D aquifer models and associated water-quality data, to inform water management strategies, policies, and regulations. The principal users of groundwater information, which is transferred mainly in the form of high-quality data sets, technical reports, and peer-reviewed scientific papers, are regional councils and territorial authorities, DOC, MFE, MOH, and MPI. The NAQWG (National Air Quality Working Group) use air pollution data to revise air quality standards, and NZTE (NZ Trade and Enterprise) factor food authentication research into their regulatory and marketing strategies. The IAEA-RCA (International Atomic Energy Agency Regional Cooperative Agreement), through MFAT, broker multi-country hydrological research initiatives around the Pacific Rim and SE Asia. Forestry, horticulture, farming, and viticulture industries, community groups, iwi/Māori (e.g. Whakarewarewa Trust, Ngāti Hauā Iwi Trust, and Ngāti Rangiwewehi), and others with a vested interest in water quality and/or supply (e.g., utility providers), are also key users of groundwater data and models.

SCIENCE FOR A SAFER NZ

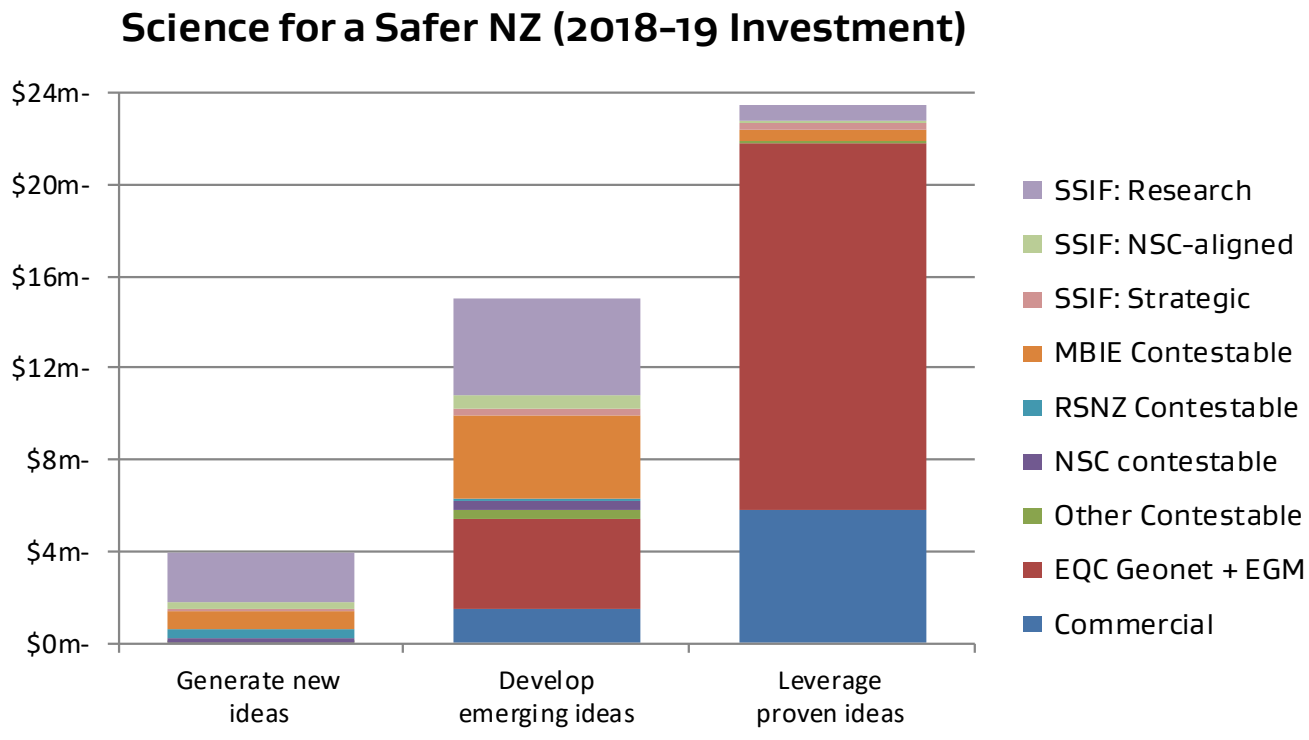
As the lead institute in New Zealand for geological hazard research, our role is to develop and support the nation's ability to understand, communicate and mitigate the impacts of earthquakes, tsunamis, volcanic eruptions, and landslides, and its ability to become more resilient to these hazards.

The desired outcomes for New Zealand are reduced economic, environmental, and social impacts of natural hazards on communities and infrastructure, and, ultimately, improved national wellbeing. To achieve this, we will undertake research to better understand natural hazards and community exposure, and support risk mitigation and community resilience. We will partner with other researcher providers, end-users, and communities in national and international programmes for disaster risk reduction, to develop safeguards from the impact of natural hazard events. And we will provide authoritative and independent information and advice to support risk mitigation, community resilience, and informed decision-making in response to, and in preparation for, natural hazard events.

Nearly half (47%) of the 2018-19 investment of $42.5 million comes from EQC support for GeoNet plus MBIE support for EGM; the remainder is from SSIF (21%), contestable (15%) and commercial (17%) sources. 49% supports the Hazard Monitoring Theme, 25% Understanding Hazards, 8% Assessing Risk, and 18% Societal and Economic Resilience.

Research to 'leverage proven ideas', relates mainly to the delivery of immediate geohazard advice to key stakeholders via GeoNet, EGM, and geohazard consultancy services; research to 'developing emerging ideas' relates to acquiring a better understanding of geological hazard, risk assessment, and societal and economic resilience; whereas research to 'generate new ideas' is focused on acquiring a fundamental understanding of geohazards, their triggers and predictability.

The strategic move to invest more SSIF into refining and enhancing the National Hazard Model has significantly increased the investment in 'generate new ideas', relative to the 2016-17 profile.


Science for a Safer NZ (2018-19 Investment)
$24m-
$20m-
$16m-
$12m-
$8m-
$4m-
$0m-
Generate new ideas
Develop emerging ideas
Leverage proven ideas
SSIF: Research
SSIF: NSC-aligned
SSIF: Strategic
MBIE Contestable
RSNZ Contestable
NSC contestable
Other Contestable
EQC Geonet + EGM
Commercial

HAZARD MONITORING

Science outlook

GeoNet, the geohazard monitoring system we operate, has a pivotal role in supporting natural hazard research in all its forms. GeoNet services include the collection and publication of geological data from the GeoNet sensor network, and maintenance of an on-call duty system to monitor, detect and assess geohazard threats related to earthquakes, tsunami, volcanic eruptions, and landslides. The GeoNet Sustain project (the national geodetic framework and tsunami gauge network), funded by EQC and LINZ, maintains and reinforces GeoNet's existing infrastructure, operations and services. GeoNet is well-equipped to deliver leading-edge hazards information to all New Zealanders, when and where they want it.

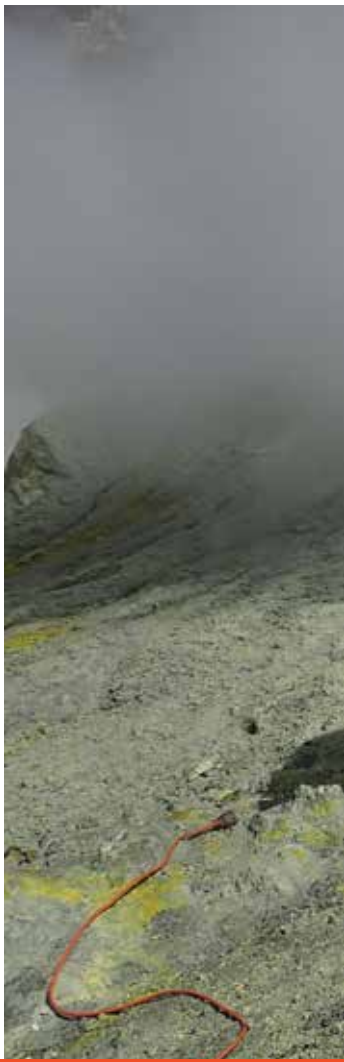
There is an ever-pressing need to provide better real-time forecasts for all four geological perils and their impacts, so the public can be better prepared for impending events, and know how to respond when adverse events happen (see page 2, 'GeoNet enhancements'). The GeoNet Enhanced Geohazard Monitoring (EGM) project, funded by MBIE, will implement 24/7 awake geohazard monitoring services, concentrating initially on tsunami and large earthquakes, but with the intention to cover all perils by 2021. The ultimate goal is to provide enhanced communication of hazard and risk through multiple channels, and comprehensive response planning for all future events in New Zealand.

Research aims

- Improve the scope and value of the GeoNet service, by:
  - providing 24/7 awake monitoring, initially for tsunami and large earthquakes, then for volcanic eruptions and landslides;
  - developing systems to provide fast and effective advice for local-source tsunami warning, while supporting the 'long, strong–get gone' self-evacuation message;
  - providing better access to data and information for researchers and other users;
  - improving the speed of detecting and assessing geological hazard threats in New Zealand;
  - progressively improving the certainty and accuracy of our advice to responsible agencies about hazard threats; and
  - progressively moving to impact forecasting for all perils to provide improved information for decision makers.

Uptake and implementation

Because GeoNet provides real-time data on earthquake, volcanic eruption, and tsunami events, its user base includes all sectors of society. Primary delivery of hazard information is to key Government ministries and agencies, namely MCDEM, MBIE, DOC, EQC, lifelines groups, LINZ, regional councils and territorial authorities, and regional CDEM groups. The information is used to inform strategies around advice to the public, and longer-term policy development. GeoNet also interfaces with the public via the media, and makes available information on the severity and characteristics of events (accessing citizen-science data) to interested parties via its website.



IMPACTS

4. Effective response to hazard events

GeoNet real-time data on the location and size of hazard events, and forecast impact scenarios, has been taken up by government agencies, the media and the public, and used to facilitate effective response procedures, and planning for future events.

5. Timely response to hazard events

Early warning or forecasting capability for all perils has been established and utilised, leading to more-timely decision making by CDEM and other response groups and planners, lessening the impacts of hazard events on people and infrastructure.

MEASURES OF SUCCESS

By June 2019, GeoNet has a 24/7 awake monitoring service in place, including enhanced capability to respond to local-source tsunamis.

By June 2021, the speed of detecting and assessing geohazard threats in New Zealand has improved by 50%.

By June 2023, GeoNet is providing impact forecasting for some geohazard threats, further enhancing the quality of advice to decision makers.

UNDERSTANDING HAZARDS

Science Outlook

Critical to a resilient society is the ability to understand and mitigate the risk from the range of potential geohazards we subject to. Thus, we look to provide sound information on which to base decisions on the priorities for action, and methods to reduce risk. We seek understanding of geological processes and the hazards they pose to society, as the first step to quantifying risk. Through discovering new insights into when, where, why, and how an earthquake strikes, a tsunami is triggered, a volcano erupts, or a landslide occurs, we are able to build models to compare risks between different perils. In this context, we are actively ensuring that New Zealand is well positioned as an international hazards laboratory, and there is integrated research leading to comparative risk across all hazards, through the development of end-to-end research projects (see page 2, 'Shining a light on subduction; and page 3, 'Profiling our super-volcano').

