GNS SCIENCE 2016 ANNUAL REPORT

MAKING A WORLD OF DIFFERENCE

BOTH LOCALLY

The capabilities of GNS Science cover the spectrum of geosciences and are complemented by skills in isotope technologies and social science. Our strategic value to New Zealand encompasses knowledge and understanding of indigenous energy sources, groundwater, mineral resources, geological hazards, climate change, risk assessment, air quality monitoring, new materials, and marine geology. Our approach is to be highly collaborative and this enables us to assemble the best possible teams for every project.

CONTENTS

LIVING ON A PLATE BOUNDARY

Nature's forces can change our world dramatically at any time. Our work in understanding the processes and impacts of earthquakes, eruptions, tsunamis, and landslides helps to reduce the risks and downstream impacts of these hazards, increases the resilience of our buildings and infrastructure, and helps to minimise casualties. The more we learn about these hazards, the better prepared we are to deal with them.

SCIENCE AND SOCIETY

Communicating our science to the public is a priority for GNS Science. We have a range of channels for distributing our public messages including teacher networks, school visits, the media, public presentations, YouTube, social media, our website and exhibitions. One such exhibition is Dinosaur Footprints: A Story of Discovery, which has toured New Zealand for nearly three years. With support from principal sponsor NZ Oil & Gas, it has been showcased at 11 venues and seen by more than 250,000 visitors.

MONITORING AIR QUALITY

Two thirds of New Zealanders live in urban areas that experience episodes of degraded air quality, particularly in winter. We use our specialist expertise in ion beam analysis to identify the sources of tiny particles of matter suspended in the air. This gives territorial authorities a sound basis for developing mitigation strategies to improve air quality and reduce chronic health problems caused by air pollution.

PROTECTING OUR GROUNDWATER

Groundwater accounts for about 30% of New Zealand's water consumption. We use innovative methods to map, characterise and monitor many of New Zealand's 200 known aquifers. Both local and central government rely on our maps, 3D models and analysis to develop policy and day-to-day management of precious freshwater resources.

AND GLOBALLY

Our skills in geothermal energy development and advising on mitigation of geological hazards are in demand in Asian and Pacific nations. We also provide specialist services in marine geology and geophysics, particularly relating to the United Nations Convention on the Law of the Sea (UNCLOS). In these applied science areas we are among the best in the world. The additional expertise we acquire with this international work is brought back home where it can be applied in local settings for the benefit of New Zealand.

DAM SAFETY IN VIETNAM

We are working with partner organisations Damwatch Engineering and Vietnam's Water Resources University to improve the safety and risk management of dams in Vietnam. Funded by the Ministry of Foreign Affairs and Trade through the New Zealand Aid Programme, the multi-year project aims to improve dam safety and manage flood risks posed to downstream communities from dam discharges. The focus is the 1000km-long Ca River Basin, which contains 978 dams.

REDUCING RISKS FROM NATURAL HAZARDS IN INDONESIA

We are part-way through a multi-year project working with Indonesian communities to help them become better prepared for the impacts of earthquakes, tsunamis, floods and landslides. With a population of 250 million and frequent natural disasters, the Indonesian Government is taking action to reduce losses from natural disasters and boost community resilience. Funded by the Ministry of Foreign Affairs and Trade through the New Zealand Aid Programme, the project sees us working in four provinces to reach nearly 4 million people.

ANTARCTIC CLIMATE PROBES

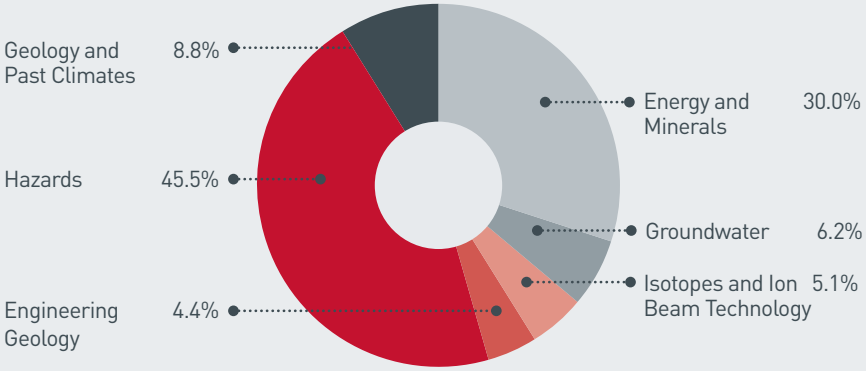
GNS Science leads or participates in numerous multi-national projects to recover Antarctic climate records by drilling either into the ice or into the seafloor sediment below the ice shelf. The aim is to drill back in time to recover a history of environmental changes to guide our understanding of how Antarctica responded to past climatic changes, especially during periods of rapid global warming. This is helping to reveal the potential timing and magnitude of future climate and sea level changes.

GEOTHERMAL ENERGY IN THE PHILIPPINES

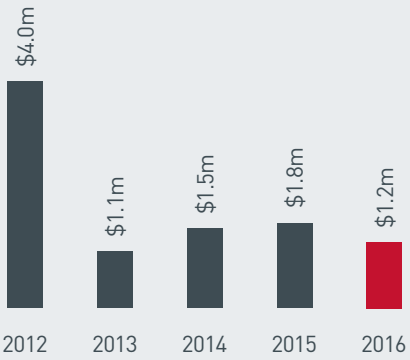
GNS Science provides specialist advice for geothermal developments in a number of countries including the Philippines. In the Philippines, we do this with our partner organisation, Energy Development Corporation. EDC is one of the largest geothermal companies in the world with 1200MW of installed geothermal capacity. Collaboration between the two companies dates back to the 1970s, and GNS Science has been involved in the discovery and development of several major fields in the Philippines.

OUR YEAR IN NUMBERS

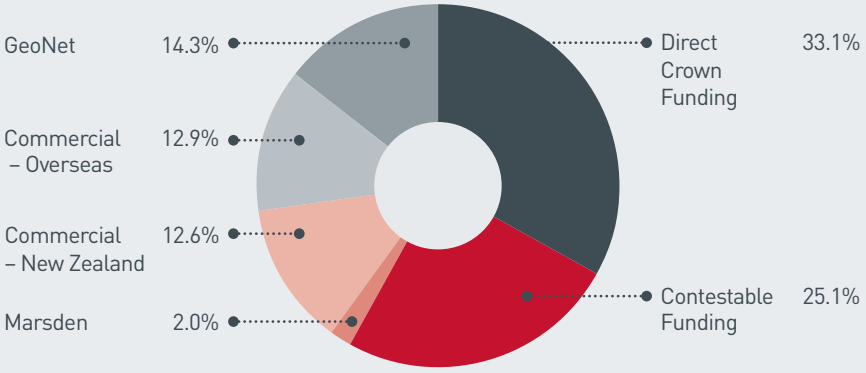
REVENUE BY SECTOR OUTCOME AREAS



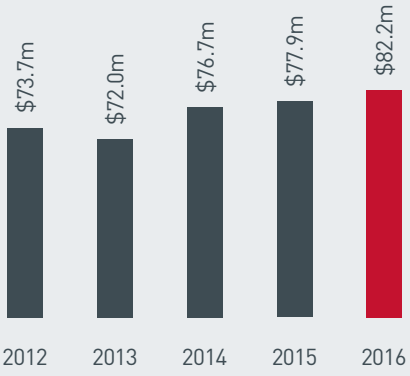
AFTER-TAX PROFIT



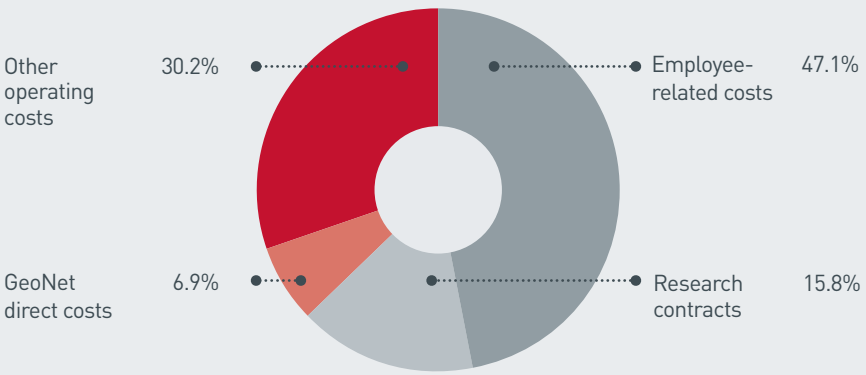
REVENUE SOURCES



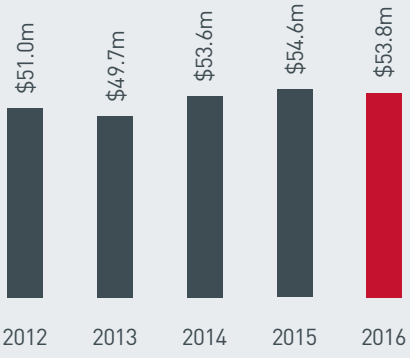
REVENUE



EXPENSE ANALYSIS



TOTAL ASSETS



DELIVERING ON OUR VISION

The passion and dedication of our staff never ceases to amaze. There have been occasions where our field teams work through the night in remote parts of New Zealand to have a project set up and ready to go at dawn. It is not unusual for these projects to run non-stop for days, capturing data and observations at regular intervals. What follows is usually months of analysis and interpretation on high-end computers to produce results that can ultimately feed into sectors that are vital to New Zealand's economy and wellbeing.

Our purpose is to obtain the latest knowledge and the best possible understanding of natural processes occurring in the Earth's crust and turn this into useful information that informs public policy and addresses both economic and non-economic challenges and opportunities. Our outputs drive innovation and economic growth in New Zealand's geologically based energy industries, help manage our groundwater resources, and increase our resilience to geological hazards. A fourth arm of our business uses isotope technology to develop environmental and industrial applications.

We are conscious that our outputs must be relevant to support a fast-growing economy that meets the needs and aspirations of New Zealanders. At the heart of our business are four deeply rooted objectives. They are:

- Producing excellent science of the highest quality
- Doing relevant science that has tangible outcomes that benefit New Zealand
- Building and strengthening national and international science relationships that advance our objectives
- Partnering with Māori for mutual benefit wherever and whenever possible.

Our research is supported by a mix of funding from the Crown (MBIE strategic funding and contestable), the Earthquake Commission (support for GeoNet), and domestic and international clients. Everything we do contributes to our vision of a cleaner, safer, more prosperous New Zealand.

GeoNet turns 15

New Zealanders can be genuinely proud of our nationwide geohazard monitoring system, GeoNet. It came into being in 2001 when the Earthquake Commission (EQC) entered an agreement with GNS Science to substantially upgrade and expand New Zealand's geohazard monitoring networks. EQC's annual funding of GeoNet stands at $12 million. We would like to thank EQC for their enduring support and the remarkable progress they have facilitated over the past 15 years.

Prior to 2001, New Zealand's geohazard monitoring network was precarious and sparse. It now consists of a nationwide network of more than 600 instruments that provide near real-time data on earthquakes, volcanoes, tsunamis, landslides, and tectonic deformation of New Zealand's landmass.

GeoNet is regularly held up as an international example of best practice. It not only produces rapid information for emergency response and public consumption, but the vast amount of high quality data it collects enables scientists to produce significant advances in understanding geological hazards. A measure of its success is that there have been 250,000 downloads of the GeoNet Quake App, and during widely felt earthquakes the GeoNet website receives 16,000 hits per second. Thanks to GeoNet, it is clear that New Zealanders understand vastly more about earthquakes, tsunamis, and volcanic eruptions than they did 15 years ago.

Local government impact

Our impact in local government policy development was amply demonstrated this year in the input we had to the revised 'hazard chapter' of Christchurch's District Plan. This work was led by staff from our Social Science and Hazards Planning Group who managed the Crown's response to the planned changes.

This has involved coordinating 16 government agencies to produce three comprehensive submissions, as well as contributing to specific chapters. It has required highly specialised and technical knowledge of the Resource Management Act, plan making, plan implementation, monitoring, natural hazard and risk management, and how scientific information can be incorporated into district plans.

The outcome was that amendments in both the GNS Science and Crown submissions were included in the final version of the Plan. The Plan will provide a regulatory framework that will underpin land-use decisions and natural hazard mitigation in Canterbury for the next 10 years.

Groundwater programme marks 25 years

Our National Groundwater Monitoring Programme marked 25 years in existence this year. It keeps track of trends in groundwater quality nationally and shares its data via a web-accessible database. The quality of water in New Zealand's 200 known aquifers is important because about one million New Zealanders use groundwater for their water supplies, and groundwater provides 30% of our total consumptive water requirement. Groundwater also provides about 50% of the water needs of the agriculture and horticulture sectors.

Run in partnership with 15 regional councils, the Programme samples 112 sites throughout the country four

times a year. We analyse the samples for 17 parameters to provide a national perspective on groundwater quality. The database that is fed by the programme is one of eight nationally-significant databases operated by GNS Science. As well as providing inputs to the Ministry for the Environment's three yearly report on the status of New Zealand's fresh water, it is also a basis for developing improved management techniques to help safeguard groundwater quality.

In the past year we made a number of improvements to the database including simplifying the navigation, adding new data browsing features, and a new 'help feature' that facilitates searches and data retrieval. This has improved the database's usability and value to its wide range of users.