Research aims

- Advance understanding of earthquakes, to better understand risk by:
  - using active fault data to quantify the rate at which faults with high slip rate, high hazard, and/or poor characterisation move;
  - quantifying earthquake predictability, and developing enhanced earthquake forecasting models;
  - improving understanding of the seismic cycle, including stress build-up and release, fault mechanics, and fault interactions;
  - refining models of earthquake rupture;
  - improving earthquake attenuation models for engineering and risk applications; and
  - quantifying space-time variability in strong-ground motion.
- Use high-frequency scattering methodology and a dense aftershock dataset to understand seismic wave effects in the near surface, and their impact during the largest earthquakes.
- Probe the Hikurangi subduction zone using full-waveform inversion to determine what controls the spatial variation of mega-thrust slip behaviour.
- Derive new geologic slip rate and paleo-seismic data for four of the faults involved in the 2016 Kaikōura Earthquake—the Papatea, Hundalee, Humps and Hope (Seward) faults.
- Improve medium-term forecasts of large earthquakes in the Wellington region, enhancing the forecasting model through improved understanding of precursory seismicity.
- Determine how and why slow-slip earthquakes are triggered by regional earthquakes in shallow subduction zones, by applying novel methodologies from landslide mechanics.
- Better constrain seismic and tsunami hazard of the Kaikōura-Marlborough regions by determining the magnitude and frequency of past-coastal uplift.
- Diagnose the nature and history of slip along Hikurangi margin faults, to develop more-accurate earthquake and tsunami forecasts.
- Determine the sources of tsunami and the processes of propagation and inundation, to devise a quantitative frequency-magnitude framework for tsunami forecasting.
- Advance understanding of active volcanism, to improve response times, by:
  - determining the frequency, size, and style of volcanic eruptions through analysis of eruptive deposits, and their potential impacts on communities;
  - developing conceptual and numerical models of sub-surface eruption processes; and
  - imaging subsurface conditions (pre-eruption signals) in volcanic systems.
- In collaboration with Victoria University, use knowledge of super-volcano eruptive dynamics to create a Caldera Health Status System, and devise mitigation strategies based on eruption hazard and impact models that are co-produced with iwi, CDEM, and volcano advisory groups).
- Advance understanding of landslide hazards, by:
  - characterising the spatial distributions of landslide occurrences from rain, earthquakes, and other triggers, and their role in landscape evolution;
  - recording, monitoring and modelling landslide processes in time and space, including initiation, run-out mechanisms, and societal impacts; and
  - determining the geo-mechanical properties of soils and rocks, and how they influence the causes and evolution of landslides.
- Develop a decision-making framework and toolset that will immediately inform risk and risk-management methods and practices in relation to Kaikoura Earthquake landslides.

IMPACTS

MEASURES OF SUCCESS

6. Better mitigation planning

Advanced information on the causes, frequency and consequences of hazard events in New Zealand has provided response agencies with tools to make more-effective and timely mitigation plans, reducing risk across all hazards.

7. Enhanced global research presence

Excellent research and strong collaboration has positioned New Zealand as a geohazards research centre of global significance for understanding hazard and associated risk.

By June 2019, a global volcanic impacts database hosted by GNS Science is being operated, in collaboration with the US Geological Survey and the Global Volcano Model.

By June 2020, an automated operational earthquake forecasting framework is in place.

By June 2022, an operational landslide forecasting framework is in place.

Uptake and implementation

The main users of hazard cause-and-effect models are government ministries and agencies, for informing strategy, policy, and operational procedures. These include DOC, EQC, MCDEM, Met Service, MFE, MBIE Building System Performance, NZTA (New Zealand Transport Agency), regional councils and territorial authorities. Insurance providers and underwriters, infrastructure providers, geotechnical consultants (such as BECA, DamWatch, Transpower, and Vector), iwi/Māori, and the public are also key end-users. Outputs are customised to specific needs, and include technical reports, popular articles and workshop presentations, as well as website postings and media releases. Because much of the research output is in the form of fundamental data sets and codes, other researchers are important next users; these include scientists involved in collaborative research and outreach through the Resilience Challenge, QuakeCoRE, DEVORA, It's Our Fault, and East Coast LAB.

ASSESSING RISK

Science outlook

Risk can be treated by a range of mitigation methods—avoid, transfer, reduce, or accept. Our research underpins decisions about which treatment option is optimal: Do we avoid a lahar by not building in potential pathways for future events? Can we transfer the risk by insurance and, if so, how can insurers better assess the premium we should pay? Can we strengthen our buildings in areas of high earthquake activity, thus lowering the likelihood of business interruption? Do we have the discussion with our communities that we are comfortable to accept a certain level of risk from a low probability, high-impact event such as a Tohoku-size tsunami, so long as we build in safeguards such as good evacuation planning?

Our RiskScape-based research makes us uniquely placed to inform national conversations on natural hazards risk. We are developing multi-hazard risk models, engaging with decision makers to guide the most effective methods for risk mitigation, and improving our knowledge of how best to communicate risk to all New Zealanders. Key to this is establishing enduring partnerships with government agencies to ensure seamless and sustained delivery of quality risk advice, using our expertise to develop strong risk management across government and the private sector.

Underpinning RiskScape is the updating and development of models for a full range of geological perils, leading to the creation of a comparative National Natural Hazard Risk Model.

Research aims

- Develop the RiskScape risk assessment tool, to support effective management of natural hazard impacts on New Zealand communities, infrastructure and business.
- Improve the reliability and applicability of national hazard models, by:
  - combining multiple data sets from earthquake geology, earthquake catalogue, and geodesy to more completely capture the earthquake process in the National Seismic Hazard Model (NSHM);
  - modelling the impact of data quality and uncertainty on earthquake hazard in the NSHM;
  - developing a national-scale Tsunami Inundation Hazard Model (TIHM);
  - developing earthquake-induced and rainfall-induced landslide forecasting models; and
  - developing a volcanic eruption forecasting model.

Uptake and implementation

Risk analysis is undertaken by government ministries and agencies, such as DOC, EQC, LINZ, MCDEM, MBIE Building System Performance, NZTA, and the Local Government Risk Agency, insurance and infrastructure providers, businesses, and community groups (including iwi/Māori) via web-accessed RiskScape tools. These enable users to build their own hazard and asset modules, then import these for impact and loss modelling. They can also apply user-developed modules independently or in combination with RiskScape-provided modules. National hazard models, codes, and peer-reviewed scientific publications, present underpinning data for RiskScape development, and down-stream risk and resilience modelling.

IMPACTS

MEASURES OF SUCCESS

8. Enhanced risk analysis and uptake

Enduring partnerships with insurance and other companies have ensured uptake of accurate and timely risk evaluations, and widespread use of RiskScape to assist geohazard risk-reduction activities, resulting in more resilient New Zealand communities and businesses.

By June 2020, RiskScape tools are being used by at least half of all regional councils and territorial authorities and key Government stakeholders.

By June 2022, an improved National Seismic Hazard Model is the basis for all earthquake risk modelling in New Zealand.

9. National Natural Hazard Risk Model

A comprehensive National Natural Hazard Risk Model has been used to underpin development of RiskScape, as the basis for refined hazard-risk assessment, risk-based land-use planning, informed emergency responses, and appropriate investment in mitigation and risk-transfer mechanisms.

SOCIETAL & ECONOMIC RESILIENCE

Science outlook

As host and partner to the Resilience Challenge, we sustain momentum around social and economic resilience research, by playing a leading role in helping the Government fulfil its obligations to the Sendai Framework for Disaster Risk Reduction, and contributing to the development of a national strategy for disaster risk reduction and resilience (see also page 18).

We undertake research aimed at understanding the social, economic and cultural factors that enhance community resilience, developing economic models for quantifying the economic impacts of disasters (loss modelling). We also assess the performance of the built-environment under different hazard intensities, translating this into measures suitable for modelling social and economic impact, and recovery strategies (see page 3, 'Smarter buildings').

Research aims

- Advance understanding of the social, economic, and cultural factors that enhance community resilience to geological hazards, by:
  - exploring ways to improve the preparation and implementation of mitigation plans and policies;
  - devising strategies for enhancing community resilience to disasters; and
  - developing methods to improve behavioural responses warnings, and disaster recovery.
- Improve methods for achieving acceptable levels of functionality of the built-environment in cities after an event by:
  - determining the habitability and functional recovery of buildings;
  - modelling interdependencies of critical lifelines and infrastructure; and
  - modelling damage to horizontal infrastructure, outage and recovery of utility networks.
- Improve infrastructural resilience through better knowledge of the behaviour of anthropogenic slopes, and developing efficient strategies for robust remediation approaches.
- Develop a tool for simulating the flow of pedestrians during a tsunami evacuation response, and establish procedures for using model outputs to improve evacuation planning.

Uptake and implementation

Evidence-based societal resilience advice, in the form of science reports, policy briefs, stakeholder and community workshops, is accessed primarily by government ministries and agencies, such as ACC (Accident Compensation Commission), EQC, MCDEM, MFE, MOH, MSD (Ministry of Social Development), and regional CDEM and lifeline groups. Pacific-rim countries, notably Vietnam, Indonesia, Vanuatu and Samoa, also benefit from targeted research, via NZAID. Data and models pertaining to infrastructural resilience are fed directly into MBIE Housing and Construction policy, and building codes. Community feedback, in the form of public talks and media articles, is widely accessed by iwi/Māori and the public.

IMPACTS

10. Better-informed policy development

Land-use planning, emergency management, and economic risk research findings have become embedded in government policy, leading to increased societal resilience to geohazards.

11. Enhanced preparedness, response and recovery

Policies containing effective natural-hazard planning procedures, with practical provisions to develop resilience, such as through best-practice communication, engagement and training, have resulted in communities that can respond effectively in a disaster and have a high recovery capacity.

12. Improved infrastructure design

Uptake of advice on design codes and standards has led to improved infrastructure design for earthquake and landslide protection, resulting in safer buildings and infrastructure, reduced socio-economic impact, and evidence-based investment planning.

MEASURES OF SUCCESS

By June 2019, research findings on societal resilience have become a key part of MCDEM's new strategy.

By June 2020, functionality advice has contributed to revision of the Building Code and/or standards, such as NZS1170.5 and NZ3604.

By June 2023, societal resilience toolboxes have become a key component of the strategies for at least three quarters of regional councils.

SCIENCE FOR A MORE PROSPEROUS NZ

Our role is to provide the nation with tools to enhance resource security, energy stability, and sustainable development of its geothermal energy, petroleum, and mineral resources, and to develop new high-value materials and processes for industry.

The desired outcomes for New Zealand include environmentally responsible use of our energy and mineral resources, and creation or enhancement of high-value industries that generate national wealth. To achieve this, we will delineate and quantify New Zealand's natural energy and mineral resources, and assist the discovery and development of new minerals and manufacturing processes.

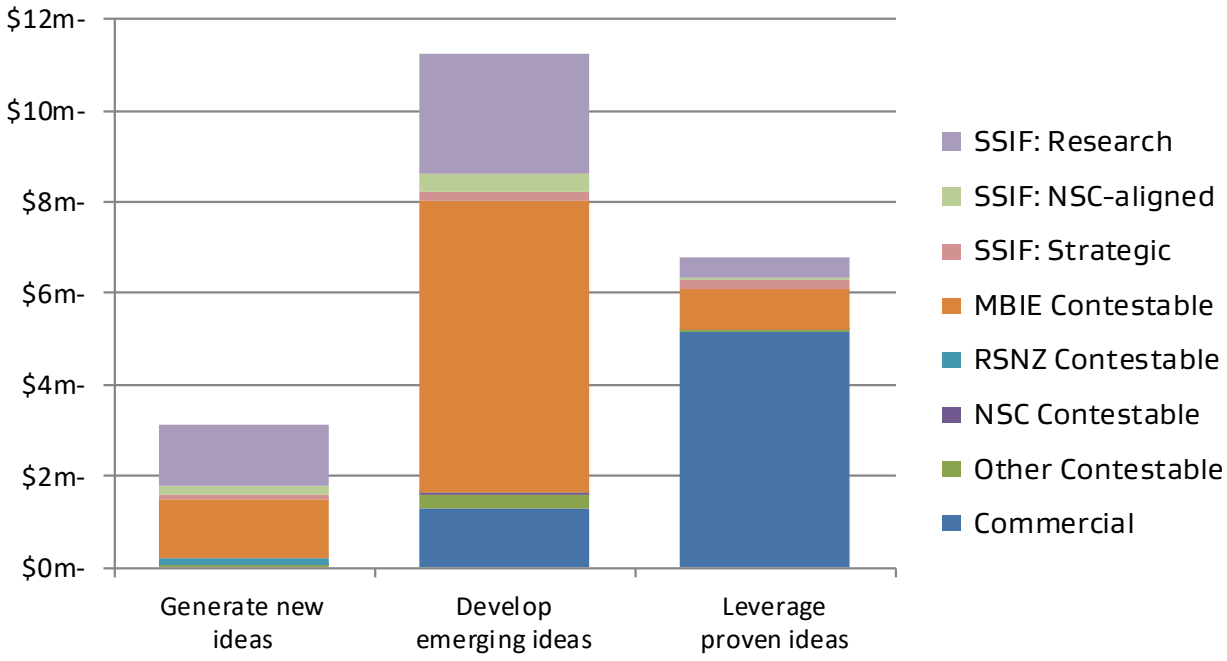
We will collaborate with universities, government agencies and industry to provide leadership in understanding and promoting geological resource potential, and with high-value industries to promote uptake of new technologies. And we will apply our knowledge to provide independent and respected advice to inform debate on resource development, and on opportunities in minerals, energy and high-value industries.

The 2018–19 investment of $21 million is made up of 26% SSIF, 43% contestable, and 31% commercial. 35% supports the Renewable Geothermal Energy Theme, 37% Petroleum Resources, 10% Mineral Resources, and 18% New Materials & Processes.

Research to 'develop emerging ideas', relates to characterising our known geothermal, petroleum and mineral resources; research to 'leverage proven ideas' relates to the delivery of knowledge supporting the existing extraction industries; whereas research to 'generate new ideas' is focused on realising the potential of offshore gas hydrate and seafloor massive sulphide resources, and innovative ways to improve energy efficiency.

The recent downturn in domestic consultancy from the geothermal and petroleum sectors has seen a sharp decrease in 'leverage proven ideas', relative to the 2016-17 profile.

Science for a More Prosperous NZ (2018-19 Investment)



RENEWABLE GEOTHERMAL ENERGY

Science outlook

In recognition of the critical contribution geothermal makes to our energy security, we continue to contribute strongly to supporting the viability of the industry, to help the Government advance towards its goal of 100% renewable electricity generation by 2035. Our research addresses a range of barriers to profitability, including the maintenance of permeability and fluid flow, the discovery of new fields, and environmental degradation.

Two main challenges face the industry, namely improving the efficiency of existing field-management operations, and developing reliable assessments of new geothermal resources. We are addressing these by developing a deep understanding of structure and dynamics of the Taupo Rift, and the geothermal systems within it, near surface geothermal resources and their direct-use potential, and novel approaches to improving the sustainability and efficiency of geothermal production, and extracting additional value from geothermal fluid streams. We also seek to reduce the risks of drilling unproductive wells, and insufficient resource, to maintain generation by improving the predictive capabilities of geothermal resource assessment models. As a result, cheaper geothermal developments will be possible for greenfield sites, and sustainable expansions of existing sites.

Research aims

- Support sustainable development of New Zealand's high- and low-temperature, deep and shallow geothermal resources, by:
  - understanding near-surface systems, through remote sensing and modelling, to maximise direct-use potential;
  - determining the hydrodynamics of deeper systems and their heat sources; and
  - developing and trialling novel techniques for metal extraction from geothermal effluents.
- In collaboration with The University of Auckland, improve the predictive capabilities of geothermal resource assessment model, by developing new approaches to interpreting and extracting information from geothermal field data.

Uptake and implementation

New Zealand-based geothermal companies Contact Energy, Mercury NZ, Ngāti Tuwharetoa Geothermal Assets, Tauhara North No.2 Trust, Tikitere Trust, and Top Energy, as well as several overseas companies, including Chevron, EDC, Origin Energy, and Pertamina, make extensive use of our expertise and research findings on a day to day basis to improve production efficiency, and in the longer-term to de-risk exploration strategy and operations. Knowledge transfer is by way of technical reports, geoscientific data, hands-on advice, industry workshop presentations (e.g. NZ Geothermal Workshop; World Geothermal Congress) and scientific papers. Geotechnical companies, including AECOM, BECA, HADES Systems, MB Century, and Tiger; and direct-use companies in the heat pump, horticulture, manufacturing and processing, and tourism industries also make use of information specific to their needs. Environmental regulators, including EECA (Energy Efficiency & Conservation Authority), EPA (Environmental Protection Agency), and regional councils (principally Bay of Plenty, Northland, and Waikato) use research findings to set policy. Economic development agencies, such as NZP&M, Enterprise Great Lake Taupō, Grow Rotorua, MFAT, NZTE, and Te Puni Kōkori use research findings for strategy development and trade promotion. IPGT (International Partnership for Geothermal Technologies) provides a link for member governments (USA, Australia, New Zealand, Iceland, Switzerland, and Japan) to coordinate R&D and technological development.

IMPACTS

13. Enhanced operational efficiency

Regular uptake by geothermal companies of geoscientific information relating to deep or near-surface geothermal systems, improved modelling and monitoring tools, and solutions to process efficiency issues, has resulted in a more profitable sector, and an increased contribution to New Zealand's energy needs.

14. Greater socio-economic benefit

Retention of high-quality research capability in New Zealand has provided cutting-edge solutions to exploration and production barriers, reducing costs for greenfield geothermal development, and sustainable expansion of existing plants, and advancing the Government's goal of 100% renewable electricity generation by 2035.

MEASURES OF SUCCESS

By June 2019, New Zealand geothermal reservoir models are being built using a new flow simulator, and validated using a suite of enhanced modelling tools.

By June 2022, resource assessment models are being used to plan new greenfield developments in New Zealand, increasing the amount of renewable electricity generation.

PETROLEUM RESOURCES

Science outlook

As the principal provider of petroleum geoscience research in New Zealand, we cover a wide range of specialist disciplines, providing local expertise, knowledge, and geoscientific data to the global companies exploring here. We address the question of how geologically prospective New Zealand is by qualifying and quantifying critical parameters of the petroleum systems in our sedimentary basins. This helps reduce technical uncertainty and aids investment decision making.

Our sedimentary basin research includes the study of critical aspects of petroleum source, reservoir, seal, trap and charge, where there are gaps in knowledge that impede exploration success. Although we provide technical overviews of frontier basins to support existing licenses there, we maintain a strong focus on the proven oil-producing region of Taranaki, where seismic mapping has provided a benchmark for evaluating and refining future exploration planning. Our expanded data sets of geochemical and petrophysical properties of petroleum sources, reservoir rocks, and fluids are driving new interpretations of our petroleum systems. High-resolution fluid-flow models in known petroleum fields in Taranaki are forming an empirical basis for predicting petroleum charge scenarios for as-yet undiscovered petroleum accumulation there, and elsewhere in New Zealand's EEZ. This diversified approach is helping to improve regional exploration play concepts and drilling target delineation. A nationally-significant compendium of maps, the Atlas of Petroleum Prospectivity, depicts current knowledge of the petroleum potential of our offshore basins, informing industry on the relative merits of areas for exploration.

we are assessing The potential of the gas hydrates resource along the eastern coastline of the North Island. in terms of economic viability, production hazard, and environmental implications, contributing base-line evidence for informed decision-making on future development.

Research aims

- Advance understanding of the structure, stratigraphy, and prospectivity of New Zealand's sedimentary basins, by:
  - creating new maps and derivative 3D models of the evolution of Taranaki Basin structure and stratigraphy through geological time;
  - providing an improved technical basis for evaluating petroleum potential; and
  - applying new concepts to understanding sedimentary architecture.
- In collaboration with NIWA, Otago and Auckland universities, GEOMAR (Germany), and incorporating Vision Mātauranga and deliberative community engagement, assess the implications of developing prospective gas hydrate resources along the Hikurangi margin, by:
  - determining New Zealand-specific frameworks for from gas-hydrate energy production;
  - predicting the geo-mechanical responses induced by production drilling; and
  - investigating the impact that changes in seafloor stability or methane flux could have on marine ecosystems.
- In collaboration with The University of Canterbury, publish new-generation digital maps and metadata of potential subsurface petroleum habitats in New Zealand's EEZ, to aid exploration targeting.
- Provide new insights into oil and gas occurrences in New Zealand's EEZ, by:
  - determining the types, volumes, and essential properties of petroleum source rocks;
  - chemically analysing oils, condensates, and gases to determine sources, migration pathways, and controls on the distribution of oil versus gas;
  - modelling the movement of petroleum fluids through strata over geological time; and
  - promoting informed dialogue between the public, iwi, and industry on environmental, social, economic, and cultural issues pertaining to petroleum exploration.

Uptake and implementation

The main research outputs are tailored explicitly to the needs of the primary end-users. NZP&M uses petroleum data and interpretations to develop strategy around exploration activity, and to promote New Zealand to international exploration companies. Research-based consultancy is undertaken for nearly all companies exploring in and around New Zealand, and partnerships have been established with several New Zealand and overseas universities and international seismic companies.

We have a high level of engagement with exploration and seismic companies, with more than ten companies providing co-funding, access to 3D seismic data volumes, petroleum fluid samples, and specialised datasets for our research. Annual workshops are held to present the latest research results and data to companies and NZP&M, whilst customised workshops are organised for individual companies on request. Our Petroleum Basin Explorer (PBE) web portal provides open access to geoscientific data and information.

IMPACTS

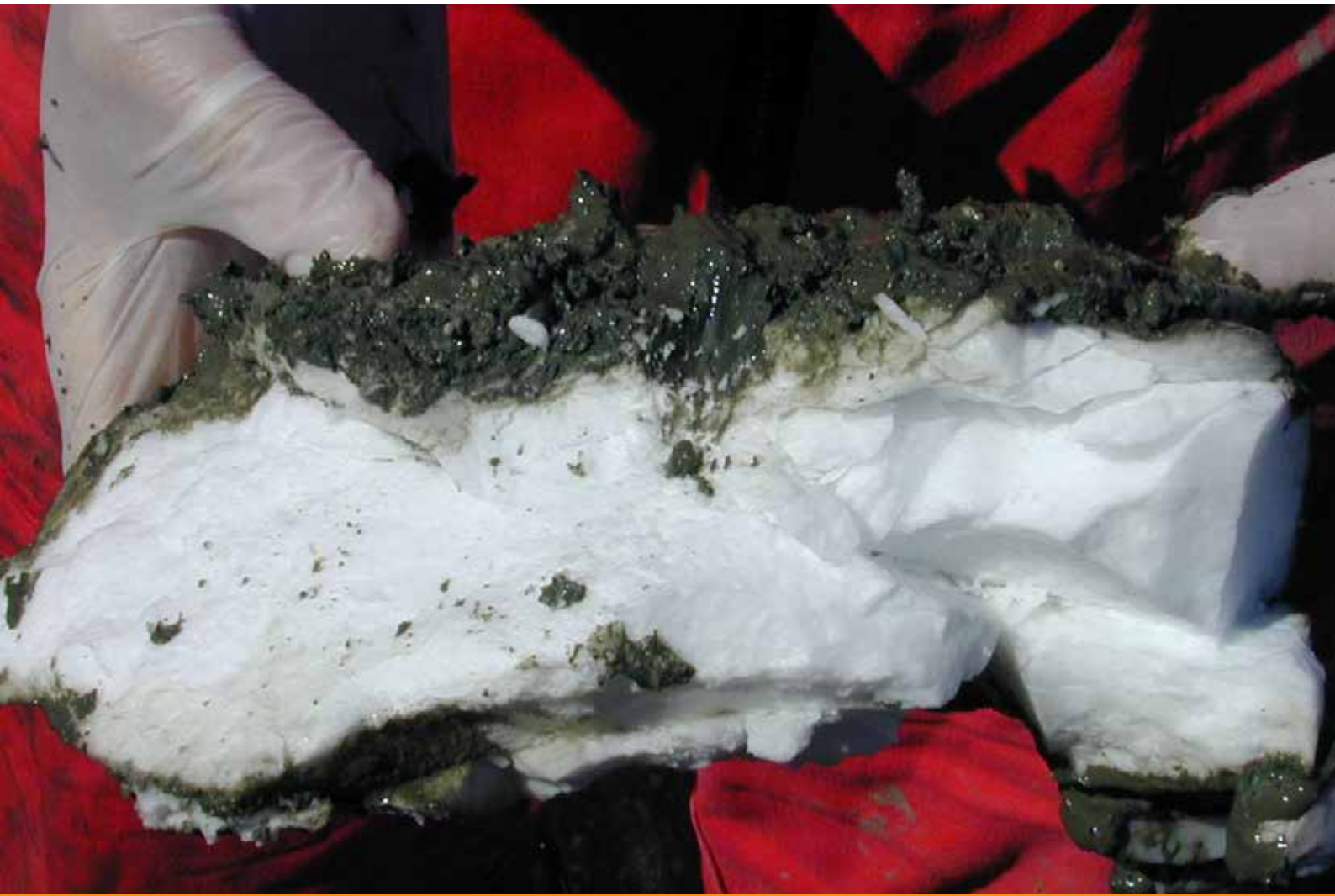
15. Improved resource management

Enhanced knowledge of the prospectivity of petroleum resources within our sedimentary basins has led to greater confidence in New Zealand as an attractive destination for oil and gas exploration, new commercial discoveries, greater security of energy supply, and increased exports of oil and natural gas derivatives; knowledge of the scale and quality of our gas-hydrate resource has encouraged exploration drilling; and informed debate on the risks, consequences, and potential benefits of petroleum exploration and production has led to improved management of the resource.