Vital contributor to the petroleum sector

Our Petroleum Geoscience group provides technical assistance to companies operating in New Zealand and also to other companies evaluating block offers and considering bidding for exploration permits. The specialists in this group have a broad range of expertise and many decades of cumulative experience. They play a vital role in an industry that is New Zealand's fourth largest export earner. Their efforts help to kick-start many exploration campaigns as well as introducing exploration operators to the latest research and ideas on New Zealand's sedimentary basins.

Development of indigenous energy sources remains a high priority area for government policy. It is important that New Zealand has the type of scientific leadership that GNS Science provides so we can make informed decisions about the use of our natural energy endowments. On pages 34 and 35 we outline two major projects that are building a wealth of new knowledge on the prospectivity of New Zealand's sedimentary basins and presenting it in user-friendly formats for industry and government agencies.

International recognition for the quality of our science

We were delighted and proud this year to be acknowledged by *Nature* for the high calibre of our research in earth and environmental sciences. The 2016 Nature Index tables ranked GNS Science the 22nd institution in the Asia-Pacific region in earth and environmental sciences, making us the leading New Zealand institution in this category. In addition, GNS Science ranked 15th corporate institution globally for research output behind the likes of Pfizer, MerkKGaA, GlaxoSmithKline, and Bristol-Myers Squibb. This is a superb achievement and reflects positively on all staff at GNS Science. The Nature Index is a database of author affiliation information collated from research articles published in an independently selected group of 68 high-quality science journals. The Index provides a close to real-time proxy for high-quality research output at a national and regional level.

Working with Māori

This year, in association with our iwi partners, we hosted a one-day public seminar at Te Papa to showcase some of the joint projects we are undertaking with our Māori partners. Called *The Hidden Treasures of the Earth – Ngā Kura Huna a Papatāūnuku*, the event featured eight presentations on applied earth science topics plus discussion on the place of Mātauranga Māori in a modern economy. Topics included hunting for dinosaur fossil remains in Te Urewera, learning about pounamu occurrence in the South Island, looking after groundwater resources, provenancing Māori artefacts, and the impacts of air pollution. The event highlighted how the work of GNS Science is useful to Māori, not only contributing to their prosperity but also helping iwi find solutions for their own environmental and scientific challenges.

Resilience to Nature's Challenges

We are host of this National Science Challenge and one of 11 formal partner organisations. It is one of 11 of the Government's National Science Challenges and is supported by a $19.6 million investment from the Ministry of Business Innovation and Employment until 2019. The Challenge represents an enlightened combination of the earth and physical sciences, engineering, social sciences, governance, economics and business and enterprise. It will bring the latest resilience-building tools and techniques to rural, urban, coastal, and Māori communities.

In this first year of operation, 10 research programmes have got underway within the Challenge representing 80 scientists from at least 16 organisations. The work spans economic incentives for resilience in communities to engineering aspects of our lifeline networks. An important part of the Resilience Challenge ethos is to build a public appetite for new science solutions and knowledge.

Joining KiwiNet

This year GNS Science became a member of KiwiNet which is a consortium of 19 Crown Research Institutes, universities, and other publicly funded research organisations who are dedicated to finding new ways to commercialise innovative technologies. KiwiNet's role is to empower researchers looking to commercialise their efforts by helping them to access the tools, connections, investment, and support they need. Being part of this progressive organisation is introducing us to new ideas and fresh opportunities. As a result, we are in a stronger position to contribute to the growth of high-value industries in New Zealand.

Looking ahead

The next 24 months will be an exciting and productive time for geosciences in New Zealand. A standout among an impressive line-up of projects is the year-long visit to New Zealand waters by the US-based scientific drilling ship *JOIDES Resolution.* This marine geoscience project is occurring under the auspices of the 26-nation International Ocean Discovery Program – the world's largest geoscience initiative.

From late 2017, this ship will complete five back-to-back expeditions off the New Zealand coast, each lasting about two months. Researchers from GNS Science are involved in all five expeditions.

In the words of one of our participating researchers: "This initiative is so big and so far-reaching, it will probably not be repeated in our lifetimes".

The ship will collect sediment cores, make down-hole measurements, and install instruments beneath the ocean floor off the Gisborne coast to obtain information about how planet Earth works. It will focus on issues of global importance. These include improving the understanding of the Earth's climate and oceans, better assessment of earthquake and tsunami hazards at the plate boundary east of the North Island, and adding to the understanding of seafloor mineral deposits, gas hydrates, and deep-sea microbial communities.

The exceptional quality of New Zealand's earth sciences and the uniqueness of our plate boundary environment are the key ingredients in securing the services of this ship for a full year. The scale of the project is unprecedented for New Zealand in both its scientific and monetary value. It represents an investment of more than $100 million in New Zealand science. There is more information on this extensive project, and the source of its funding, on page 41.

We look forward to sharing news of the expeditions with New Zealanders. The project will offer invaluable training opportunities for the next generation of New Zealand scientists and engineers. There will also be opportunities for students, teachers, and the public to engage with science. The scientific knowledge acquired during the five voyages will benefit New Zealand, and the rest of the world, for decades to come.

Changes to the GNS Science Board

Deputy Chairman Ken Shirley retired from the Board on 30 June 2016 after six years' service and fellow Director James Johnston resigned in May to take up a position with the judiciary following three years' service. We thank them for their input to the Board and to the organisation during their terms. In January 2016 Chris Bush joined the Board and we are benefitting from his experience as a health and safety consultant in the energy sector.

Finally, we would like to thank our staff and stakeholders for their dedication and support. We are eager to build on our successes and produce science that delivers even greater economic benefits for New Zealanders. As we work to achieve this, we will be forging new partnerships and developing new initiatives with the common theme of helping New Zealand become cleaner, safer and more prosperous.

Dr Nicola Crauford
Chairman

Dr Neal Wai Poi
Acting Chief Executive

DRIVING INNOVATION AND ECONOMIC GROWTH

Our business is defined by our Statement of Core Purpose and understanding our place in the national innovation system.

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, that develops industrial and environmental applications of nuclear science, that increases New Zealand's resilience to natural hazards and that enhances understanding of geological and earth-system processes.
- GNS Science will fulfil its Purpose through the provision of research and consultancy services and knowledge in partnership with key stakeholders including industry, government and Māori to achieve the following outcomes.

Statement of Core Purpose Outcome Statements

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 outcomes, GNS Science is the lead Crown Research Institute in:

- geothermal energy, oil, gas and gas hydrates (including carbon sequestration)
- mineral and geobiological resources
- geological hazards, risk mitigation and social impacts of natural hazards
- earth-system processes and landscape evolution
- groundwater processes and quality
- the geological component of global environmental processes and climate change
- 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 we will deliver against this Statement of Core Purpose, and describes what the shareholders will receive for their investment
- meet our obligations as a Crown company and remain financially viable
- develop strong, long-term partnerships with key stakeholders, including industry, government and Māori, and work with them to set research priorities linked to the needs of end-users
- maintain a balance of research that provides for near-term needs of end-users and also demonstrates longer-term vision
- transfer technology and knowledge from domestic and international sources to key New Zealand stakeholders
- develop collaborative relationships with other research institutions to form the best teams
- 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
- seek advice from advisory panels to help ensure the quality and relevance of our research
- have policies, practices and culture that optimise recruitment and retention
- enable the innovation potential of Māori knowledge, resources and people
- maintain databases, collections and infrastructure sustainably and provide appropriate access
- seek shareholder consent for significant activity beyond our scope of operation.

ACHIEVEMENTS ENVISIONED IN OUR 2015/16 STATEMENT OF CORPORATE INTENT

CORE SCIENCE AREA	THEME	NEAR-TERM GOALS	PROGRESS/ACHIEVEMENT
SCIENCE FOR A CLEANER NEW ZEALAND	Environmental Stewardship	Develop and calibrate a groundwater model for the Southland region and assist Environment Southland to apply this model under the National Policy Statement for Freshwater Management 2014	• Completed a comprehensive hydrochemistry report on the Southland region (Fluxes and Flows project). The findings have been incorporated into Environment Southland's groundwater management and strategies. • Finalised a 3D geology model of the Southland region and used it to develop a regional groundwater flow model (Fluxes and Flows project). The model contains four Freshwater Management Units (FMU), which are base units recommended by the NPS-FM for integrated freshwater resources management. • Developed a groundwater flow model for the Aparima Freshwater Management Unit, based on the regional flow model. This model will be used in parallel with a transient surface water model to simulate groundwater and surface water flows. • Completed a field data acquisition programme to collect age tracer data (e.g. radon, tritium) to be used in the groundwater model for the Aparima catchment.
		Iwi partnerships investigate monitoring air quality around Whakarewarewa and groundwater quality around Lake Rotorua with Ngāti Rangiwewehi	• Operating air monitoring equipment at Whakarewarewa Thermal Village in Rotorua in association with the owners and operators of the Village. As well as helping the local community understand the impacts of air pollution, this project is part of nationwide outdoor air sampling and analysis that GNS Science undertakes. As such, it has international significance. • We also work closely with Ngāti Rangiwewehi and Bay of Plenty Regional Council on a long-term project to better understand the freshwater resources on the western side of Lake Rotorua to ensure the health and wellbeing of the Ngāti Rangiwewehi people and provide a scientific and cultural foundation to inform future decision making in the catchment.

CORE SCIENCE AREA	THEME	NEAR-TERM GOALS	PROGRESS/ACHIEVEMENT
SCIENCE FOR A SAFER NEW ZEALAND	Enhanced resilience to natural hazards	Contracting and initiation of Resilience National Science Challenge and funding of first round of research projects	The Resilience Challenge is fully operational, and it has contracted 10 research projects representing 80 scientists from at least 16 organisations.
		Comprehensive response planning with future framework for all-perils 24/7 warning centre	Through the RiskScape project, GNS Science has estimated the spatial distribution of risk on coastal infrastructure around New Zealand from tsunamis. Through collaborations with NIWA, GNS Science has supported assessment of infrastructure from flooding around New Zealand.
		Growing partnerships with key agencies particularly the Earthquake Commission (EQC), the Ministry of Civil Defence and Emergency Management (MCDEM) and Auckland Council	**EQC** • Both organisations enjoy strong ongoing collaboration and engagement. Successfully re-contracted the GeoNet project this year with increased funding. • Assisted EQC in estimating losses to the EQC portfolio from a number of future earthquake scenarios and other hazard events. • Strong engagement on advocacy of all-of-government approaches to minimising the impact on the New Zealand economy and society from future natural hazard events. • Collaboration on research priorities that are funded through EQC, the Natural Hazards Research Platform and the Resilience Challenge (the latter two hosted by GNS Science). • Frequent relationship meetings at multiple levels in both organisations. **MCDEM** • Supporting MCDEM through the development stages of the national strategy on disaster resilience. • Working with MCDEM and other agencies in benchmarking and reporting for New Zealand on the Sendai Declaration on disaster risk reduction. • Supported MCDEM in developing the scenario and planning for Exercise Tangaroa, undertaken in August and September 2016. • Revised protocols for advice to MCDEM in the event of emergencies, which are reflected in the Director's Guideline on Response Planning in Civil Defence and Emergency Management. • Frequent relationship meetings at multiple levels of both organisations. **Auckland Council** • Held regular relationship meetings at multiple levels with the Council. Joint initiatives include hazard impact assessments, urban mapping projects, land instability investigations, and tsunami evacuation planning.

CORE SCIENCE AREA	THEME	NEAR-TERM GOALS	PROGRESS/ACHIEVEMENT
SCIENCE FOR A MORE PROSPEROUS NEW ZEALAND	Wealth from geological resources	Develop paleogeographic models describing depositional evolution for all frontier basins and new baseline geoscience knowledge to guide resource estimation	• Finalised 10 digital paleogeographic maps covering the Reinga-Northland, Deepwater Taranaki, Taranaki and Wanganui basins as part of our multi-year Petroleum Atlas programme. The maps, which are being delivered to industry, are derived from up-to-date open-file seismic and well data and depict the likely distribution of source, reservoir and seal rocks in these basins. We are nearing completion of paleogeographic maps covering the Great South and Canterbury basins. • Integrated paleontological, sedimentological and geochemical analyses (organic and inorganic) of the Waipawa Formation in eastern North Island to provide improved controls on the depositional history and distribution of this important prospective source rock.
		Improve understanding of methane hydrates and their role as a viable transition fuel and source of future wealth	• Carried out the first-ever scientific drilling within New Zealand's East Coast gas hydrate province during a German-led research voyage aboard RV *Sonne*. The results give the first direct insight into the reservoir rocks that host gas hydrates in New Zealand. • Used a combination of seismic velocity analysis and rock physics to improve our understanding of reservoir rocks and delineate new areas for targeted gas hydrate exploration.
UNDERPINNING GEOSCIENCE KNOWLEDGE	Geoscience knowledge	More efficient and effective access to geoscience databases of national significance	Made various improvements to the eight databases in this class so information within them is more accessible, more standardised, and more aligned with the needs of end-users. In addition, we have added new information to a number of the databases to make them more comprehensive, and at least one database has added a help feature to facilitate searches and data retrieval.