MEASURES OF SUCCESS

By June 2020, increased uptake and use by the Government and the petroleum sector of research results, including the Atlas of Petroleum Prospectivity and petroleum systems databases, is resulting in petroleum exploration wells drilled in Taranaki Basin and one or more frontier basins.

By June 2023, interest in New Zealand's gas hydrates by exploration companies is resulting in an exploratory drilling programme.



MINERAL RESOURCES

Science outlook

Although the minerals industry in New Zealand is relatively small by international standards, it still makes a significant (c. 1%) contribution to New Zealand's GDP. Our research is aimed at growing this, and attracting new exploration investment, particularly with respect to the critical metals (see page 21) needed to support New Zealand's 'green'-technology manufacturing industry.

To achieve this, we are providing the Government and industry with information on mineralisation styles and processes, regional to deposit-scale exploration models, and mineral prospectivity. This is used to better identify areas of higher mineral potential and exploration targets for de-risking exploration and extraction operations. Key to this is the acquisition and interpretation of new geological, geophysical and geochemical mineral exploration data, and delivery in appropriate product formats. We are placing more emphasis on understanding the tectonic and geological drivers for mineral deposition, in relation to the evolution of Zealandia. Research aimed at increasing knowledge of specialised aggregate resources is also being undertaken, to ease concerns over supply related to increasing demand for infrastructure development and housing.

Research aims

- Determine the origin and distribution of onshore mineral deposits, and their geological and economic context, to enhance their prospectivity and our ability to locate them, by:
  - addressing the issue of scale of mineral systems by studying metallogenic provinces, mineral camps, mineral deposits, and ore formation processes;
  - creating 3D mineral exploration models for key strategic deposit types;
  - devising innovative geoscientific methods for mineral exploration; and
  - updating an inventory of aggregate and mineral occurrences.
- Improve exploration methods for seafloor massive sulphide (SMS) deposits along the Kermadec arc, by:
  - determining the size, extent, and heat flow of active seafloor hydrothermal systems;
  - conducting high-resolution geophysical surveys to accurately locate and map sea-floor hydrothermal systems;
  - conducting remotely-operated vehicle (ROV) surveys to surgically sample hydrothermal systems for vent fluids, minerals, and rocks for genetic studies;
  - delineating the 3D structure of sea-floor hydrothermal systems and their associated mineralised systems through IODP drilling; and
  - developing holistic models for the formation of copper-gold, and other 'critical metals' required for 'green' technologies.
- In collaboration with Otago and Auckland universities, make available regional to deposit-scale exploration models to aid the discovery of new world-class gold-silver deposits in New Zealand and better-target resources in known deposits, by:
  - determining geological and structural controls on the occurrence of volcanic, intrusive, and orogenic ores, and characterising their geochemical and geophysical footprints to determine geochemical and mineralogical vectors to mineralisation; and
  - validating ore-deposit models.
- Use the trace-element and isotopic (Lu-Hf, O, U-Pb) composition of zircon as a pathfinder for mineral deposits in New Zealand's Western Province.

Uptake and implementation

The end-users of mineral data and interpretations are: NZP&M, who use mineral data, interpretations, and models to inform strategy and licensing policy, and resource assessment reports to attract mineral exploration companies, such as Hardie Pacific, to New Zealand; exploration and production companies, such as OceanaGold, and Blue-Pacific Minerals, who use research findings to inform and de-risk exploration strategies and enhance operational efficiency; consultants, such as Kenex, RSC, and Opus, who access basic mineral data to undertake their contracted work; iwi/Māori, including Te Rūnanga O Ngāi Tahu, Ngāti Hako, and Te Arawa; and regional councils, in particular Northland, Waikato, West Coast, and Otago, who also apply mineral prospectivity data to inform decision-making around resource assessment. Apart from published reports and data sets, the most effective modes of knowledge transfer are industry conference papers (AusIMM; PACRIM), articles in industry magazines and, particularly for the frontier offshore realm, peer-reviewed journal papers.

IMPACTS

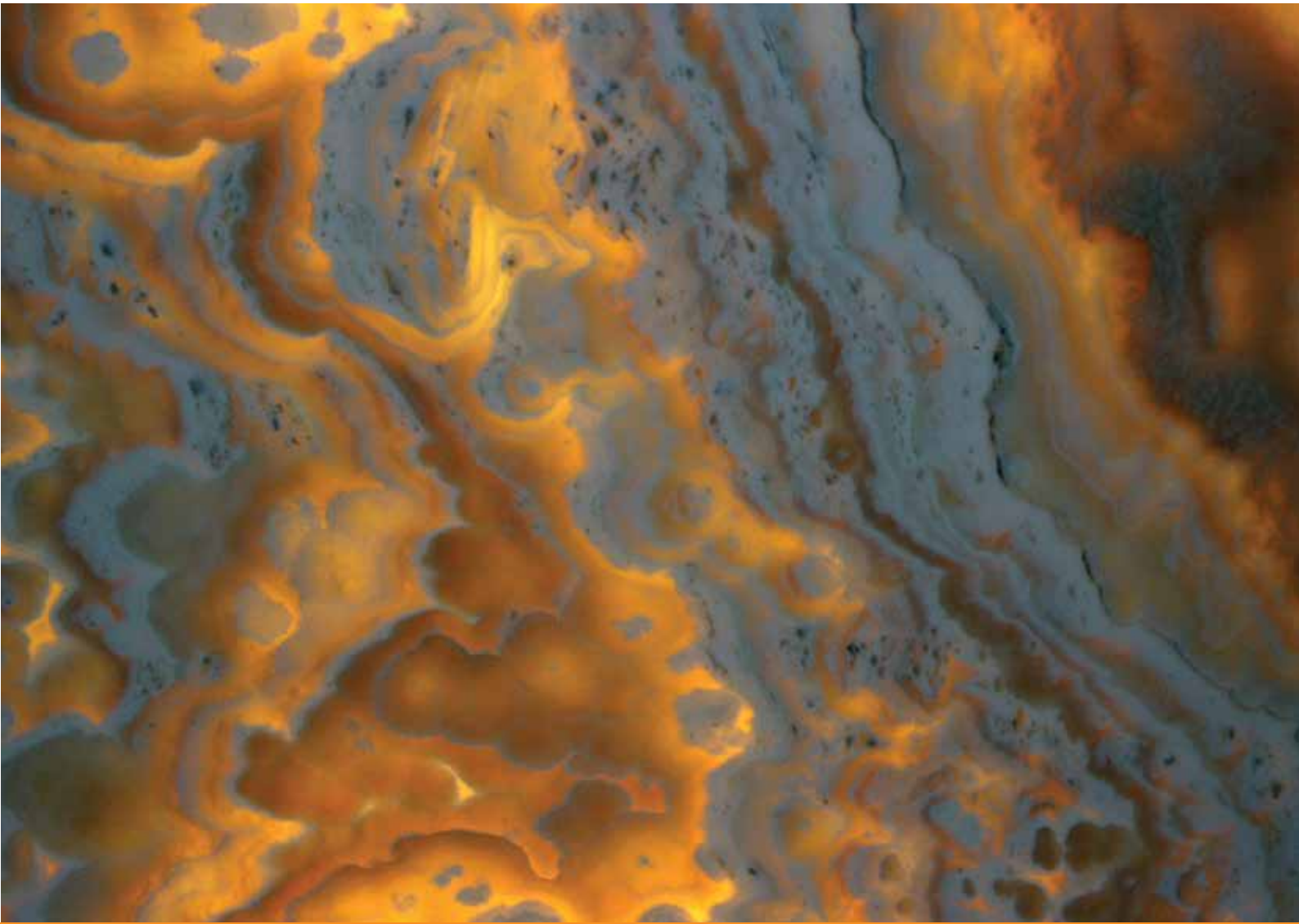
MEASURES OF SUCCESS

16. Enhanced mineral prospectivity

The provision of enhanced models and targets for exploration onshore, and within our EEZ, has enabled better-focused and more-efficient exploration, resulting in increased Government revenues, flow-on wealth creation, and security of supply, particularly for the critical metals required for 'green'-technology manufacturing.

By June 2020, new exploration and deposit models, and digital map products, are widely used by the minerals industry for investment-risk analysis.

By June 2022, New Zealand's mineral potential, as ranked in the Fraser Institute annual mining survey, has risen 10 points, taking it into the top 50 globally.



NEW MATERIALS & PROCESSES

Science outlook

Taking advantage of our niche in ion beam technology, we undertake research in advanced materials, with applications in the development of sensor devices and systems, and functional surfaces. Both areas have rapidly expanding global markets that are already worth billions of dollars. We modify the near-surface region of metallic and other substrates to alter surface properties, or to enhance performance in sensor applications (see page 3, 'Smarter buildings'). We work closely with several New Zealand manufacturers to develop and prototype the devices needed for energy conservation, security systems, food processing, medical applications, and other markets.

We are developing new materials and technologies for storage and efficient use of energy and energy networks and are seeking ways to achieve resilience of energy infrastructure to natural hazards. This includes development of new materials for improved energy efficiency in industrial processes (e.g. direct use of geothermal energy), new devices to harvest waste heat, and storage devices customised to local conditions.

Research aims

- Develop fundamental new materials and sensors for high-value manufacturing applications, as proof-of-concept precursors to more-specific product and process applications.
- Create new devices by firing ^{28}Si atoms into native silicon to eliminate ^{29}Si atoms that interfere with quantum computing.
- Develop a true cool black pigment, distinct in its ability to reflect most solar radiation.
- Develop next generation band-pass filters for use in the GHz communication bands.
- In collaboration with Victoria and Auckland universities, contribute to the development of a roadway-charging system for electric vehicle, by optimising methods for producing magnetic nanoparticles, nanofibers, microcrystalline powders, and polymers for the fabrication of magnetic flux guides.

Uptake and implementation

Close engagement or partnership with high-value manufacturers, such as Gallagher Group and Page MacRae, engineering consultants, such as HEPA, and technology incubators, such as WNT Ventures, Astrolab, and Powerhouse, ensures there is an active two-way flow of innovative ideas and knowledge. Involvement in R&D networks established within the University of Auckland's Product Accelerator, the MacDiarmid Institute, the Science for Technological innovation NSC, the NZ Materials Manufacturing Network, and TIDA, also facilitates uptake and implementation of research findings. Scientific papers, reports and industry seminars provide effective avenues for peer-review, while patents, where appropriate, ensure for IP protection.

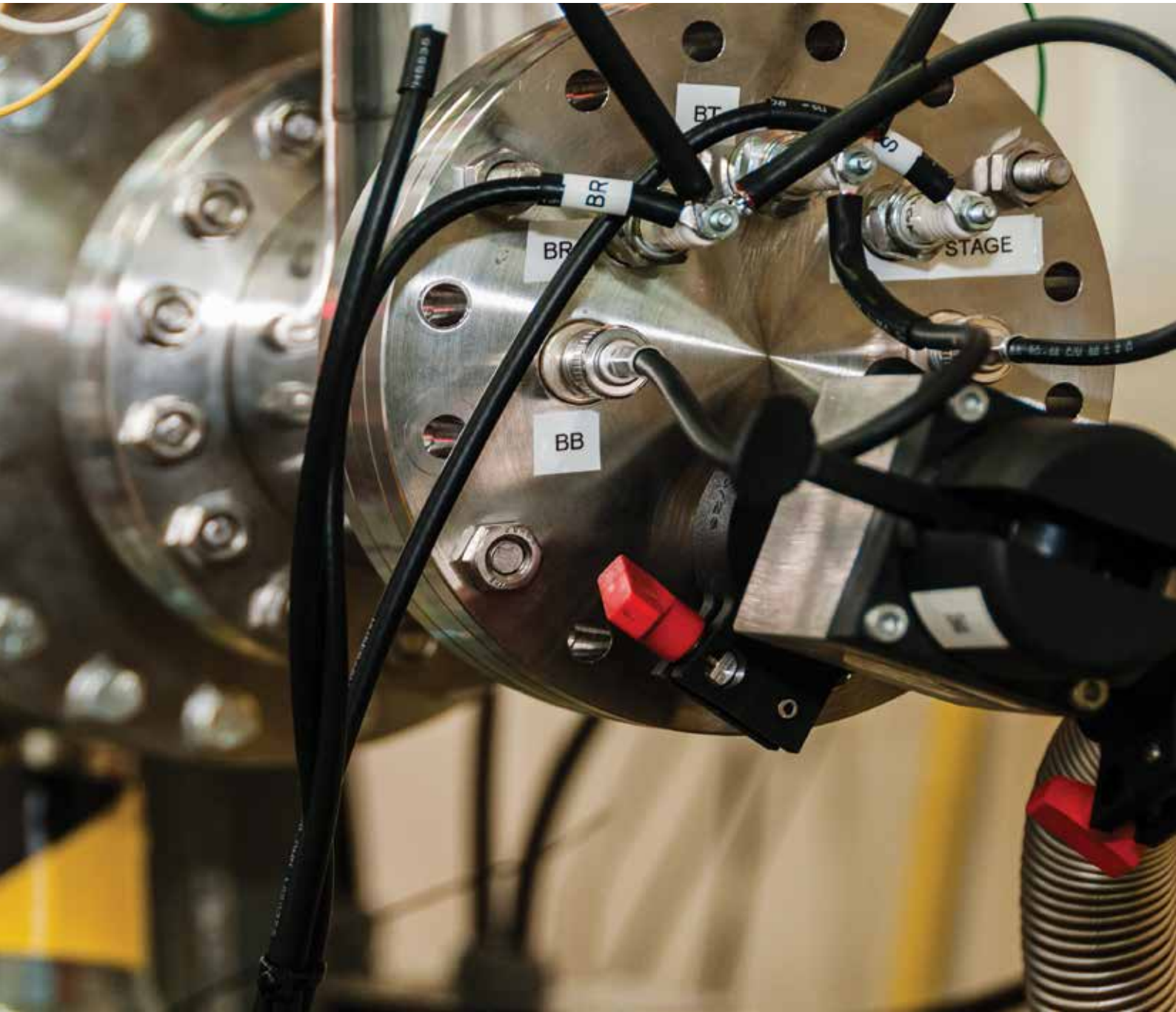
IMPACTS

MEASURES OF SUCCESS

17. More energy-efficient products

Technological innovations for renewable energy use have been developed by New Zealand companies, leading to more energy-efficient primary and manufacturing industries and products, and wealth creation.

By June 2020, R&D created by GNS Science is taken up and used by at least one primary industry or manufacturing company.



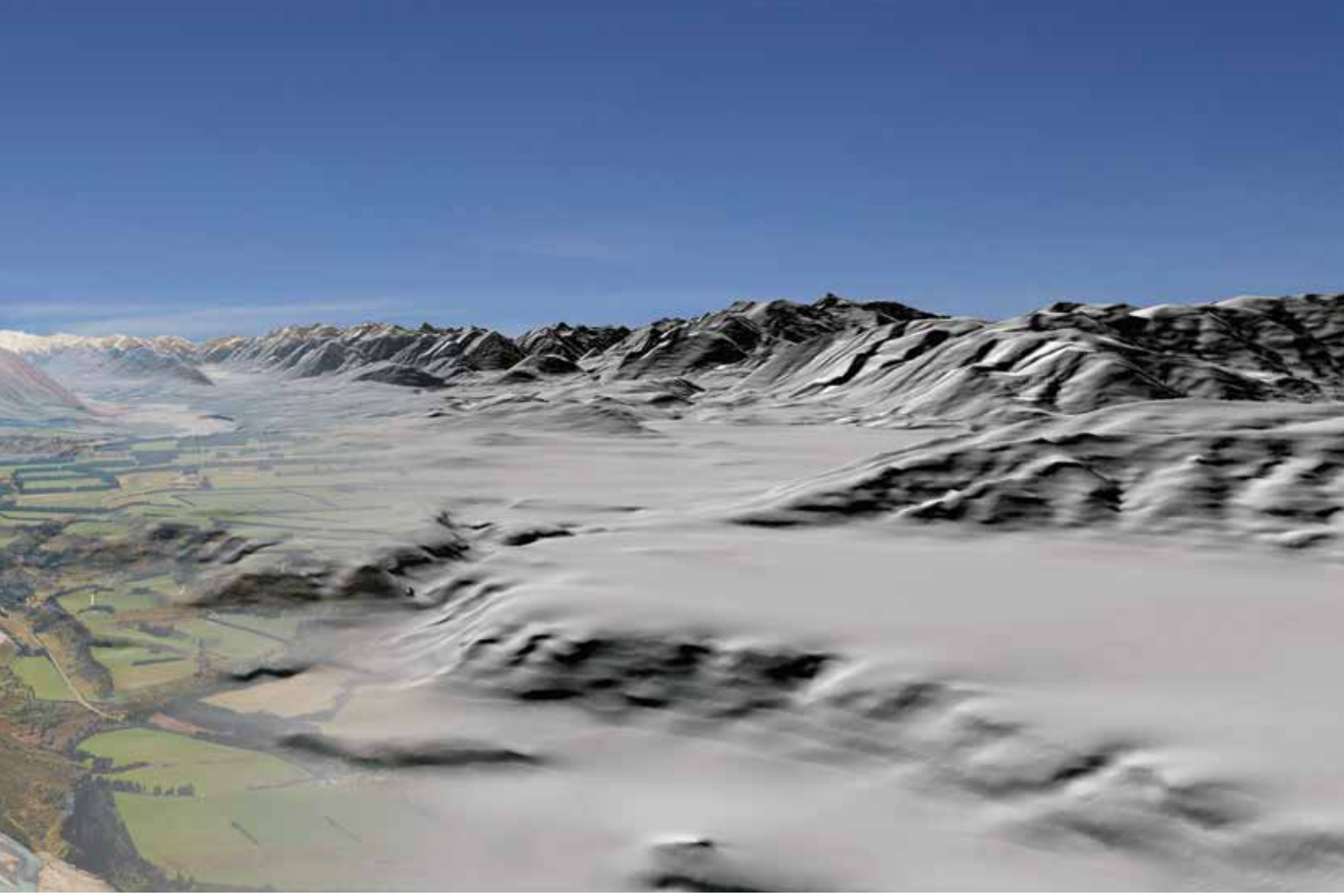
UNDERPINNING GEOSCIENCE KNOWLEDGE

Our role is to expand understanding of Earth science in New Zealand and to ensure that geoscientific information, data, and collections are acquired, managed, and made available to next- and end-users now and in the future, thus providing a comprehensive and accessible knowledge base to support policy and decision making by Government, communities, and industry.

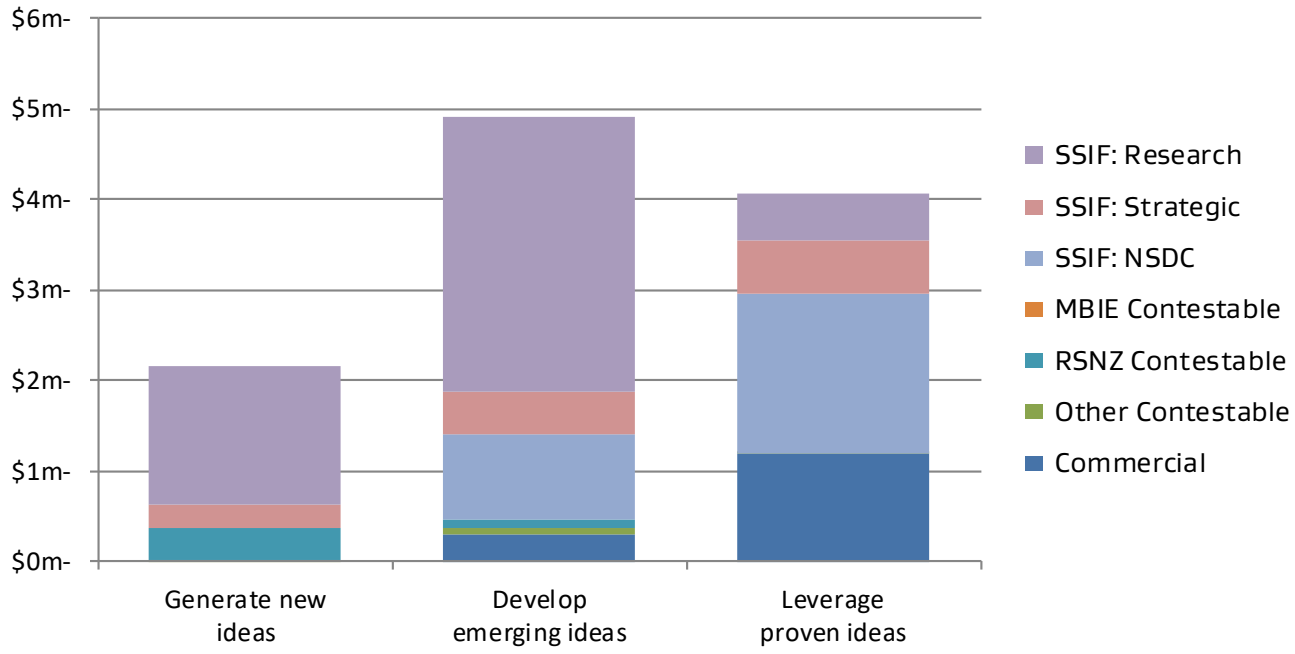
To achieve this, we will continue to explore and map the geological history, structure and processes of Zealandia. We will cooperate with the producers, users, and stewards of geoscience data and collections to ensure security and accessibility now and into the future. We will use geoscience information, high-performance computing, data analysis, and new technologies to facilitate innovation that serves local, regional, and national needs. And we will promote, educate and build public and stakeholder awareness of our geology, associated geoscience information and its potential benefits for the nation.

The 2018–19 investment of $11 million is 82% SSIF, 5% contestable 13% commercial. 72% supports the Zealandia Revealed Theme, and 28% Geoscience Information.

Research to 'generate new ideas' relates to data acquisition and the development of fundamental understandings of the geological makeup of Zealandia; research to 'develop emerging ideas' relates to database development and the refinement of pre-existing knowledge (mapping); whereas research to 'leverage proven ideas' relates to support of our Nationally Significant Databases and Collections (NSDC), and the use of acquired geoscience knowledge to solve current geoscientific problems.