CORPORATE NEAR-TERM GOALS	PROGRESS/ACHIEVEMENT
Streamline relationship management with key government agencies	An organisational stakeholder engagement strategy is currently under development.
Catalogue and evaluate commercialisation potential of extant IP portfolio	Re-established internal PSAF commercialisation committee which will oversee the commercialisation and IP portfolio. Potential projects will be integrated in the newly implemented CRM system over the coming year so we can better identify the opportunities between the business development and commercialisation pipelines.
Improve forward revenue pipeline projection information	Implemented an organisation-wide Customer Relationship Management (CRM) system. This system will increase visibility of the project pipeline and assist understanding of partner and collaborator interactions at an organisation level.
Monthly corporate productivity statistics communicated to all staff	Collected productivity statistics for all staff based on timesheet data. This data is included in departmental dashboards showing comparisons across the business and shared with staff at department meetings.
Systems and practices that fully meet requirements of the new health and safety in employment (HSE) legislation	Undertook a significant amount of work to identify and close the gaps to ensure our internal systems, practices and documentation complied with the new HSE legislation from April 2016.
More efficient and transparent career path, performance, development and remuneration systems	Our performance development planning, remuneration and career framework project continued during the year. Some processes were refined and implemented in the current year, with full delivery effective for the 30 June 2017 remuneration round.
Refreshed information services strategy with plans developed and implementation started relating to databases, infrastructure, and records	Reviewed and refined the information services strategy with significant emphasis on implementing improved security management, better internal IT processes and taking advantage of modern platforms and tools. Developed a database management maturity model and measured our databases against this to establish the current state. A picture of the future state is under development, and a roadmap of projects and implementation will flow from this.

VISION MĀTAURANGA

GNS Science is committed to developing partnerships with Māori to deliver mutual benefit. Every year, we collaborate with Māori on a number of projects. Our joint projects contribute to the social, economic, cultural and environmental fabric of New Zealand.

This year we are collaborating in three Vision Mātauranga Capability Fund projects. The Government set up the Fund to grow the skills and capacity for Māori participation in science and innovation and to support outcomes that benefit New Zealand.

Our three Vision Mātauranga projects are:

- working with South Westland iwi Kāti Māhaki to develop capacity in earth science
- enhancing natural hazard awareness and preparedness with East Coast iwi Ngāti Porou and Ngāi Tāmanuhiri
- working with Ngāi Tūhoe to search for dinosaur-age fossils in Te Urewera in northern Hawke's Bay.

Rare minerals in South Westland

The first project is focused on Aotea, a rare rock containing the blue mineral kyanite, found only in South Westland. Aotea is a special treasure that south Westland iwi Kāti Māhaki have cared for, gathered, traded and gifted for generations. It has cultural and commercial value to the rūnanga. However, Kāti Māhaki want to understand sustainability of the resource before deciding how best to manage the geological resources in this remote and beautiful part of New Zealand. The two-year project is combining both traditional mātauranga Māori and scientific knowledge to inform wise and sustainable management of Aotea. It will do this through a series of wānanga and fieldwork.

Geological hazards on the East Coast

In this project, we are working with Ngāti Porou, Ngāi Tāmanuhiri and the Gisborne District Council to raise iwi awareness of and resilience to natural hazards within their rohe on the North Island's East Coast. The project will take place in three phases. The first step will be a compilation of mātauranga Māori and scientific knowledge about natural hazards on the East Coast. The second phase will see a team from GNS Science, Ngāti Porou, and Ngāi Tāmanuhiri visit Indonesia to share indigenous knowledge and experiences of natural hazards. In the third phase, knowledge gained from the earlier compilation and the Indonesian visit will be shared at iwi level through a series of hui, workshops, school teaching modules, media engagement, iwi websites, and magazines. The purpose of the Indonesian visit is to heighten iwi awareness of natural hazards and their impact in a cultural context. Indonesia and the East Coast are both vulnerable to many of the same geological hazards. Ultimately, the project will build iwi capacity in natural hazards and enable more informed engagement with the local council on civil defence and hazard planning matters.

Searching for dinosaur remains in Te Urewera

The third project, being led by Ngāi Tūhoe with input from GNS Science and Victoria University of Wellington, involves searching for dinosaur and other prehistoric fossils within Te Urewera, in inland northern Hawke's Bay. Current knowledge of New Zealand dinosaurs comes almost exclusively from a rock formation slightly south of this area. The formation continues into Te Urewera, and scientists believe there is a good chance of discovering dinosaur-age fossils in this unexplored area. Tūhoe have occupied Te Urewera for many generations – it is their homeland – and the presence of dinosaur fossil deposits within their rohe is of great interest. Tūhoe's goal in this collaboration is to better understand their whenua, to gain skills in earth sciences fieldwork and in identifying and preparing fossils, and also to encourage uptake of educational opportunities in earth sciences.

RESILIENCE TO NATURE'S CHALLENGES, KIA MANAWAROA – NGĀ ĀKINA O TE AO TŪROA

The Resilience Challenge is one of the most ambitious initiatives ever undertaken by New Zealand to research and apply new scientific solutions to transform our response, recovery and bounce-back from our legion of natural hazards. As one of 11 National Science Challenges, the Resilience Challenge is supported by a $19.6 million investment from the Ministry of Business, Innovation and Employment (MBIE) until 2019, with a further $40 million earmarked for the second phase until 2024.

GNS Science is the host of this important initiative and one of 11 formal partners involved (NIWA, Scion, The University of Auckland, Canterbury University, Otago University, Massey University, Lincoln University, Victoria University of Wellington, BRANZ and Opus International). The base investment is boosted by aligned funding from GNS, NIWA and Scion as well as co-funding and aligned funding added from a raft of other agencies participating in the transdisciplinary work.

Ten programmes underpin the mission-led research of the Resilience Challenge, with over 80 research staff involved from at least 16 organisations. This work marks a new, networked approach to addressing complex issues of public-good research, specifically to apply transdisciplinary methods and a co-creation approach to research design and implementation. In this first year of full operation, 10 Resilience programmes are working in several parts of the country together with stakeholders from the local government and private sectors.

Key sites for our 'co-creation laboratories' this year include an urban focus on resilience issues pursued for our three largest cities and a rural resilience programme in the West Coast, Canterbury and Kaikoura regions. Mātauranga Māori research is under way in Central North Island, Bay of Plenty and Taranaki as well as Wellington and Christchurch. Furthermore, the Edge programme is concentrating on the management of acute coastal and lowland hazard issues in a pilot project focused on Hawke's Bay.

Supporting these programmes are specialist research teams taking a resilience angle to hazards, economics, governance, culture and infrastructure. A further team is researching new measures to track and develop targets for improved resilience, and a small programme is researching the emerging practices of co-creation research.

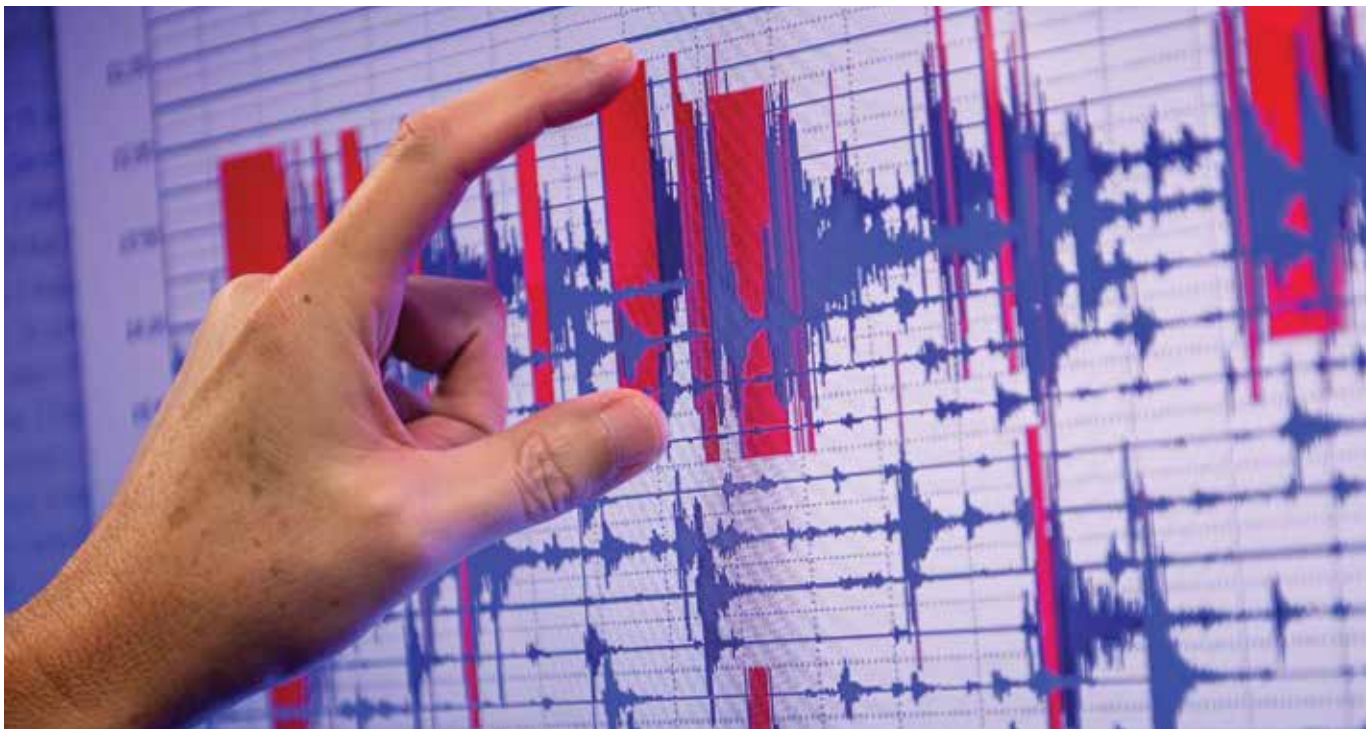
Further progress over the 2015/16 year has included the following:

- Building new capability in resilience research by the appointment of over 12 newly funded PhD students to the Resilience Challenge (including three Māori PhD students). Over the first five years of this programme, at least 22 new PhD graduates in areas from social science to economics and hazard studies will result, building a new cohort to help secure New Zealand's future in natural hazard resilience.

National SCIENCE Challenges

RESILIENCE TO NATURE'S CHALLENGES

Kia manawaroa – Ngā Ākina o Te Ao Tūroa

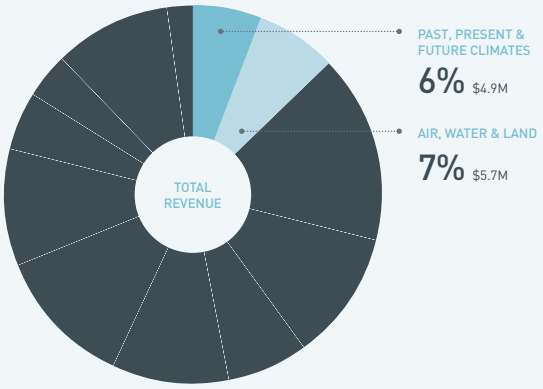


- Setting up a Challenge office, including the appointment of Anne-Marie Rowe as Challenge Manager. She brings 20 years' experience in the university science research management and health sectors.
- An independent Governance Group was inducted in late March 2016 with a science workshop. This Governance Group includes Ian Fraser (Chair), Parekawhia McLean, Greg Orchard, Bruce Wills and Professor Steve Weaver. This collective brings a highly experienced level of oversight to the Resilience Challenge, spanning infrastructure, local government, community health, iwi leadership, agriculture and academia.
- The Resilience Challenge brand has been launched and is now being promoted via a series of outreach activities, newsletters and social media activities.

WHERE OUR RESEARCH FUNDING IS INVESTED

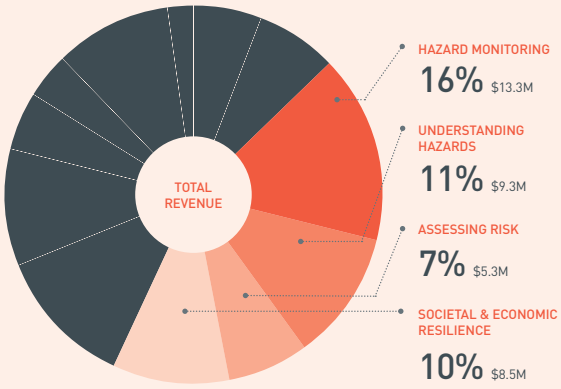
CORE SCIENCE AREA 1

SCIENCE FOR A CLEANER NEW ZEALAND



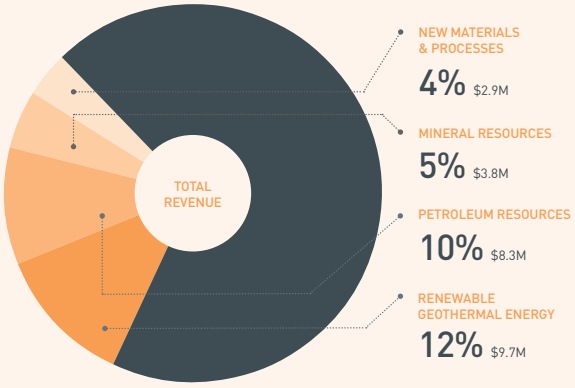
CORE SCIENCE AREA 2

SCIENCE FOR A SAFER NEW ZEALAND



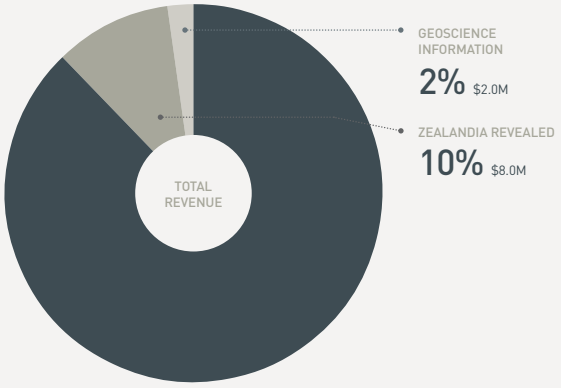
CORE SCIENCE AREA 3

SCIENCE FOR A MORE PROSPEROUS NEW ZEALAND



CORE SCIENCE AREA 4

UNDERPINNING GEOSCIENCE KNOWLEDGE



SECTOR PRIORITIES

CORE SCIENCE AREA 1

SCIENCE FOR A CLEANER NEW ZEALAND

THEMES

Past, Present & Future Climates • Air, Water & Land

SCP OUTCOMES

CORE SCIENCE AREA 2

SCIENCE FOR A SAFER NEW ZEALAND

THEMES

Hazard Monitoring • Understanding Hazards • Assessing Risk • Societal & Economic Resilience