Underpinning Geoscience Knowledge (2018-19 Investment)



ZEALANDIA REVEALED

Science outlook

As an island nation with one of the largest marine jurisdictions in the world (95% of its total EEZ; c. 6 million km^2), New Zealand has continental-scale resources, with attendant responsibilities and opportunities. It also has significant hazards related to the contact between the two active tectonic plates that straddle the continent, and Zealandia's sedimentary basins record the climate history of the southwest Pacific. Building on research begun in the 1960s, we will continue to survey and study the underlying geology of this vast continent, a task that is large by any measure. Our focus will be on collecting and interpreting geoscientific data in the Tasman and Campbell frontiers, northeast and southeast of New Zealand, respectively, the submarine volcanoes of the Kermadec arc, and the plate boundary zone extending from East Cape to Fiordland. The aim is to acquire information on the tectono-stratigraphic history of Zealandia, and baseline information on climate and environmental history, and on-going improvements to the New Zealand Geological Timescale, to underpin assessment of its hazard, climate change, and resource potential.

Such integrated marine and onshore research requires sophisticated and expensive infrastructure, which is leveraged through collaboration with overseas marine research organisations, such as IODP (see page 2, 'Probing Zealandia'). After drilling in the Tasman Sea (Lord Howe Rise) to investigate subduction initiation, drilling along the Hikurangi margin is investigating, for the first time, the physical controls on subduction earthquakes, including slow moving (days to months) plate-boundary slip events. Drilling of Brothers submarine volcano in the Kermadec arc is exploring the associated hydrothermal system, and the role of underlying magma. Other drilling legs within New Zealand's EEZ and the Ross Dependency are investigating climate change and gas hydrate formation.

Research aims

- Determine the underlying geological structure, and model the tectonic evolution of Zealandia, by:
  - synthesising long-term and short-term active crustal deformation, including rates of horizontal and vertical motion, strain, and stress;
  - analysing Hikurangi margin subduction and fore-arc processes, and Alpine Fault continental collision processes; and
  - determining feedback between tectonics and landscape evolution.
- Determine the crustal structure, tectonic history, resource potential and natural hazards of offshore Zealandia, using geophysical data, building on IODP drilling of the Lord Howe Rise, Brothers Volcano, and Hikurangi margin, and observatory installations monitoring near-surface deformation and seismicity.
- Develop a 3D model of the Taupo Rift, with a focus on faulting, large-scale structure, and dynamics;
- Refine the New Zealand timescale via integrated biostratigraphic and isotopic research.
- Determine the tectono-stratigraphic evolution, paleogeography, and sediment dispersal pathways within Cretaceous-Cenozoic successions of our offshore sedimentary basins (the Zealandia Megasequence).
- Detect temporal changes in stress associated with aseismic slip on the subduction interface, and determine how these stress changes impact seismicity in surrounding regions.
- Use Interferometric Synthetic Aperture Radar (InSAR) and GPS to measure South Island deformation, and provide new evidence for 'hidden faults'.

Uptake and implementation

Because of the fundamental nature and broad scope of research carried out under this theme, the main users are other researchers, who build on the knowledge and apply it to their own research into hazard resilience, environmental sustainability, geological resources, and crustal evolution. Thus, the main modes of knowledge transfer are high-impact peer-reviewed scientific papers and international conference presentations. This, and ready access to one of the world's best natural laboratories for studying active tectonics, results in a high degree of international science collaboration.

IMPACTS

MEASURES OF SUCCESS

18. Deeper understanding of crustal evolution

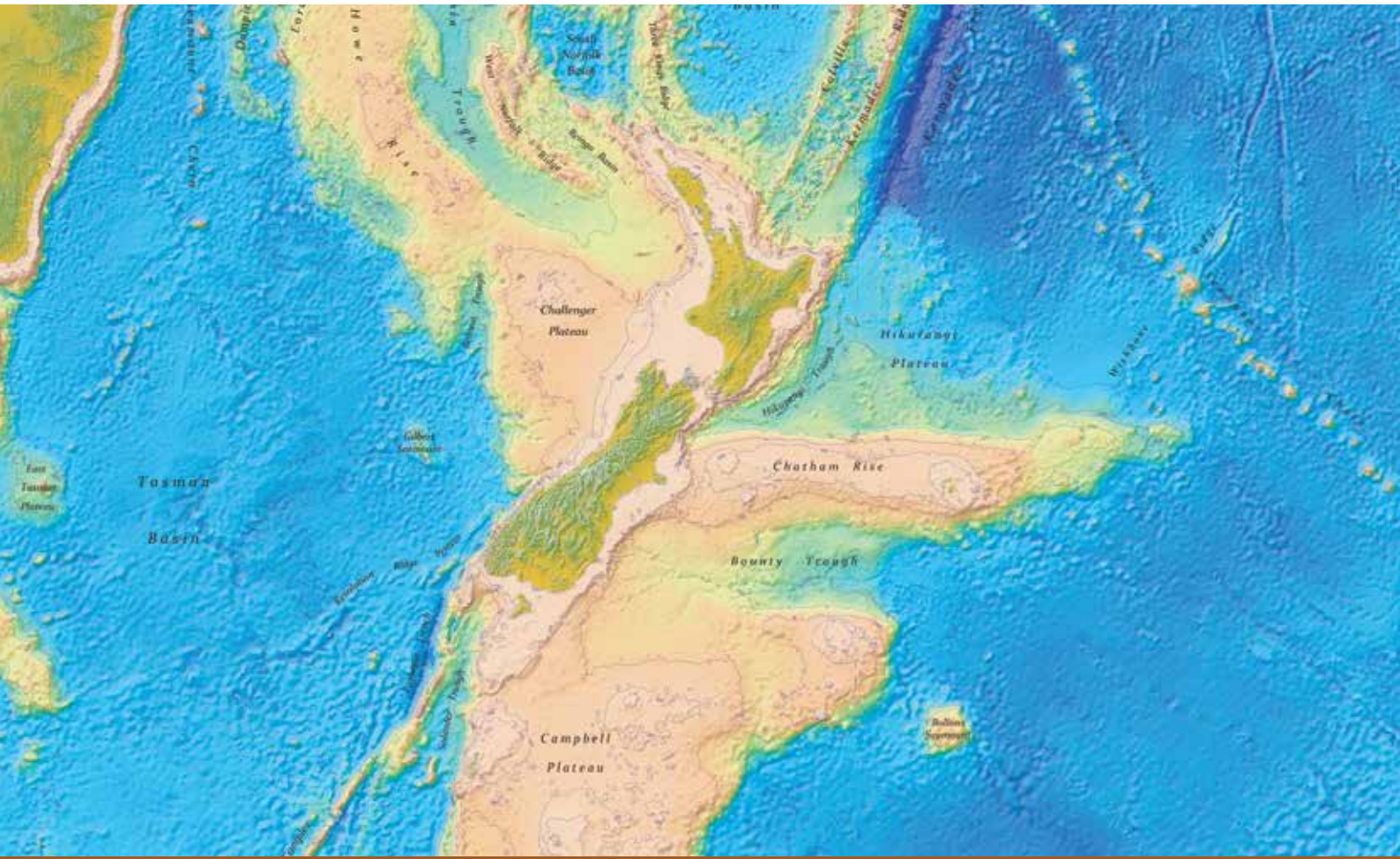
Higher-resolution and more-accurate characterisation of the composition, stratigraphy, structure, temporal and spatial tectonic evolution of, and fluid flow through, Zealandia, onshore and offshore, has underpinned estimates of resource and hazard potential.

19. Deeper understanding of Earth deformation and plate boundary processes

Enhanced knowledge of current rates of deformation and landscape change, and the nature of the Hikurangi megathrust, Taupo Rift, and Alpine-Marlborough-North Island Fault systems, has informed models of seismic hazard, leading to refined time-dependent estimates of seismic and tsunami hazard.

By June 2019, IODP drilling of the Hikurangi subduction zone, the Tasman Sea, and Brothers Volcano, is providing high-quality samples and data for analysis, and new and important insights.

By June 2021, tectonic, paleogeographic and geodetic information are being taken up and used for marine-and land-use planning and decision making, hazard assessment and risk mitigation, and/or resource assessment.



GEOSCIENCE INFORMATION

Science outlook

We have a long-term role as the national provider of trusted geoscience knowledge and of hosting, maintaining, and enhancing Nationally-Significant geoscience and geospatial Databases and Collections:

» Earthquake Information Database (EID)

» Fossil Record File (FRF)

» Geomagnetic Database (GMD)

» National Groundwater Monitoring Programme (NGMP)

» National Paleontology Collection (NPC) and associated databases

» National Petrology Reference Collection (NPRC) and PETLAB

» Regional Geological Map Archive and Data File (RGMAD)

» Volcano Database (VDB)

We also maintain approximately 30 other nationally-important databases and datasets that underpin New Zealand geoscience. Some of these are publicly accessible, including the Geological Resource Map of New Zealand (GERM), Landslide Database (LDB), Active Faults Database (AFDB), Petroleum Basin Explorer (PBE) and associated databases, Geodetic Database, and the Strong Motion Database.

To realise the full value of these assets to the nation and the research community, we actively seek ways to enhance efficient and widespread utilisation, by: improving the quality and depth of our data; managing national sample collections; updating and delivering geological maps, analyses and information; implementing global standards; and adopting emerging technologies for enhanced data delivery.

Research aims

» Assess the functionality of all our nationally significant and other nationally important databases, and validate their effectiveness within the context of a wider database management strategy and implementation roadmap.

» Maintain and improve data integrity for the Earthquake Information Database, progressively 'relocating' historic earthquake data, ensuring improved and more consistent seismic moment and magnitudes for historic and recent events.

» Maintain an up-to-date Stratigraphic Lexicon and enhance the National Paleontology Collection with new catalogues and taxonomic data.

» Improve functionality, security, and robustness of the delivery mechanisms for the Fossil Record File, integrating it better with the National Paleontology Collection.

» Collect and process continuous magnetic data from Eyrewell (Canterbury), Scott Base (Antarctica) and Apia (Samoa) for the Geomagnetic Database, submitting the data to the INTERMAGNET global directory to the required specifications.

» Maintain the National Groundwater Monitoring Programme, analysing samples for water quality parameters (chemistry, age, nutrients, and microbial biodiversity), improving legacy data quality, and optimising data accessibility.

» Absorb new collections into the National Petrology Reference Collection and enter associated information into the PETLAB online database, improving public accessibility through new data licensing, and reviewing database quality, structure and functionality.

» Acquire geospatial information on geological features of New Zealand and its territories through digital capture of legacy geological maps held in the Regional Geological Map Archive and Data File, updating national digital geological map products and generating new geological maps and associated datasets of cities, volcanic centres and Antarctica, adopting relevant international data standards, and ensuring versatile and technologically-current delivery of these geological map products.

» Migrate all relevant data to a redesigned comprehensive Volcano Database structure and implement data-quality assessment procedures, future monitoring-related data capture and data visualisation and accessibility interfaces.

Uptake and implementation

Ready access to quality geoscience data, in the form of analyses, data sets, archived samples, images, maps, and map products, is required by a wide range of users involved in research, strategy, or decision making. Government-funded researchers supported by, for example, MBIE Endeavour, RSNZ Marsden, QuakeCoRE, DEVORA, It's Our Fault, East Coast LAB, and the Resilience, Deep South, Sustainable Seas, and Our Land and Water NSCs, add value to the data to create new knowledge across a broad range of sectors.

Officials in government ministries, regional councils, territorial authorities, and other agencies use the information as an evidence base for development of policy and procedure. Technical officers within the resource, infrastructure, environment, and civil defence sectors use the data to de-risk economic analysis and to inform critical decision making. Geoscience information, in the form of popular articles and media releases, is also taken up by iwi/Māori and the public to enhance their knowledge of Earth systems, and help inform opinion and community decision making.

IMPACTS

MEASURES OF SUCCESS

20. Enhanced database efficacy

Our most important databases and collections are all of a known quality, and have documented operating principles and properties, allowing their data to be used with more efficiency, confidence, and consistency.

By June 2019, a Data Management Strategy and Roadmap is in place for our eight Nationally Significant Databases and Collections, and all are being managed to those expectations.

By June 2021, there is enhanced usage, with positive feedback, for our publicly-accessible databases, leading to impacts across a wide range of geoscience applications in the environment, resources, geohazard, and education sectors.

HORIZON SCANNING

A component of our SSIF (c. $2.4 million annually), named the 'Strategic Development Fund' (SDF), is allocated contestably on a two-year cycle to investigate the potential of innovative research ideas. Such ideas may require 'pilot' testing for research or commercial potential before they can be considered for longer-term investment.

Examples of targeted projects, to be completed by June 2019, include:

- Integrating biostratigraphic research over four IODP legs in the New Zealand region, generating well-calibrated paleontological data from across Zealandia that will transform the NZ Geological Timescale and biostratigraphic database.
- Determining fossil fuel and CO_2 fluxes for New Zealand's largest city, Auckland.
- Enhancing our Vision Mātauranga research capability by appointing a new Māori social scientist and increasing support for existing Māori researchers.
- Strategically designing, building, and implementing features to enhance the OpenQuake engine for research and commercial use.
- Addressing the weakness in generating probabilities of additional large earthquakes in Kaikoura-like events by developing an advanced modern earthquake simulator.
- Addressing deficiencies in the National Seismic Hazard Model that affect our ability to conduct seismic hazard consultancy, namely insufficient modelling of fault uncertainty, and a lack of documentation of fault-source development.
- Supporting on-ship involvement with IODP drilling of Brothers Volcano, increasing our understanding of mineral deposit formation along arcs, sub-seafloor architecture, and the relationship between magmatic fluid discharge and the deep biosphere.

- Building the foundations for a game-changing fabrication technology for rapid micro-electronic prototyping (atomic 4D printing).
- Bringing together a team of scientists and support staff to firmly, tangibly, and indelibly associate GNS Science with the past, present, and future discovery and exploration of onshore and offshore Zealandia.
- Using data acquired from IODP drilling of the Tasman Frontier to refine our understanding of Paleocene-Recent tectonic and climate events in NW Zealandia.
- Developing a non-proprietary information store for next-generation 3D geological modelling components.

From 2018-19, we have boosted our SSIF investment in two key strategic areas:

1. Developing and updating models for a fuller range of natural hazard perils, putting in place the building blocks for creating a comparative natural hazard risk model (see page 46, Research aims); and
2. Developing modelling capability to deliver a hydrological 'QMap' of New Zealand, and associated models (10-year plan), creating the building blocks that will allow decisions on sustainable groundwater management (see page 38).

We have also set aside some SSIF to further improve our implementation of Vision Mātauranga in our science programmes, recognising the need to develop capability and culture to both increase engagement, and support scientific development, with Māori.

We have invested a similar amount for the development of a data and analytics strategy, recognising that Big Data and analytics will shape the future science and innovation landscape, and that GNS Science needs to understand and capitalise on the opportunities that will arise from better utilisation and custodianship of our national data sets.

SSIF will also be used to integrate social science disciplines across our research portfolio, beyond natural hazards, to broaden GNS Science's impact and influence with communities.

PERFORMANCE MONITORING

The overall performance of GNS Science is monitored via the set of Key Performance Indicators (KPIs) set out in the table below. The KPIs are complementary to the 27 Measures of Success linked to the Research Aims and Impacts detailed on pages 34 to 65.

2018–19 deliverables additional to the 'Upcoming Milestones' on pages 2 and 3 and the 'Horizon Scanning' initiatives on pages 66 and 67 are:

- GeoNet has a 24/7 awake monitoring service in place, including enhanced capability to respond to local-source tsunamis.
- A global volcanic impacts database hosted by GNS Science is being operated, in collaboration with the US Geological Survey and the Global Volcano Model.
- Research findings on societal resilience have become a key part of MCDEM's new strategy.
- New Zealand geothermal reservoir models are being built using a new flow simulator, and validated using a suite of enhanced modelling tools.
- IODP drilling of the Hikurangi subduction zone, the Tasman Sea, and Brothers Volcano, is providing high-quality samples and data for analysis, and new and important insights.
- A Data Management Strategy and Roadmap is in place for our eight Nationally Significant Databases and Collections, and all are being managed to those expectations.

Indicator	Measure	Year ending 30 June	Forecast 2017-18	Budget 2018-19	Outlook 2019-20	Outlook 2020-21
Strategic Intent						
Priority setting	Surveyed end-users* have confidence that GNS Science considers their sector's priorities when setting their research priorities		>70%	>70%	>70%	>70%
Team selection	Surveyed end-users* have confidence that GNS Science has assembled 'best' teams for research delivery		>85%	>85%	>85%	>85%

Indicator	Measure	Year ending 30 June	Forecast 2017-18	Budget 2018-19	Outlook 2019-20	Outlook 2020-21
Impact						
Research delivery	Research milestones (critical steps) on track or completed		>85%	>85%	>85%	>85%
Impact case studies	Impact case studies published		3	3	3	3
Knowledge transfer	Surveyed end-users* have adopted knowledge from GNS Science in the past three years		>90%	>90%	>90%	>90%
Science Excellence						
Peer-review	Programme reviews carried out		5	5	5	5
Publication impact	Impact of scientific publications (weighted citation index)**		3.0	3.0	3.2	3.2
Joint publications	Papers co-authored		90%	90%	90%	90%
Research Leverage						
Discovery science	Proportion of (basic) science investment (new ideas generation)		30	30	30	30
Co-funding	Commercial revenue per scientist FTE ($000)		80	80	80	80
Consultancy	Commercial reports per scientist FTE		1	1	1	1
Vision Mātauranga						
Māori engagement	Projects with Māori stakeholders embedded in the research		4	4	5	5
High Performance Culture						
Health & Safety	Recordable injuries per 200,000 work hours (rolling 12-month average)		<3	<3	<2	<2
Staff morale	Percentage of staff proud to work for GNS Science (biennial climate survey)		75%	75%	>80%	>80%

* Based on a biennial MBIE-commissioned Colmar Brunton Survey (>50 respondents)

**Mean 2-year impact factor for SCImago-assessed journals, weighted by the number of GNS Science publications

FINANCIAL FORECASTING

GNS Science has in recent years delivered consistent base-line normalised operational profits, which have been punctuated by increased activity and associated revenues caused by significant national events—for example responses to the Canterbury earthquakes of 2010-11, and the Kaikoura earthquake of 2016.

The strategic reorganisation of our executive and corporate services, and science division structure, coupled with changes to SSIF allocation, clearly has financial consequences. In the short-term, financial performance will be adversely affected by costs associated with conducting the Strategic Review, and restructuring, after which we anticipate the Institute to be well placed to deliver strong and sustainable financial performance.

Capital investment plans include on-going investment in scientific equipment to support our science activities and to secure new revenue streams. Our rolling IT upgrade, and our building and facility refurbishment programmes will continue. Our capital investment programme will, however, be affected by the ongoing Strategic Review.

GNS Science has sufficient actual and forecast cash flows to meet the requirements of the business during and beyond the years affected by the Strategic Review. Commercial revenue declined during 2017-18, due to difficult trading conditions in the energy sector, but is expected to rebound over time as a result of Strategic Review initiatives.

A major, nationally significant infrastructure investment by MBIE has been made around the delivery of a 24/7 immediate geohazards warning system (EGM), and forecast revenue and cash flow streams reflect this.

Budgeted revenue for the 2018-19 financial year is $94.4 million with planned earnings before interest and tax of $2.2 million.

Deployment of SSIF

The $27.54 million SSIF investment (see table, page 71) enables GNS Science to build with confidence and with speed, science capability in areas of national need. Without SSIF, developing capability would have been a slow and uncertain process via contestable bidding. Our science users also benefit from being able to align their funding with our SSIF and hence boost outcome delivery.

SSIF has remained constant since its introduction in 2010, apart from a $423k increase in support for our Nationally Significant Databases and Collections in the 2015 Budget. At a programme level, there has, and will continue to be, investment adjustments made on the basis of changing sector priorities and shifts in international science (see pages 6 and 67). Such changes are implemented by the Executive with Board approval.

Commercial value

Section 16(3) of the CRI Act requires the Company to furnish an estimate of the current commercial value of the Crown's investment. We use net asset value as a proxy for the commercial value of the Group. The net asset position as shown in accordance with the company's accounting policies for 30 June 2017 was $34.9 million

Dividend policy

Our dividend policy states that the Company may elect to return surplus cash to shareholders in the form of a dividend when no sound investment opportunities exist (including reinvestment, commercialisation, capital expenditure, and the retention of important capabilities). In determining surplus cash, the Board will also give consideration to the ongoing financial viability of the company and their obligations under the Companies Act 1993. Any dividend would be paid within two months of the end of the financial year.

Compensation

Where the Crown wishes us to undertake activities or assume obligations that will result in a reduction of our profit or net worth, the Board will seek compensation sufficient to allow the Company's position to be restored. No compensation is currently being sought from the Crown.

Government Outcome Area	Research ($k)	NSC Aligned ($k)	Database Support ($k)	Total ($k)
Biological Industries	0	0	0	0
Energy and Minerals	6,431	400	821	7,652
Hazards and Infrastructure	10,937	1,000	1,160	13,098
Environment	3,835	900	714	5449
High-value Manufacturing	424	250	0	674
Capability Enhancement	666	0	0	666
Total	22,292	2,550	2,696	27,538

Group Ratios and Statistics						
Year ending 30 June	**Forecast 2018**	**Budget 2019**	**Outlook 2020**	**Outlook 2021**	**Outlook 2022**	**Outlook 2023**
Revenue ($000s)						
Total Revenue	87,806	94,414	95,470	97,350	99,460	101,600
Revenue growth	1.7%	7.5%	1.1%	2.0%	2.2%	2.2%
Operating results ($000s)						
Operating expenses (excluding depreciation)	82,766	86,253	86,526	87,698	89,152	90,930
EBITDA	5,040	8,161	8,944	9,652	10,308	10,669
EBIT	(1,880)	2,161	2,944	3,652	4,158	4,422
Profit before tax	(1,250)	2,701	3,444	4,152	4,708	4,972
Profit after tax	(900)	1,945	2,480	2,990	3,390	3,580
EBITDA per FTE	13	20	22	24	25	26
Total assets	60,777	60,476	62,166	64,380	67,504	70,816
Total equity	34,011	35,706	37,936	40,676	43,816	47,146
Capital expenditure	4,300	7,350	6,850	6,350	6,350	6,850
Liquidity						
Quick ratio	2.4 x	2.3 x	2.2 x	2.2 x	2.3 x	2.5 x
Interest coverage	168.0 x	N/A	N/A	N/A	N/A	N/A
Profitability						
Return on equity	(2.6%)	5.6%	6.7%	7.6%	8.0%	7.9%
Operating margin	5.7%	8.6%	9.4%	9.9%	10.4%	10.5%
Operational risk						
Profit volatility	25.0%	25.0%	23.3%	22.2%	21.8%	9.5%
Forecasting risk	(2.6%)					
Growth/Investment						
Capital renewal	0.8 x	1.2 x	1.1 x	1.1 x	1.0 x	1.1 x
Financial strength						
Equity ratio	56.0%	59.0%	61.0%	63.2%	64.9%	66.6%

ACCOUNTING POLICIES

REPORTING ENTITY AND ACTIVITIES

The Institute of Geological and Nuclear Sciences Limited is established under the Crown Research Institutes Act 1992 and the Companies Act 1993. Its subsidiary companies are established under the Companies Act 1993. The financial statements have been prepared in accordance with the Crown Research Institutes Act 1992, the Public Finance Act 1989, the Companies Act 1993, the Crown Entities Act 2004 and the Financial Reporting Act 2013.

Consolidated financial statements for the group comprising the Institute of Geological and Nuclear Sciences Limited (the Company) and its subsidiaries are presented and the effects of intra-group transactions are fully eliminated in the consolidated financial statements. Subsidiaries are those entities controlled by the Company. Control is achieved where the Company has the power to govern the financial and operating policies of an entity to obtain benefits from its activities.

The subsidiaries of the Company are:

Isoscan Limited

Isoscan Food Limited

Geological Surveys (New Zealand) Limited

Geological Risk Limited

GNS Science International Limited

The principal activities of the Group are to undertake geoscience and isotope science research, development and commercial projects, predominantly in New Zealand.