SCP OUTCOMES

CORE SCIENCE AREA 3

SCIENCE FOR A MORE PROSPEROUS NEW ZEALAND

THEMES

Renewable Geothermal Energy • Petroleum Resources • Mineral Resources • New Materials & Processes

SCP OUTCOMES

CORE SCIENCE AREA 4

UNDERPINNING GEOSCIENCE KNOWLEDGE

THEMES

Zealandia Revealed • Geoscience Information

SCP OUTCOMES

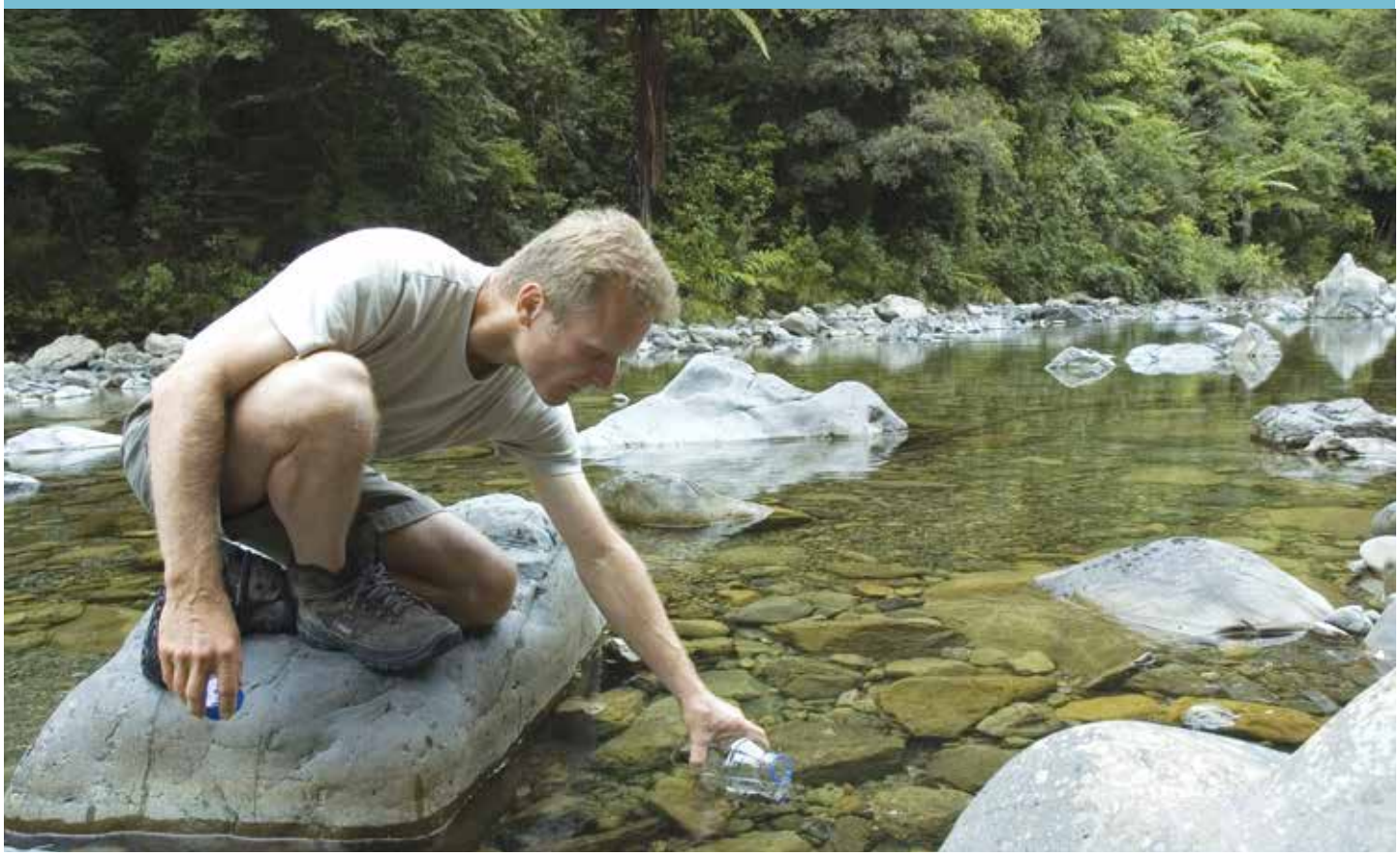
SCIENCE FOR A CLEANER NEW ZEALAND

Freshwater and clean air are valuable natural assets that are vital to our social, cultural and economic wellbeing. Those charged with managing the quality of water and air do so with the confidence that our science provides high-quality, independent information on which to base their decisions.

Above ground, we play an important role in helping to minimise air pollution in towns and cities. We do this by analysing tiny particles trapped on air filters that regional and city councils place throughout New Zealand. A typical air filter analysis might show the main culprits are vehicle emissions, domestic heating, industrial sources, sea salt and wind-blown soil. Councils use our analysis to develop mitigation measures. Multi-year measurements enable councils to track the effectiveness of their measures in reducing air pollution.

Groundwater supplies 35% of the water used domestically in New Zealand and about 80% of agricultural needs. Regional authorities rely heavily on the information we provide through our groundwater monitoring networks and aquifer case studies. Our national monitoring programme provides a countrywide baseline perspective on groundwater quality and can tell the difference between natural changes and those that are human induced.

We also contribute to understanding climate change and provide inputs for modelling changes to climate in the future. We do this by analysis of weather and atmospheric records contained in ice and sediment cores extending back into geological time. Our internationally acclaimed paleoclimate research provides essential observation-based data to elucidate the types and scale of change to which we will need to adapt in the future.



PAST, PRESENT & FUTURE CLIMATES

Our research in this area is essential for improving predictions of the rate and scale of future climate change in New Zealand and assessing the likely impacts of these changes. Much of this work takes place through international collaborations and sheds light on how climate change has affected the southwest Pacific region from Antarctica to the tropics. Part of this work involves reconstructing pre-instrumental climate records for the past 100,000 years from drill cores recovered from strategic locations. This improves knowledge of the timing and scale of abrupt shifts in climate and helps to assess the impact of these events on our terrestrial and oceanic environment. This helps significantly in informing adaptation and mitigation strategies and in ground-truthing climate models.

FROM SHEETS OF RAIN

The prevailing weather in New Zealand comes mainly from the west and along with it rainfall, the source of New Zealand's greatest natural environmental asset: abundant freshwater.

Water keeps New Zealand green, clean and beautiful. This singular natural resource is the principal impetus that fuels and sustains the two major drivers in our economy: agriculture and tourism.

But with climate change, what does the future hold for sustainability of this valuable natural resource?

The Lake Ohau Project, led by GNS Science and Victoria University of Wellington, aims to address this question by detailed examination of what has transpired in the recent geological past.

Most of the South Island's lakes, especially those located within 50km of the Southern Alps, are of glacial origin. They were all occupied by glacial ice until about 17,000 years ago when there was significant warming and dramatic melting and retreat of the ice.

It follows then that the lake floor sediments of the South Island lakes might preserve a detailed natural archival record of environmental history that is up to 17,000 years old. It becomes a matter of finding a suitable lake, drilling it, recovering a continuous sedimentary core and analysing and deciphering it.

Scientists chose Lake Ohau as the most suitable place to carry out this research, and it was successfully drilled in March 2016 with recovery of 80 metres of continuous sedimentary core. Detailed investigations of the core are taking place under the leadership of geologists Richard Levy and Marcus Vandergoes from GNS Science and Gavin Dunbar of Victoria University of Wellington.

The scientists anticipate the core will yield a very coherent understanding of the seasonal, annual and decadal processes operating in the Lake Ohau catchment and the Southern Alps. Against this background, short-lived high-impact weather events (flooding and drought), geological events (earthquakes and landslides) and biological events (forest seeding events and algal blooms) will stand out.

Most importantly, the results will illuminate the history of the westerly wind, associated rainfall and its climatic impact on the South Island over the past 17,000 years.

This information will provide welcome evidence-based knowledge to both the New Zealand and the international science community for more robust modelling of future climate change and its impacts in New Zealand. This will lead to enhanced mitigation and adaptation strategies.

DIATOM RECORDS OF EXTREME COLD IN ANTARCTICA

Antarctica is ringed by sediments on the seafloor that are charged with the mineralised skeletal remains of microscopic single-celled algae called diatoms. Diatoms exist mostly suspended in oceanic waters, and they flourish only within the top 200 metres through which light can penetrate.

These tiny organisms produce exquisite solid cell wall structures called frustules. Built from hydrated silica (more like opal than glass), frustules are box-like, comprising two components (hence 'diatom' meaning split in two) that are of unequal size and fit snuggly together, rather like a container within a slightly larger lid.

They may be thought of as tiny floating glasshouses that form the very base of the marine food chain. They are so abundant that they are responsible for absorbing and fixing up to 25% of the annual global carbon dioxide budget. Because of their importance in the food chain and their potential to lock away carbon dioxide, they are highly relevant in the context of ocean health and future climate change.

Paleontologists James Crampton, Richard Levy and colleagues have analysed the occurrence and distribution of 129 species of fossil diatom preserved in sediments recovered from 34 drill cores from all around Antarctica. The drill cores record 15 million years of oceanic productivity in Antarctic waters.

The data is so good that the team has been able to derive highly resolved rates of species origination and extinction. They establish the tempo of normal background species turnover. Most significantly and most unexpectedly, they reveal the 'abnormal': five marked episodes of enhanced species turnover.

The question is why? What controlled these five events? The science team argues for wholesale environmental shock due to the onset of extreme cooling and glaciation coming hard on the heels of relative warmth in Antarctica.

The ages of these species turnover events (14.65–14.45, 13.75–13.55, 4.9–4.4, 3.55–3.4 and 3.00–1.95 million years ago) are a good match with the timing of significant climate change events derived from independent chemical proxies (oxygen and carbon isotopes). This is the first time that fossil data has been used to demonstrate the biological impact of climate change with such precision in the context of the Southern Ocean and Antarctica.

The next stage in this research will involve the use of this data to calibrate sophisticated computer models of ecosystem function, to constrain future ecosystem changes that might result from global warming. This modelling will be undertaken in collaboration with colleagues in Europe and New Zealand.

AIR, WATER & LAND

We undertake a range of groundwater research to help address the quality and sustainability of freshwater supplies in New Zealand. Our studies improve the understanding of the geological structure, flow paths and flow rates of New Zealand's 200 known aquifers. This enhances the ability to know how aquifers will respond to pressures such as land-use intensification and climate change. It also improves the understanding of the way contaminants are transferred between air, land and water and the resulting environmental impacts. We also contribute to managing and mitigating air pollution by using our ion beam technology to determine the origins of particulate matter in the air. Councils use this information to develop strategies to reduce air pollution.

MONITORING THE QUALITY OF OUR INDOOR AIR

For many years, we have used our niche capability in ion beam technology to help councils monitor outdoor air pollution in New Zealand towns and cities. They use our analysis to guide the development of mitigation measures to improve the quality of urban air. We are now turning our attention to measuring the quality of indoor air in New Zealand. Currently, there are no official standards or guidelines for this, even though medical research has shown that poor indoor air quality can result in multiple chronic health issues.

Recently, we started a new project that is funded by BRANZ and involves a collaboration among GNS Science, Massey University, and the University of Otago Medical School. The overarching objective is to produce findings that lead to warmer, drier, healthier homes and schools. Its aims are two-fold – to find out about the quality of air in school classrooms and how this varies by region; and to find out about the nature and source of indoor air pollution in New Zealand homes and garages.

The school component is being led by Massey University and involves deploying air sensors in classrooms at a total of 100 schools in Auckland, Wellington. Christchurch and Dunedin. Measurements will occur continuously over a two-month period. Air quality in schools is an under-researched area, and this project will provide a baseline for future studies.

A pilot study we recently conducted showed a spike in air particulate matter concentrations between 9am and 3pm in school buildings. The main culprit was soil particles students bring indoors on their shoes and clothing, which settle in the carpet. A solution for schools to mitigate this is to wet-clean their carpets once a term.

GNS Science is leading the homes component, which will place sensors in up to 10 houses in Wellington. There will be a range of old and new houses, built-in garages versus detached garages and different proximities to major roadways. Sensors will be placed outside the house as well as in the garage, living area, kitchen, bathroom and bedrooms. The outside sampler will be an open-air reference.

All the samplers will sample air at a height of 1.5m every hour round the clock for three weeks. We will measure for the standard air quality indicators – carbon dioxide, carbon monoxide, nitrous oxide, formaldehyde and air particulate matter. Outcomes from the project will provide solutions for the construction industry that will help to make our homes and schools healthier.

MARLBOROUGH AQUIFER STUDY PROVES ITS WORTH

The Wairau Plains groundwater system is the largest such system in Marlborough and supplies freshwater to about half of the province's population of 50,000 and also supports crucial agriculture and horticultural industries. Understanding the dynamics of this 380 square kilometre groundwater system is important to ensure it is sustainably managed for future generations.

A recent study, jointly undertaken by GNS Science and the Marlborough District Council, has resulted in a much better understanding of the aquifer's structure, its water flow paths and the connections to springs and smaller neighbouring aquifers.

The study enables scientists and others to visualise, in more detail than previously, water flow patterns in three dimensions as well as understanding the geological structure of the aquifer to a depth of 40m. The advances in recognising flow patterns and understanding the porosity and grain size of aquifer sediments will apply to similar systems in other parts of New Zealand.

It shows the connectivity among many springs and streams on the Wairau Plain, a feature that was poorly understood before. The study explains why springs occur in certain places and particularly the importance of aquifer sediment type. It reveals new features about the aquifer structure and the influence that aquifer sediments have on groundwater flow patterns.

For the Council, the study has been helpful in explaining the gradual decline in the groundwater levels of some wells since the early 1980s. It is also a valuable input for refining water allocation limits. It also identifies the distributions of gravels, sands and silts and artesian groundwater pressures in the Lower Wairau Plain. As an additional benefit, the Council has been able to use this information in an assessment of liquefaction potential in land earmarked for development near Blenheim.

As well as promoting better groundwater management, the study is providing a basis for assessing different land-use practices and their influence on nutrient runoff. For Wairau Plains communities, it has raised the awareness of the impact of land-use activities on not only underlying aquifers but also on hydraulically connected springs, which, in some cases, may be many kilometres away.

The take-home message for communities living over alluvial gravel aquifers is the interconnectedness of groundwater and aquifer-fed springs and overlying land use.

SCIENCE FOR A SAFER NEW ZEALAND

New Zealand's location on an active plate boundary means that 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 our economy, landscape and social wellbeing.

Our research helps to reduce the economic and social costs of natural hazards. This work provides robust evidence-based data and analysis that feeds into disaster risk management options such as land-use planning, engineering standards, emergency response planning and risk transfer through insurance.

We do this by improving the understanding of the processes that cause earthquakes, volcanic eruptions, tsunamis, and landslides. We estimate the size, frequency and potential impacts of each of these geological hazards. Our expertise in risk and loss modelling helps to quantify the impact of natural disasters on infrastructure and people. This provides quantitative estimates of likely damage and loss of assets and casualties, which is crucial for risk managers, hazard planners and the insurance industry.

HAZARD MONITORING

GeoNet is the anchor stone for the monitoring of geological hazards in New Zealand. The Earthquake Commission (EQC) currently funds GeoNet at approximately $12 million a year. GeoNet operates a nationwide network of more than 600 instruments that send near real-time information to GNS Science data hubs at Lower Hutt and Wairakei. In the coming years, GeoNet will put more emphasis on impact reporting and more two-way communication with its large community of users. At present, GeoNet's focus is event reporting, where it provides rapid information on where, when and how big. With impact reporting, it plans to provide near real-time information on the likely impacts to people and infrastructure. This will rely on a combination of data from instruments, community reporting or citizen science, and computer modelling informed by research.

GEONET MARKS 15 YEARS OF NON-STOP DEVELOPMENT

Our national geohazards monitoring system GeoNet marked its 15th birthday this year. It came into being in 2001 when EQC entered an agreement with GNS Science to substantially upgrade and expand New Zealand's geohazard monitoring networks. As well as real-time monitoring of New Zealand's geohazards, GeoNet collects high-quality data, which is made publicly available at no cost. The data is of far higher quality and collected by many more instruments than in pre-GeoNet times. This is due to 15 years of steady investment by EQC and Land Information New Zealand. Their funding has enabled GeoNet to build a modern and comprehensive geohazard monitoring network, which produces tangible benefits for New Zealanders.

GeoNet data underpins research into the likelihood and impact of potentially devastating earthquakes, eruptions, tsunamis, and landslides. Researchers both in New Zealand and internationally are continually adding value to the data.

They produce value-added products and analyses that can then be used by others. Engineers use GeoNet-derived information to inform the design of structures that are safer and better equipped to handle the extreme forces of nature. The emergency management sector uses information produced immediately after an event to decide where first responders need to target their activities. Risk analysts use the information to weigh up the risks from different perils for insurance and infrastructure planning.

In addition, EQC is able to use analyses derived from GeoNet data to help international reinsurers gain a better understanding of the risks New Zealand faces. This has enabled EQC to secure reinsurance following the Canterbury earthquakes.

The Department of Conservation and the ski industry use the underpinning research and monitoring networks to help reduce the risks for recreational users of Tongariro National Park.

GeoNet's comprehensive record of aftershocks from the Canterbury earthquake sequence has enabled scientists to develop aftershock forecasting for New Zealand. These forecasts help to convey realistic expectations of how likely or unlikely different scenarios are in the days, months and years following a large earthquake. All of this leads to safer and more resilient communities that are better able to recover quickly from natural disasters.

UNDERSTANDING HAZARDS

New Zealand is subject to the full range of geohazards, and a resilient society needs to mitigate the risk they pose. As a first step to quantifying risk, GNS Science works to understand the processes involved in earthquakes, eruptions, tsunamis and landslides. For earthquakes, this involves a better understanding of the seismic cycle, namely stress build-up and release on faults, interactions between faults and the evolution of crustal stress over multiple earthquake cycles. As a highly collaborative organisation, we work extensively with international colleagues who are attracted to New Zealand as a natural hazards laboratory. Having this intellectual horsepower focused on our hazards helps to boost the physical understanding of hazards and their potential impact on our communities.

SENSING ACTION IN THE TAUPO VOLCANIC ZONE

The central North Island is home to one of the most dynamic volcanic regions on the planet – the Taupo Volcanic Zone (TVZ). Understandably, it is subject to significant GNS Science surveillance and research.

The TVZ is an active rift system that is largely responsible for the shape of the North Island, which is being ripped open to create a slowly growing V-shape with the fulcrum at about Waiouru.

In terms of maintaining a resilient New Zealand society and economy, we recognise that it is important to learn as much as possible about the behaviour of the TVZ.

The TVZ boasts two of the most productive caldera volcanoes in the world – Okataina and Taupo. It is also host to 23 geothermal fields, some of which have been harnessed for renewable energy.

GNS Science researchers led by geodesy specialist Ian Hamling have published analyses of image data acquired by two satellites operated by Japanese and European space agencies.

The results for the period 2003–2011 are revealing. By comparing image data from year to year, changes in the elevation of the land surface within the TVZ have been measured. During this period, large parts of the TVZ have been subsiding by up to 2cm a year.

However, there has been marked uplift in the Matata region on the Bay of Plenty coast over the same period. This corresponds with a swarm of small earthquakes around Matata between 2004 and 2011, mostly between magnitude 2.0 and 4.0 and at depths between 2km and 8km.

Scientists have concluded that, since 1950, there has been a 0.2 cubic kilometre growth of a previously unrecognised magma chamber about 9km under the Bay of Plenty coast, causing inflation of the Earth's surface of about 1cm a year. The growth of the chamber is equivalent in volume to about 80,000 Olympic swimming pools.

Magma bodies are reasonably common under large areas of the central North Island, and identifying another magma accumulation is not a huge surprise, nor does it mean that an eruption might be imminent, and it has not changed the volcanic hazard of the Bay of Plenty region.

However, investigations such as this are an important part of improving the understanding of the TVZ and its underlying anatomy.

LAKES GIVE UP ALPINE FAULT'S SECRETS

A major earthquake on the Alpine Fault in the South Island within the next 70 years is considered highly probable. This very distinct feature runs up the spine of the South Island with the Southern Alps uplifted on its eastern side. Research by many scientists over the past four decades has added considerably to the understanding of its rupture history and the likely impacts from its next big earthquake.

But there are still uncertainties, and with every new insight, there can be a fresh set of questions as well. GNS Science is undertaking a range of research to understand the fault's behaviour, but it is no easy task establishing how often it moves, how big its earthquakes are and how widely the impacts will be felt. We know from the past 20-plus ruptures on the southern section of the fault that large earthquakes occur there every 300 years, plus or minus 70 years. However, different sections of the fault appear to rupture at different intervals. The most recent rupture on the Alpine Fault occurred about 1717, and it produced an earthquake of about magnitude 8.0.

One of the projects GNS Science is undertaking to increase the knowledge of the fault is exploring the natural environmental archives preserved in sediments at the bottom of alpine lakes adjacent to the fault. The focus has been Lakes Ellery, Paringa, Christabel, Kaniere and Mapourika. In undertaking this work, Jamie Howarth and colleagues have established a new subdiscipline in New Zealand earthquake science – lacustrine paleoseismology. It is a line of inquiry that Jamie started while he was a PhD student at Otago University.

Earthquakes shake the landscape, steep hillsides are mobilised and there are tell-tale influxes and disruptions of sediments in lakes. It is a matter of collecting drill cores of these sediments, analysing them, determining the timing of the sediment influx events using radiocarbon dating and interpreting the results.

While the rupture history of the southern segment of the Alpine Fault between Haast and Milford Sound is reasonably well understood from research efforts in the past two decades, the history of the middle segment between Haast and Fox Glacier is less clear.

Preliminary results from lacustrine paleoseismology are very encouraging and provide an exciting new way to address the uncertainties outlined above. Scientists now have a record of 12 ruptures on the middle segment of the Alpine Fault spanning the past 3500 years. This provides a more complete picture of the rupture history of the fault, which helps considerably with risk modelling and preparedness.

ASSESSING RISK

Risk can be handled a number of ways – avoid, transfer, reduce or accept – and our research focuses on informing decisions on which option is optimal. Living with some degree of risk is inevitable. Communities need to be comfortable that they can accept a certain level of risk from a low-probability, high-impact event, so long as we build in safeguards such as good evacuation planning. Part of our role is in developing multi-hazard risk models such as RiskScape to guide the most effective risk mitigation strategies. Another tool in this category is our National Seismic Hazard Model, which includes the national database of New Zealand's earthquakes going back 150 years and information on active faults going back thousands of years.

LANDMARK GISBORNE TSUNAMI STUDY

The East Coast of the North Island has one of the highest levels of tsunami risk in the whole country. The most dangerous potential source is the adjacent offshore Hikurangi Subduction Margin, a source of earthquakes. A tsunami generated from here could arrive at some parts of the East Coast in only a few minutes, with little or no warning other than the earthquake itself. Tsunamis generated from Peru or Chile also pose a threat to the East Coast, but the arrival time would be much longer, typically 14 hours or more, and the Pacific Tsunami Warning Centre based in Hawaii would trigger an advance warning.

Two tsunamis were generated in the Hikurangi Subduction Margin in 1947, both of which caused damage to cottages and sheds on the coast north of Gisborne. A recent GNS Science study at Puatai Beach north of Gisborne shows that the East Coast has been struck by three or four tsunamis that have left sand deposits as high as 9–12 metres above sea level in the past 1,200 years. The most recent occurred about 300 years ago.

GNS Science has been computer modelling tsunami possibilities for New Zealand over the last 15 years, as part of its core work. The tsunamis in the Indian Ocean (2004), Samoa (2009), Chile (2010), and Japan (2011) have each added information to this work, carried out by a small team of tsunami scientists. The increasing level of sophistication of risk assessments has enabled the team to calculate that, for most Gisborne residents, there is a higher probability of being involved in a serious road accident than being killed by a tsunami. However, for those living close to the coast, there is typically a higher risk of being killed by a tsunami than by an earthquake.

In March 2015, GNS Science published a report for the Gisborne District Council that maps the tsunami risk for Gisborne City and Wainui Beach on the northern outskirts of the city. The significance of this study is that it maps the risk to life for a specific location, with probabilities, using computer modelling for a locally sourced tsunami.

The study enables the Council to use the information for decisions on land use, zoning, mitigation measures and awareness programmes. It highlights, for example, the importance of the coastal strip of sand dunes in the area for protection against tsunamis. It also highlights that the southeast corner of Gisborne City would be the urban area of greatest risk to life from a 1-in-500 year average-return-interval tsunami. Over a 50-year period, there is a 10% probability of this type of tsunami. GNS Science will continue to work with the Council to help inform its long-term decision making.

THE CONTINUING DEVELOPMENT OF RISKSCAPE

Decision makers wanting to model the impacts of a natural disaster can now be aided by a new version of RiskScape software developed over the past year. The latest version gives users in central and local government, universities and the insurance industry open access to the software.

RiskScape has been developed by GNS Science and NIWA in collaboration with several universities over the past 12 years to help model the possible economic impacts of natural disasters and to inform infrastructure and emergency planning. It is designed mainly for use by not-for-profit and local and central government agencies.

It can be used to model the natural hazards most likely to affect New Zealand – volcanic eruptions, earthquakes, tsunamis, wind storms and floods – and to quantify the casualties, damage, downtime and economic losses. RiskScape has an inventory of all of New Zealand's buildings.

Users can choose what natural disaster they model – such as an eruption in Auckland, an earthquake in Wellington or flooding in the Hutt Valley. The software is a tool that channels the long-term research by the two Crown Research Institutes into science-based decision making that will increase New Zealand's resilience to natural hazards.