REVENUE

Strategic Science Investment Fund

The Company is party to a Strategic Science Investment Fund (SSIF) agreement with the Crown to perform research activities. Revenue under this contract is treated as a Government Grant under NZ IAS 20.

Revenue from other research and commercial contracts

Revenue earned from the supply of goods and services is measured at the fair value of consideration received. Revenue from services is recognised based on the percentage of work completed. Any amounts received in relation to work not yet commenced are recorded as revenue in advance.

Revenue from the supply of goods is recognised when the significant risks and rewards of ownership of the goods have been transferred to the buyer.

PROPERTY, PLANT AND EQUIPMENT

Property, plant and equipment are stated at cost less accumulated depreciation and impairment. Cost includes expenditure that is directly attributable to the acquisition of the item. Assets have been depreciated on a straight-line basis at rates calculated to allocate the assets' cost over their estimated remaining useful lives. Freehold land is not depreciated.

The estimated useful lives, residual values and depreciation methods are reviewed annually, with the effect of any changes in estimate accounted for on a prospective basis.

The gain or loss arising on the disposal or retirement of an item of property, plant and equipment is recognised in profit or loss.

Heritage assets - collections, library and databases

The Company owns various collections, library resources and databases that are an integral part of the research work undertaken by the Company. These collections are highly specialised and there is no reliable basis for establishing a valuation. The two major collections are:

The National Paleontological Collection
The National Petrological Reference Collection

INTANGIBLE ASSETS

Software, patents and capitalised development costs have a finite life and are included at cost less accumulated amortisation and impairment. Amortisation is charged on a straight-line basis at rates calculated to allocate the assets' cost over their estimated remaining useful lives.

The estimated useful life and amortisation method are reviewed annually, with the effect of any changes in estimate being accounted for on a prospective basis.

The following useful lives are used in the calculation of amortisation:

Software	4–8 years
Patents	4–17 years
Capitalised development costs	4–8 years

DEFERRED TAX

Deferred tax is accounted for using the comprehensive balance sheet liability method in respect of temporary differences arising from differences between the carrying amount of assets and liabilities in the financial statements and the corresponding tax base of those items. In principle, deferred tax liabilities are recognised for all taxable temporary differences.

Deferred tax assets are recognised to the extent that it is probable that sufficient taxable amounts will be available against which deductible temporary differences or unused tax losses and tax offsets can be utilised.

The carrying amount of deferred tax assets is reviewed and reduced to the extent that it is no longer probable that sufficient taxable profits will be available to allow all or part of the assets to be recovered.

Deferred tax assets and liabilities are measured at the tax rates that are expected to apply in the period in which the liability is settled or the asset realised.

Under Section OB1(2)(d) of the Income Tax Act (2007), the Company is not required to maintain an imputation credit account.

EMPLOYEE ENTITLEMENTS

Liabilities for wages and salaries, annual leave, long service leave and retirement leave are recognised when it is probable that settlement will be required and they are capable of being reliably measured.

Employee benefits to be settled within twelve months are reported at the amount expected to be paid and are classified as current liabilities. Employee benefits not expected to be settled within twelve months are reported at the present value of the estimated future cash outflows.

Provisions for long service leave and retirement leave depend on a number of assumptions such as the expected employment period of employees, salary levels and the timing of employees taking leave. When measuring employee benefit liabilities risk-free discount rates provided by The Treasury are used as the appropriate discount rates, the salary increase factor is based on forecast information and employee pattern of leave has been determined after considering historical data.

TRADE AND OTHER PAYABLES

Trade and other payables are non-interest bearing and are normally settled on the 20th of the month following receipt of invoice. The carrying value of creditors and other payables approximates their fair value.

RELATED PARTY TRANSACTIONS

The Crown is the ultimate shareholder of the Company. No other transactions with New Zealand government owned entities are considered as related party transactions in terms of NZ IAS 24.

FINANCIAL INSTRUMENTS

Capital management

The Group manages its capital to ensure that entities in the Group will be able to continue as going concerns while maximising the return to shareholders through the optimisation of the debt and equity balance.

The capital structure of the Group consists of cash and cash equivalents, and equity attributable to equity holders of the parent, comprising issued capital and retained earnings. The Group is not subject to any externally imposed capital requirements.

Currency risk

The Group undertakes certain transactions denominated in foreign currencies. Exchange rate exposures are managed within approved policy limits using forward foreign exchange contracts.

These derivative financial instruments are initially recognised at fair value on the date the derivative contract is entered into and are subsequently remeasured to their fair value at the end of each reporting period. Derivatives are carried as assets when the fair value is positive and as liabilities when the fair value is negative. The resulting profit or loss is recognised in profit and loss immediately, unless the derivative is designated effective as a hedging instrument, in which event the timing of the recognition in profit or loss depends on the nature of the hedging relationship.

The effective portion of changes in the fair value of cash flow hedges is recognised in other comprehensive income and accumulated in a cash flow hedge reserve. The gain or loss relating to any ineffective portion is recognised immediately in profit or loss.

Interest rate risk

The Group operates a call account and has short-term deposits on which interest is earned. Where possible the Group manages exposures to interest rate fluctuations through prudent management of its treasury operations.

In managing interest rate risks the Group aims to reduce the impact of short-term fluctuations on earnings. Over the longer-term, however, permanent changes in interest rates will have an impact on profit.

Credit risk management

The financial instruments which expose the Group to credit risk are principally bank balances, short term investments and accounts receivable. The Group monitors credit risk on an ongoing basis.

Bank balances and short-term investments are held with New Zealand registered banks in accordance with the Group's treasury policy.

No collateral is held by the Group in respect of bank balances, short term investments or accounts receivable. The maximum exposure to credit risk is represented by the carrying value of each financial asset in the Balance Sheet.

Liquidity risks

The Group manages liquidity risk by maintaining adequate reserves, cash deposits and reserve borrowing facilities, by monitoring forecast and actual cash flows and matching the maturity profiles of financial assets and liabilities, all of which are of a short-term nature. The Group continues to generate sufficient cash flows from operations to meet financial liabilities.

COMMITMENTS

Non-cancellable operating lease commitments

Operating lease payments are recognised on a systematic basis representing the pattern in which economic benefits from the leased asset are consumed over the lease term.

Leases are classified as finance leases whenever the terms of the lease transfer a significant portion of all of the risks and rewards of ownership to the lessee. All other leases are classified as operating leases.

The Group has no leases which would be classified as finance leases.

PREPARATION DISCLOSURES

Statement of compliance

The financial statements have been prepared in accordance with New Zealand generally accepted accounting practice. They comply with New Zealand equivalents to International Financial Reporting Standards and other applicable Financial Reporting Standards, as appropriate for profit-oriented entities. The financial statements also comply with International Financial Reporting Standards.

Accounting policies have been applied consistently to all periods presented in the financial statements.

Measurement basis

The financial statements of the Group have been prepared on an historical cost basis, except that derivative financial instruments are measured at their fair value.

Transactions in foreign currencies are converted at the New Zealand rate of exchange ruling on the date of the transaction. Monetary assets and liabilities at year end are converted to New Zealand dollars at the exchange rate ruling at balance date.

The financial statements are presented in New Zealand dollars which is the Group's functional currency. All values are rounded to the nearest thousand dollars.

Interest in joint arrangements

A joint arrangement is an arrangement whereby the Company or its subsidiaries have joint control over an entity. Joint control is the contractually agreed sharing of control of an arrangement, which exists only when decisions about the relevant activities of that entity require the unanimous consent of the parties sharing control. A joint arrangement is either a joint operation or a joint venture. For a joint operation the Group recognises its share of assets, liabilities, revenues and expenses on a line-by-line basis using the proportionate method. For a joint venture the Group recognises its interest in a joint venture as an investment and accounts for that investment using the equity method.

Classification of financial assets and liabilities

The Group holds loans and receivables. These are measured at cost less impairment, or in the case of trade receivables, reduced by an allowance for doubtful debts.

Financial liabilities, excluding derivative financial instruments, are classified as 'other financial liabilities'.

Other financial liabilities are initially measured at fair value, net of transaction costs. Other financial liabilities are subsequently measured at amortised cost, with interest expense recognised on an effective interest basis.

Critical accounting estimates and judgements

In applying the accounting policies, there is the requirement for judgements, estimates and assumptions to be made about the carrying amounts of some assets and liabilities. The estimates and assumptions are based on historical experience and other relevant factors. Actual results may differ from these estimates.

Accounting policies where critical estimates have been made include property, plant and equipment, intangible assets, impairment of assets and liabilities and employee benefits. Judgement has been applied in determining not to value heritage assets for financial reporting purposes.

New standards and interpretations not yet adopted

Standards and interpretations effective in the current period - there are no new standards and interpretations effective in the current period with a material impact.

Standards and interpretations approved but not yet in effect – New or revised standards and interpretations that have been approved but are not yet in effect have not been adopted for the year ended 30 June 2017. The adoption of these standards and interpretations is not expected to have a material recognition or measurement impact on the financial statements. These will be applied when they become mandatory.

IMAGE CREDITS

FRONT/BACK COVER:
The road to Aoraki, deep in the Southern Alps, *Hamish Clark - unsplash.com*

UPCOMING MILESTONES (pages 2–3):
Auckland Skyline at sunset, *Unknown*

Seismic Monitoring, *Unknown*

Lakes Waikareiti and Waikaremoana, Te Urewera National Park, *Dougal Townsend*

Mount Herschel and pack ice, Antarctica, *Lloyd Homer*

Joides Resolution ocean drilling research ship berthed in Wellington, *Margaret Low*

Groundwater, Pupu springs, *Unknown*

A low-angle shot of the sharp edges of a glass skyscraper shrouded in fog, *Patrick Tomasso*

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Sea Caves; Jam Roll Bay; Tongaporutu; Taranaki Coast, *Lloyd Homer*

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Lake Tekapo, *Tobias Keller - unsplash.com*

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The road to Mt Cook, *Quentin Leclercq - unsplash.com*

Benmore Power Station, *Llyod Homer*

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Colombo Street after Christchurch Earthquake 2011, *Margaret Low*

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Crater on White Island (Whakaari) Volcano, Bay of Plenty, *Lloyd Homer*

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Sweet corn booth at Whakarewarewa Village, *Margaret Low*

Piako River, *Unknown*

Awahou Stream, Kaitiaki, *Unknown*

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Maori Cape, *Unknown*

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Flecked Peak, Mid Burn, Stuart Mountains, Southland, *Lloyd Homer*

Inside the ice core tent, Antarctica, *Nancy Bertler*

Mount Erebus, Antarctica, *Lloyd Homer*

Kaikoura Peninsula, Marlborough, *Lloyd Homer*

Fumarole 0 Reinstall, White Island, *Tony Hurst*

Road damage at Mounsey Creek bridge, SH1 caused by Kaikoura Earthquake 2016, *William Ries*

House teetering after a landslide, Maungaraki, Wellington, *Lloyd Homer*

Christchurch earthquake damage clearance, *Margaret Low*

GNS Science scientists with oil company representatives on the North Taranaki Coast, *Peter King*

Symmetry in Energy, Ngatamariki Geothermal Power Station, Taupō, *Chris Sisarich - nzstory.govt.nz*

Gas Hydrate sample, *IFM-GEOMAR*

Marble like mineral deposits, *Unknown*

Ion beam implanter National Isotope Centre, *Margaret Low*

Canterbury plains and Southern Alps blend into 3D topographic data, *GNS Science*

Zealandia Map, *GNS Science*

Hokonui Hills - strike ridges in the Southland Syncline, *Lloyd Homer*

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GPS measurement equipment on the top of the Southern Alps, *Aline Peltier*

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Cliffs and lagoon at Castlepoint, Wairarapa, *Lloyd Homer*

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Waiau Falls, Coramandel, *Lloyd Homer*
Putangirua Stream, Te Kopi, *Lloyd Homer*

ACCOUNTING POLICIES (page 74–77)
Money, *Public Access - negativespace.co*

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