It enables a user to pose a range of risk-related questions and make decisions based on consequences. For example, it is possible to estimate the reduction in earthquake risks if buildings are strengthened and see risks associated with new suburbs in hazardous locations. RiskScape can be used to prioritise hazard mitigation measures and compare consequences from different hazard types.

It can be used to estimate the number of casualties, day or night, and determine how many people might need emergency accommodation and for how long. It can also be used to examine impacts of many events ranging from large, rare events to smaller, more frequent events.

Its outputs can be assessed down to the level of kilometre grids or suburbs, or across the whole country. The World Bank has named RiskScape as one of the best disaster modelling tools of its type and has been impressed by its user friendliness.

During its development, RiskScape has been enhanced by studies undertaken after major natural disasters such as the tsunami that struck Chile in September 2015, the Christchurch earthquakes, the 2011 earthquake-tsunami sequence in Tohoku, Japan, and the volcanic eruption at Mount Usu, Japan, in 2000.

SOCIETAL & ECONOMIC RESILIENCE

Our research underpins decisions about which treatment option for risk is most optimal. Do we avoid, transfer, reduce or accept a particular risk or set of risks? Do we strengthen our buildings and infrastructure in areas of high earthquake activity, which will lower the chances of casualties and business interruption? Or 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? We develop multi-hazard risk models that help decision makers with risk mitigation options.

NOVEL SOFTWARE TO QUANTIFY INFRASTRUCTURE LOSSES

The economic effects of infrastructure failure are substantial, long lasting and difficult to calculate. Loss of power, water and transport connections can have lasting impacts on communities and businesses, as the Christchurch earthquake sequence of 2010–11 demonstrated.

Now a new software package developed over four years with $2.8 million of funding from MBIE has been made available to help councils and large utilities with their planning and investment decisions. It has been developed through a partnership involving GNS Science, Market Economics, and Resilient Organisations, with input from other agencies including Auckland Council, and Canterbury and Massey Universities. Those involved in the Determining Volcanic Risk in Auckland (DEVORA) project also provided input.

Called the Measuring the Economics of Resilient Infrastructure Tool (MERIT), the toolkit's development included surveying Christchurch businesses affected by the 2010–11 earthquakes and modelling the economic impacts of three Auckland disaster scenarios – a major water outage, a major electricity outage and a drawn-out volcanic eruption in Manukau Harbour. The development team worked with Watercare, Transpower, Vector, and Auckland International Airport among others to source information for these scenarios.

The software does not calculate the direct costs of restoration and repair, which another model can do. Instead, it calculates the knock-on impacts to the wider regional and national economy.

It uses advanced system dynamics computational modelling so that different scenarios can be assessed. Scientists are also using the software to model the economic impacts of a large earthquake in the Southern Alps.

The package has been peer reviewed by US economist and resilience expert Professor Adam Rose (University of Southern California Sol Price School of Public Policy), who was responsible for definitive work providing an estimate of the economic consequences of the 9/11 terrorist attacks. Professor Rose visited New Zealand in 2015 to give an assessment to The Treasury on MERIT, describing it as cutting-edge technology.

MERIT can be used by councils to look at different mitigation options for a disruptive scenario and to consider the effects different infrastructure investment decisions might make to the outcome. It therefore offers the capability for regions to become more resilient and ratepayers to achieve the best value for money invested.

The current MBIE-funded MERIT development phase ended in September 2016. The development team is currently working with major stakeholders to develop a pathway for the toolkit, which includes funding to safeguard its future.

HELPING ASIAN NATIONS MANAGE RISK

GNS Science plays an important role in the Asia-Pacific region, helping nations to reduce the impact of natural disasters by building disaster risk reduction capability of local government and universities. We are part-way through a multi-year project to help Indonesia become better prepared for the impacts of earthquakes, tsunamis, volcanic eruptions, floods and landslides.

With a population of 250 million and frequent natural disasters, Indonesia has had to rely on international aid to help it recover from natural disasters. To combat this, the Indonesian Government has taken action to reduce losses from natural disasters and strengthen community resilience. It has made local governments responsible for managing hazards and risks.

Under a project called Strengthened Indonesian Resilience – Reducing Risk from Disasters, funded by the NZ Aid Programme, we are working in four provinces to reach a total of 3.75 million people. The project consists of training workshops in both Indonesia and New Zealand to learn about different approaches and the solutions to shared challenges in natural disaster management. Training focuses on enabling local government and universities to develop effective and sustainable structures and plans to reduce risks in their districts. Training covers policy, risk assessment, risk communication, community engagement, applied earth sciences and risk management methods.

As part of the project, we have jointly developed disaster vulnerability profiles for eight districts. The profiles capture the vulnerability of the natural, built, social, and economic environments to natural hazards. We have also drafted action plans to reduce the vulnerability. These have been endorsed by local governments in Indonesia and are being implemented in four districts.

Examples of initiatives arising from the project include expansion of earth sciences at Tadulako University in Palu, a public education programme, research into fault structures at Palu, improved coordination of liquefaction studies at Padang and research on installing early warning for landslides and debris flows. We have also completed training in earthquake strengthening of buildings, hazard mapping and risk modelling.

The project draws on New Zealand's expertise in applied earth sciences, disaster risk reduction, preparedness, and risk management. The numerous natural hazards that New Zealand and Indonesia have in common put us in a strong position to share our knowledge and experience. The project also supports the New Zealand Government's diplomatic initiatives in the Asia-Pacific region.

SCIENCE FOR A MORE PROSPEROUS NEW ZEALAND

New Zealand is well endowed with natural energy and mineral resources, which are important contributors to the lifestyle and energy security we expect as a first-world nation. Our contributions in this area support the Government's goal, outlined in the New Zealand Energy Strategy 2011–2021, to grow our economy and deliver greater prosperity, security and opportunities for all New Zealanders.

Geothermal energy contributes 16% of New Zealand's electricity generation. Our specialist skills and research are essential to maintaining the vitality of this industry and increasing the confidence of investors and operators by reducing the technical risks of exploration and development. Oil and gas production contributes between $2 billion and $3 billion each year directly and indirectly to New Zealand's economy. The main role of our publicly funded research in this area is developing the geoscientific basis for understanding, defining and predicting the oil and gas potential in our sedimentary basins.

When it comes to minerals, our role is in identifying the extent and grade of mineral resources in onshore and offshore New Zealand. This is crucial for appraising and managing these resources and for mining with minimal environmental impact.

Our niche capability in isotope and ion beam technologies is being used to develop new materials with characteristics such as increased hardness and wear resistance, hydrophobicity or enhanced magnetic and electrical properties. We work closely with New Zealand manufacturers to develop and prototype these enhanced materials for sectors such as food processing, energy production, medical applications, construction and agriculture.

RENEWABLE GEOTHERMAL ENERGY

We make a major contribution to the vitality of the geothermal energy industry. Our research addresses a range of opportunities and challenges for this sector. This includes assessing new fields, maintaining permeability and fluid flow, mitigation of corrosion and scaling build-up in pipes and environmental issues. A major focus for us is working with the geothermal energy industry to improve the efficiency of existing field management operations and developing assessments of new geothermal resources. Our work has helped to double the contribution that geothermal makes to New Zealand's electricity production in the past 17 years. Our research and applied services to the industry make a strong contribution to the New Zealand Government's goal of having 90% of our electricity supply generated by renewables by 2025.

FRESH APPROACHES FOR MODELLING GEOTHERMAL SYSTEMS

Geothermal energy provides reliable baseload electricity and is produced in the upper half of the North Island where the demand is greatest. Considered planning is needed to sustainably use this renewable energy source over many generations. An important part of that planning is the use of numerical modelling to predict the impact of planned developments on natural geothermal systems. This requires models that are proven and reliable.

GNS Science and The University of Auckland have long histories in numerical modelling of geothermal systems, both in New Zealand and internationally. Currently, GNS Science is leading an innovative MBIE-funded project – Geothermal Supermodels – in collaboration with The University of Auckland that is developing next-generation approaches to the numerical modelling of geothermal systems.

The underlying question is how to sustainably use multiple geothermal systems in the same region over many generations. The challenge here is that the existence of any connections between neighbouring geothermal systems cannot be directly measured. To answer this, we need new techniques to reliably predict the impact of using the energy from a geothermal system on both that system and any neighbouring systems. Our research programme addresses this in two of its core strands – new computer modelling software and the coupling of models from different scientific areas.

The new software, currently in its final year of development, will be released as open-source software that can be used by the geothermal sector worldwide. It will take advantage of the increased computing capability that has become available in recent years to provide a robust environment for building large-scale models. A beta version is currently being tested on a range of computing environments. This includes high-performance computers from New Zealand eScience Infrastructure (NeSI), which provides support systems to enable New Zealand researchers to tackle the world's biggest problems.

At the same time, we are starting to apply the software and modelling techniques to real-world problems in the geothermal sector. This work is being undertaken with geothermal development companies, and the Waikato and Bay of Plenty Regional Councils.

Internationally, there is strong interest in the outputs of this programme as they will enable offshore companies to improve the management of geothermal fields. This uptake will strengthen New Zealand's reputation as an international leader in geothermal research and development.

The new modelling suite will add significant capabilities to existing software as well as being more efficient and reliable. It will also help to reduce field development risk for geothermal energy developers. Finally, it will integrate seamlessly with existing geothermal research in New Zealand, and will increase knowledge of the structure, hydrology and hydrothermal processes that control geothermal systems.

NEW VALUE FROM GEOTHERMAL FLUIDS

GNS Science is leading the charge in assessing the viability of extracting dissolved minerals and metals from geothermal fluids with the aim of making the geothermal energy industry more profitable and more attractive to investors. At present, geothermal waters are injected back into the ground after heat has been extracted from them in power stations. Scientists estimate that many thousands of tonnes of dissolved minerals are injected back into the ground near power stations annually.

Working as an industry pathfinder, we have shown it should be possible to extract silica, lithium, boron, rubidium and caesium from geothermal brine, thus creating a valuable niche industry for New Zealand. Each geothermal field has a slightly different mix of dissolved minerals, meaning extraction techniques will need to vary from field to field.

Of all the minerals, silica is seen as the most promising to target because it is relatively abundant, extraction technologies are within reach and extraction is expected to promote increased efficiency of geothermal energy production through reduced operating and maintenance costs. Silica has a vast array of uses and is a vital component in many things used in everyday life. This includes construction materials, glass, ceramics, paint, plastic and rubber. Scientists estimate that revenue from extracting silica products from a 50MW geothermal plant could be $14–16 million a year. Other minerals that could potentially be extracted are lithium salts to make batteries to power electric vehicles and borate for fertilisers.

New Zealand geothermal scientists first identified the opportunity to extract minerals and metals in the 1960s, but it remains unrealised. Until now, extraction has not been seen as viable due to few full-scale demonstration plants, poor market drivers and lack of clear legislative and legal frameworks. However, our studies have shown that these challenges can be overcome, and New Zealand could become a world leader in this niche activity.

In 2015, we presented our findings at a stakeholder workshop in Rotorua. Among the nearly 70 attendees were representatives from power companies, local and central government, contractors, universities, Crown entities, Māori trusts and engineering companies. Feedback from workshop participants has enabled us to prioritise our future research directions.

The long-term outcome benefits of having a geothermal minerals industry in New Zealand are in economic development for regions, Māori and the industry itself. As well as producing extra revenue and creating job opportunities, it will also promote improved management of silica in power plants. Silica deposits can form on the side of pipes and reduce the efficiency of power stations.

PETROLEUM RESOURCES

In the petroleum arena, our focus is on improving the understanding of New Zealand's sedimentary basins and their petroleum potential. We provide industry, government agencies and other stakeholders with specialist evaluations ranging from regional assessments of geological history, petroleum systems evolution and prospectivity, to post-drill analysis of wells. In doing this, we draw on a wide variety of in-house technical expertise and an unmatched 150-year institutional history of earth science research in New Zealand. We recruit internationally, and this ensures we have the best available expertise for our clients. We routinely re-invest in new scientific equipment and computing technology to ensure that our capabilities keep pace with international industry standards.

MAJOR BOOST FOR PETROLEUM EXPLORATION

This year, oil and gas exploration companies got access to the first instalment in a series of new map-based geological data products that will help to pinpoint prospective areas in New Zealand's offshore territory. Available at no charge, the products will ultimately cover all of New Zealand's offshore basins and are the output of a four-year MBIE-funded project at GNS Science to produce a comprehensive digital Atlas of Petroleum Prospectivity.

The first product was the Northwest Province Datapack, encompassing the Taranaki, Deepwater Taranaki and Reinga-Northland basins. It covers 220,000 square kilometres of ocean floor, equivalent in size to 82% of New Zealand's land area. The datapack presents the most up-to-date understanding of petroleum prospectivity in a standardised ARC GIS format. It is the first time this unified approach has been applied to New Zealand's numerous offshore basins.

The project brings together about six decades of existing geoscience information, augmented by new open-file data, on subsurface habitats where oil and gas could potentially have accumulated. The workstation-ready datapacks will help to accelerate decision making by providing regional-scale information on factors such as sediment thickness, and the distribution of potential source, reservoir, and seal rocks.

In addition, a qualitative geological risk factor has been included. It provides an assessment of the uncertainties associated with the key petroleum system elements and the quality of data used. Also included is an estimation of the likelihood that potential source rocks have generated petroleum. This innovative multi-level assessment is enormously helpful to exploration companies who may be weighing up the merits of looking more closely at several areas.

Datapacks covering the other provinces will be released progressively, with the final one due in late 2018. The other Atlas areas are the Southeast Province (Great South and Canterbury basins), the Northeast Province (Pegasus-East Coast-Raukumara basins) and a far frontiers province covering less-explored basins in southwest New Zealand as well as those further from the coast. Compilation of these remaining map products is progressing steadily.

The datapacks will be made available through GNS Science's Petroleum Basin Explorer web portal and also via New Zealand Petroleum & Minerals in its annual datapack release. As various components of the first datapack were completed over the past 12 months, several have been made available to industry to address immediate needs for information.

The release of the Northwest Province Datapack has shown that there remain large parts of offshore New Zealand that are unpermitted that appear to have the elements for a working petroleum system. The main users of the digital Atlas are companies that are evaluating petroleum prospects globally, companies that are new to New Zealand, companies that are already here and looking for new opportunities, specialist providers that service the exploration industry, and government agencies that administer permit allocations.

NEW PETROLEUM SYSTEMS RESEARCH PROGRAMME TO REDUCE EXPLORATION RISK

Despite the use of many advanced technologies, the search for new oil and gas fields in New Zealand's petroleum basins remains challenging because of the many inherent uncertainties in our subsurface petroleum systems.

In late 2015, MBIE awarded GNS Science $9.6 million over four years to undertake new research to help reduce these uncertainties and to increase the availability of high-quality petroleum systems data for explorers. The overarching goal is to attract greater exploration investment to New Zealand and to increase the number of new oil and gas discoveries of sufficient size to boost New Zealand's prosperity. Supplementary co-funding, new oil and gas samples, and various exploration datasets are being provided by a number of oil companies.

The new petroleum source rocks, fluids and plumbing systems programme is investigating specialised aspects of our subsurface plumbing systems, from source to trap. Specific projects are using geochemical and paleontological techniques to identify a broader range of carbonaceous source rocks that have the potential to generate oil and gas. Geochemical fingerprints are being used to investigate the genetic and spatial relationships between oil and gas accumulations, subcommercial oil and gas shows and their source rocks to help constrain petroleum migration pathways. In addition, geological and geophysical techniques and computer modelling programs are being employed to better understand the factors that affect the dynamic movement of petroleum through subsurface strata.

We are also engaging with iwi and other stakeholders to discuss the geological and technical aspects of petroleum exploration. The intent is to foster informed dialogue concerning offshore petroleum exploration to help improve understanding of the risks, consequences and scale of potential benefits.

The research team includes collaborators from the universities of Auckland, Canterbury and Otago, Victoria University of Wellington, ESR and overseas institutions, including Durham University, Helmholtz Research Centre, RWTH Aachen University, University College Dublin and the University of Oxford. The programme is supporting eight PhD and two MSc projects and a number of internships for Māori students.

Programme outputs are being released to industry and other end-users at regular intervals via conferences, workshops and scientific journals and in digital data products and reports distributed via GNS Science's Petroleum Basin Explorer web portal and New Zealand Petroleum & Minerals' Online Exploration Database and annual datapack release.

"GNS Science's [former] Petroleum Source Rocks & Fluids programme has gleaned many valuable insights into New Zealand source rock chemistry and generative behaviour and delivered results in an easy-to-use format. In particular, the establishment of robust relationships between source rocks and hydrocarbon fluids has yielded better constraints on the distribution of actively expelling source rocks. The new programme builds on the historical work but extends to additional potential source-bearing intervals and has value for underpinning evaluation of potential in frontier areas as well as potential in the better-established areas, such as Taranaki. Shell NZ Ltd would find outputs of the future research programme valuable for the evaluation of exploration potential within the New Zealand EEZ, as it addresses one of the key challenges for exploration in New Zealand."

Frank Dessing, New Zealand Exploration Lead, Shell NZ Ltd

MINERAL RESOURCES

We provide the minerals industry and government with mineral prospectivity information. This helps in identifying exploration targets and in de-risking exploration and extraction operations. As well as industry operators and government agencies, other users of our information are regional councils and iwi/Māori interests.

The industry has a total land footprint of 134 square kilometres compared to the New Zealand land mass of 270,000 square kilometres. About 8,000 people are employed directly and indirectly in the minerals sector. As much as 86% of income earned from mining stays in New Zealand as salaries, taxes, rates, royalties, levies and payments to suppliers and contractors.

MINERAL POTENTIAL IN THE REGIONS

For a land area of only 270,000 square kilometres, New Zealand is surprisingly well endowed with mineral resources. We currently produce gold, silver, iron and industrial minerals such as bentonite, clay, perlite, pumice, serpentinite, silica sand and zeolite. Other mined materials include limestone and rock aggregate, plus coal and petroleum.

GNS Science has been investigating the potential of these natural resources. We have undertaken seven regional mineral resource assessments in Coromandel, Otago, Northland, West Coast, Waikato, Thames-Coromandel and Southland.

This programme has been carried out in collaboration with the New Zealand Minerals Industry Association (now Straterra), Crown Minerals (now New Zealand Petroleum & Minerals) and with the relevant regional councils.

In 1998, the minerals industry set itself a target to double the value of mineral and coal production within 10 years. As it happened, this was readily achieved with the global boom in coal demand and almost all other mineral commodities in the first decade of this century.

At the time, we adopted a two-pronged strategy to stimulate this objective: raising awareness of New Zealand's mineral potential and encouraging the New Zealand Government to fund airborne geophysical surveys, which provide a guide as to which areas warrant closer investigation.

This approach has led to a more invigorated industry sector, significant regional and local body support throughout the country and substantial government investment in regional mineral resource assessments. One of the many outcomes from the regional mineral resource assessment project is an estimate of $100 billion for the total-in-ground value of metals, based on 2016 prices.

New Zealand is rich in mineral resources, and there is considerable potential to find new profitable deposits.

SHEDDING LIGHT ON GOLD

Some of New Zealand's oldest sandstone formations exposed near Reefton host significant quantities of gold-bearing sulphide minerals. GNS Science minerals geologist Patricia Durance has been working with fellow researchers at Monash University, Melbourne, to identify where gold resides within the sulphide minerals and how and when this mineralisation occurred.

This work is also part of a four-year MBIE-funded project called Gold Exploration Models (GEM), which has strong industry support.

There are well known similarities between the geology of the gold-prone Bendigo Zone of Victoria, Australia, and the geology of the Reefton, West Coast, region of the South Island.

Drilled-out rock samples from ore deposits at the Globe-Progress Mine near Reefton have been subject to high-tech examination using Australia's Synchrotron in Melbourne. Thanks to funding contributions from shareholders of the New Zealand Synchrotron Group (NZSG), with GNS Science as a shareholder, New Zealand researchers have a 5% stake in this state-of-the-art instrument. This support enables GNS Science researchers free access to beamtime within a contestable, merit-based scheme.

The Synchrotron is a circular, stadium-sized electron microscope that enables us to see and explore three-dimensional objects non-invasively at the nanometre scale. It involves the synchronisation of the intense light that is released by fast-moving electrons. This electronic light is manipulated using clever magnets to reveal the inner structure of minerals.

This gives scientists unprecedented two- and three-dimensional images of the inside of crystals. In this case, the target minerals are iron, arsenic and antimony sulphides and the gold that sits within them. All of these minerals grew from hot metal-rich hydrothermal fluids that invaded the parent sandstone at some time in the past.

Detailed chemical and isotopic analysis using the Synchrotron will enable scientists to provide a geochemical framework in which to develop gold exploration models for the industry. This is a very new application of the Synchrotron, and it enables geologists to study ore-forming processes at a scale not easily achieved by other techniques. The technique has the potential to significantly improve the understanding of precious metal deposits, which would aid exploration and recovery by industry operators.

NEW MATERIALS & PROCESSES

We undertake research in advanced materials using our niche capabilities in ion beam technology. We use this capability to develop materials with enhanced physical, chemical and electrical properties and also to develop advanced sensor devices. There are rapidly expanding global markets for advanced materials already worth billions of dollars. We work closely with New Zealand manufacturers to develop and prototype these enhanced materials for sectors such as food processing, energy production, medical applications, construction, security, agriculture and high-value manufacturing.

MAGNETIC PLAYDOUGH

Scientists in our Environment and Materials Division are developing a new soft magnetic material that could increase the efficiency of electric motors, radio components and consumer electronic devices. The nanostructured material, being prototyped at our National Isotope Centre, has superior properties and performance compared to existing magnetic materials. The commercial potential of this development is significant, with global markets measured in billions of dollars annually.

Project leader Jérôme Leveneur, who describes the new material like magnetic playdough, believes the new high-performance material has the potential to benefit a wide range of industries and lead to a radical advancement in electromagnetic technologies. It can be moulded into any size or shape whereas existing materials can only be made into very particular shapes and sizes. This not only makes it easier for manufacturers to work with, but it makes it more efficient as it ensures that the magnetic field can be directed exactly where it is needed.

This year, Jérôme was awarded $20,000 from the KiwiNet Emerging Innovator Fund to further develop the new material and investigate its market potential. Part of the project involves benchmarking the new nanocomposite material against existing materials to assess its potential worth. The hope is that investigations will show that, if adopted by manufacturers of consumer electronic devices and appliances, the new material would not only boost performance of products but also improve the user experience.

Jérôme is working closely with several New Zealand manufacturers of electrical equipment who could benefit from this research. He is working on demonstrating how this novel material can outperform current materials. There is potential to develop a new class of magnetic material that is currently unachievable using conventional methods.

UNDERPINNING GEOSCIENCE KNOWLEDGE

Properly collected and archived geoscience information can be valuable for decades, if not centuries. We acquire information in a variety of ways including satellites, airborne measurements, field observations, research voyages, instrument networks, scientific drilling and laboratory analysis. It is our role to build and curate this data and make it accessible to a wide range of end-users to support decision making by government, communities and industry.

Almost everyone in New Zealand benefits in one way or another from geoscience data and collections. Benefits vary from the satisfaction of an amateur fossil hunter who takes a latest find to an expert for identification to the obvious benefits to society of a secure national energy supply to a sound understanding of natural hazards and aquifers that provide our freshwater needs. Geoscience knowledge has a role to play in giving us our roads, dams, bridges and communications networks and many of the comforts and conveniences a modern society uses every day.

Perhaps one of the greatest values of geoscience data and collections is that most have uses unimagined by the original collectors. New analytical technologies elicit different and often better information. For example, samples collected by the petroleum industry have been later used in unanticipated ways to analyse geological hazards, with core and seismic data being used to improve evaluation of earthquake hazards in urban areas.

ZEALANDIA REVEALED

The vast size of the continent that New Zealand sits on means we as a nation have continental-scale resources, opportunities and responsibilities. New Zealand's combined onshore and offshore area is 6 million square kilometres, equivalent in size to 1% of the Earth's surface. The role of GNS Science is to build a comprehensive understanding of the geology and geophysics of the subsurface in this vast area – a task that is large by any measure. This means determining the geological makeup, crustal structure, tectonic history and resource and hazard potential of this area. This provides a solid base for multiple applied areas such as urban planning, disaster mitigation, sustainable resource use, and policy development for land use.

FROM CONTINENTAL TO URBAN SCALES

From a geological perspective, New Zealand is part of the largely submerged continent of Zealandia. Formally recognised and named in 1995, Zealandia is 5.7 million square kilometres in area – about 22 times that of our land area and two-thirds the size of Australia.

GNS Science is committed to exploring Zealandia and will be doing so for decades to come. It is vast. New Zealand and New Caledonia are the most significant lands within Zealandia, but represent less than 6% of its area. The other 94% is submarine. Its geological exploration will occur at all scales ranging from continental to onshore-focused mapping at national, regional and urban scales.

To address the continental scale, GNS Science has a commitment from the International Ocean Discovery Program (IODP) to conduct five exploration projects involving scientific drilling in New Zealand waters starting in August 2017 using the US-based research ship *JOIDES Resolution*.

We have also been building the geological understanding and representation of onshore New Zealand with completion of a number of significant new geological maps. Among these is a new 1:1,000,000 map of New Zealand that includes offshore islands such as the Kermadec and subantarctic islands.

At regional scales, we have completed the first new-generation mineral province geological map of the Middlemarch area in east Otago. The map integrates airborne geophysical and geochemical information to depict subsurface geology as well as surface geology and will be used by the mineral exploration industry for target definition.

We are also nearing completion of a new 1:60,000 geological map of Tongariro National Park covering 2,000 square kilometres of the North Island's central plateau. The mapping has revealed a complex interplay between volcano eruption and cone-building with ice during periods of glaciation and de-glaciation. The map is expected to be in high demand by the hazard management and tourism sectors, as well as the public.

In urban mapping, we have completed the first of a new generation of digital-only geological map datasets of Christchurch City and eastern Canterbury – an area of roughly 2,000 square kilometres. The product includes the first published subsurface 3D models of geological and geotechnical property variation based on vast drill hole and geotechnical probe databases. The map clearly shows the spatial arrangement of the numerous geological layers under the wider Christchurch area. These 3D geological models of urban New Zealand will help with infrastructure development, groundwater management, and geological hazard planning.

YEAR-LONG OFFSHORE RESEARCH PROJECT TO START IN 2017

Scientists from across the world will come to New Zealand in 2017 and 2018 to participate in a series of unprecedented offshore investigations into the seafloor using the US-based research ship *JOIDES Resolution*. The five back-to-back research voyages, which will start in August 2017, are the culmination of years of planning and preparatory work by hundreds of scientists from many countries.

JOIDES Resolution will complete multiple drillholes beneath the ocean floor in four target areas off the New Zealand coast, and one in the Ross Sea to collect information about how planet Earth works that can only be obtained by drilling into the seafloor. The ship is operated by the IODP, which has 26 member countries, including New Zealand and all of our major trading partners. It will spend about 12 months in New Zealand waters with each of the five legs lasting about two months. Scientists from GNS Science are co-principal investigators on two of the legs.

Given that most of New Zealand's continental area is under the ocean and is largely unexplored, this is a unique opportunity to discover and understand more about our home territory and its place on Earth. The $100 million-plus investment in the five projects by the IODP is a ringing endorsement of how globally important our sector of the ocean is. The investment comes from the 26 IODP member countries, who will benefit from the scientific gains made as a result of the five voyages in our waters.

The project can be expected to produce improvements in understanding of environmental change, geological hazards and seafloor hydrothermal systems. Benefits from having one of the world's top research ships here for 12 months will include new insights in understanding earthquakes beneath the North Island, conditions for the origin of life, mineralisation at submarine volcanoes and improved knowledge of how quickly Antarctic ice sheets collapse. With earthquakes, volcanoes, tsunamis and climate change all presenting significant hazards to New Zealand, this research effort is relevant to every New Zealander.

Other impacts will include providing invaluable training opportunities for the next generation of New Zealand scientists and engineers and delivering unrivalled opportunities for students, teachers and the public to engage with science. New Zealand's involvement in the IODP comprises GNS Science, Victoria University of Wellington, NIWA and Otago and Auckland Universities together with a number of Australian universities and government organisations.

GEOSCIENCE INFORMATION

We have a long-term role as the provider of trusted geoscience databases and collections that are nationally important. We maintain eight nationally significant databases and collections and a further six that are considered important to New Zealand. They are all publicly available, and wherever possible, we adopt international or industry standards to the data and the way it is presented. We manage the databases and collections in a way that enhances their ongoing value to New Zealand. Tens of thousands of people and organisations access and benefit from our databases and collections each year.

UPGRADED ACTIVE FAULTS DATABASE

Active faults pose an ever-present threat to lives and property in New Zealand. Property buyers, real estate agents, councils and the government all need information to help assess the level of risk in land they have interests in.

They are now able to freely download information on over 300 of New Zealand's on-land active faults, which has been compiled by earthquake geologists at GNS Science. The database contains information on over 300 known active faults that have deformed the ground surface over the last 125,000 years.

It catalogues all the faults to a consistent scale of 1:250,000 and gives an expected return period for a major earthquake on any given fault. In the past two years, the earthquake geology team has added new information, including newly recognised faults in Canterbury as a result of the 2010–11 earthquake sequence.

GNS Science regards it as a nationally significant database because it informs research, planning and hazard modelling. It is an ongoing source of reference, and in the 12 months to 30 June 2016, it was viewed on the GNS Science website by more than 7300 users. As well as the public, users include scientists, students, consultants, councils and other corporate entities.

The database's basic mapping unit is a fault trace – a line mapped to define the ground surface projection and expression of a fault.

A user of the database can select a fault and then view all the features that characterise its activity to help inform a judgement on its seismic hazard.

We are planning to enhance it by adding more information on onshore active folds and offshore faults.

Onshore folds may be the only expression of blind faults, which are difficult to represent in active fault databases yet gave rise to the devastating 1931 Hawke's Bay and 2011 Canterbury earthquakes. Offshore faults have been mapped by marine geologists at NIWA and the information shared with GNS Science.

GROUNDWATER DATABASE GIVES NATIONAL PERSPECTIVE ON FRESHWATER QUALITY

GNS Science operates a national database on groundwater quality that shows long-term trends in quality of New Zealand's freshwater and enables us to distinguish between naturally occurring changes and those that are human induced. The National Groundwater Monitoring Programme (NGMP), which is run in partnership with 15 regional councils, samples 110 sites throughout the country four times a year. Samples are analysed for 17 parameters to provide a national perspective on groundwater quality.

The database is one of eight nationally significant databases operated by GNS Science. A robust record of groundwater quality is important, as there are 200 mapped aquifers in New Zealand and about a third of the country's population use groundwater for their daily freshwater supply.

One of the many uses of the publicly available database is as an input to the Ministry for the Environment's three-yearly report on the status of New Zealand's freshwater. It is also a basis for developing improved management techniques to help safeguard groundwater quality. For example, a recent joint study involving Gisborne District Council and GNS Science combined NGMP and regional monitoring data to review the regional groundwater monitoring operations in Gisborne.

In the 20 years the programme has been running, we have been able to broadly group New Zealand's groundwater into three classes, each making up about a third of the total resource.

'Natural fresh' groundwater shows little or no evidence of human impact and is chemically similar to clean river water. 'Natural evolved' groundwater shows evidence of natural water-rock interaction and may contain elevated amounts of iron and manganese. Finally, 'impacted' groundwater has nitrate concentration above natural levels due to human or land-use influences.

In the past year, we made a number of improvements to the database including simplifying the navigation and adding new data browsing features, and a new help feature that facilitates searches and data retrieval. This has improved the database's usability and value to its wide range of users.

CONTRIBUTING TO SCIENCE AND NEW ZEALAND

GNS Science is privileged to have exceptional staff who make an extraordinary contribution to New Zealand. In the past year, a number of our staff were recognised for their outstanding contributions to science.

Climate researcher **Nancy Bertler** won a 2016 Blake Leader Award for her outstanding role as manager of the Ice Core Research Facility at GNS Science and for leading 13 multi-national deployments to Antarctica to collect ice cores for climate research.

Geothermal scientist **Brian Carey** was elected as the executive secretary of the International Energy Agency Geothermal Implementing Agreement (IEA-GIA).

Paleoclimate scientist **Giuseppe Cortese** was awarded a six-month visiting professorship at the University of Bordeaux, France. His research will focus on climate and Southern Ocean siliceous productivity interactions over the past 50,000 years.

A paper co-written by geologist **Simon Cox** in *Earth and Planetary Science Letters* (EPSL) on fluid flow on the Alpine Fault became the most downloaded article during a 90-day period for EPSL and 14th for impact out of 1,468 papers since the publication started this metric.

Paleontologist **James Crampton** was made a professor at Victoria University of Wellington while maintaining his role at GNS Science. James is a leader in biostratigraphy and paleobiology within New Zealand and internationally.

Marine geochemist **Cornel de Ronde** undertook a five-city AUSIMM Distinguished Lecture tour of Australia and Papua New Guinea.

Minerals geologist **Patricia Durance** was invited to participate in the Australian Academy of Sciences 2016 Theo Murphy High Flyers Think Tank.

Geothermal scientist **Karen Houghton** was awarded two travel scholarships. Her first was the Claude McCarthy Travel Fellowship scholarship, which funds students to attend overseas conferences or to conduct PhD research. Her second scholarship enabled her to attend the 2016 Extremophiles Conference in Kyoto, Japan.

Materials scientist **Jérôme Leveneur** won the Outstanding Individual category in the 2016 Technology Valley Awards.

Paleoclimate scientist **Richard Levy** was appointed to the Executive Committee of the International Continental Drilling Program.

Hazards scientist **David Johnston** won a Ministerial Silver Award for important contributions to Civil Defence and Emergency Management in New Zealand. The award recognises the many achievements and contributions during David's 25-year commitment to emergency management in New Zealand.

Geothermal technicians **Nick Macdonald** and **Hanna-Annette Peach** were each awarded a Queen Elizabeth II Technicians' Study Award through the Ministry of Education. The award partly covers study fees, travel and materials.

Geothermal scientist **Jean Power** was awarded a student travel scholarship from The International Society of Microbial Ecology to attend the 16th International Symposium in Montreal in 2016.

Isotope chemist **Karyne Rogers** won the Outstanding STEMM Educator (tertiary and community) category in the 2016 Technology Valley Awards.

Marine geochemist **Christian Timm** won the Werner Giggenbach Prize for Geochemistry for his publication in *Nature Communications* on subduction processes in the Kermadec Arc.

Atmospheric scientist **Jocelyn Turnbull** was appointed to the World Meteorological Organisation Greenhouse Gas Scientific Advisory Group as New Zealand's representative.

Geomicrobiologist **Matt Stott** won a Fulbright Scholarship to undertake five months' study at the Thermal Biology Institute at Montana State University. Matt was also awarded the best oral presentation at the 13th International Thermophiles Conference, Santiago, Chile.

Petroleum geochemist **Richard Sykes** and co-authors were awarded the 2015 Dalway J. Swaine Award by The Society for Organic Petrology for Best Refereed Paper in Coal and Hydrocarbon Source Rock Geochemistry for their manuscript entitled, 'Marine influence helps preserve the oil potential of coaly source rocks: Eocene Mangahewa Formation, Taranaki Basin, New Zealand' published in *Organic Geochemistry*.

GNS SCIENCE AT A GLANCE

GNS Science, Te Pū Ao, is the Crown-owned science company in New Zealand that focuses on geological resources, environmental and industrial isotopes and geological hazards. We apply this scientific knowledge to create and preserve wealth, to protect the environment and to improve the safety and wellbeing of people.

Our Māori name, Te Pū Ao, refers to the foundation, origin and source of the world in its entirety, from the atomic through to planetary scales.

The benefits we deliver for New Zealand include:

- wealth and security from energy, mineral – and water resources
- mitigation of the economic and social effects of geological hazards
- development of new technologies such as nanoscale devices and non-invasive scanning.

These benefits arise directly from our research into processes and endowments within the Earth's crust including:

- rocks, minerals and groundwater
- earthquakes, volcanoes, landslides and tsunamis
- hydrocarbons and geothermal energy
- geobiology and climate history
- gravitational and electromagnetic fields
- natural isotopes and radiation.

Scope and governance

We operate as a limited liability company owned by the New Zealand Government and with an independent Board of Directors. This unique structure allows us to:

- focus on strategically important science at a national level
- engage in the full spectrum of science from basic research through to provision of consultancy services and product development

- undertake work for the public and private sectors
- operate in New Zealand and internationally
- have autonomy and self-determination.

Each year, we invest most of our tax-paid profit in scientific equipment and infrastructure. This ensures our capabilities keep pace with or lead international standards.

Our clients include:

- New Zealand central government agencies
- regional and local government
- overseas government agencies
- oil and gas exploration companies
- geothermal energy exploration and operating companies
- hydroelectricity operating companies
- the onshore and offshore minerals exploration industries
- meat, dairy, wool, timber and horticulture processing industries
- insurance and reinsurance companies
- engineers, developers, and infrastructure companies
- museums
- research organisations in New Zealand and overseas.

Staff and revenue

Our 361 staff are located in Lower Hutt (81%), Taupo (17%) and Dunedin (2%).

Our revenue for 2016 was generated from:

- direct government grants for research (33%)
- contestable public-good research contracts (27%)
- consultancy services, product development and analytical services for the private sector and for central and local government (26%)
- monitoring geological hazards for the Earthquake Commission (14%).

Visit our website: www.gns.cri.nz

BUILDING GREAT STAFF AND A GREAT WORKPLACE

We are committed to building an organisation of talented, diverse and capable leaders and staff and are fostering a workplace environment where our people feel empowered, valued and supported. Our People Plan focuses on supporting our people to be high performing. The four key themes of the plan are developing our people, driving performance excellence, creating an engaged workforce and developing effective systems and processes.

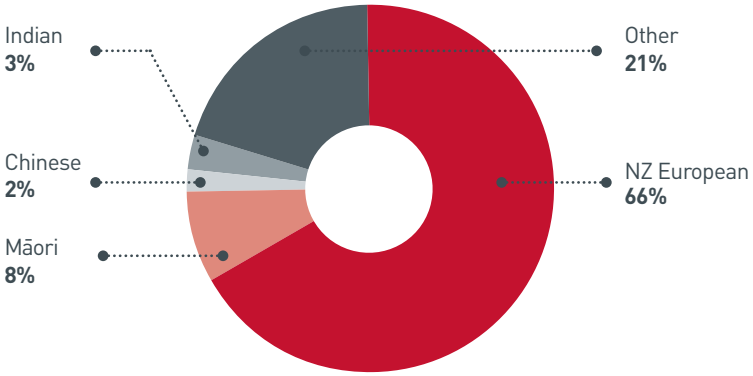
The alignment between our key people policies and practices and the seven elements of being a good employer is outlined below.

BEING A GOOD EMPLOYER

ELEMENT	OUR ACTIVITIES THIS YEAR
Leadership, accountability and culture	• Specific leadership workshops developed for managers to support a high-performance culture. • GNS Science Excellence awards launched to promote, celebrate and recognise excellence. This will be run as an annual event.
Recruitment, selection and induction	• Enhanced Interviewing Skills workshops held for hiring managers and also open to staff wishing to improve interviewing techniques. • Education relating to unconscious bias is provided to ensure a robust recruitment and selection process. • Accredited employer with Immigration New Zealand. • Organisation-wide induction workshops held to welcome new staff.
Employee development, promotion and exit	• Development conversations are a key part of the performance review process. • Development opportunities include project work, acting in roles, secondment, mentoring and coaching as well as a comprehensive list of training courses. • Staff attend and/or present at national and international conferences, trade shows and workshops to develop and maintain their technical expertise. • 19 progression applications were successful in our annual progression round with our first female scientist achieving principal scientist status. • Workforce and succession planning occurs annually. • All staff leaving our organisation have the opportunity to complete an exit interview.
Flexibility and work design	• We promote a balance between work and personal commitments through flexible working. • We are open to staff requests for changes to their working arrangements via our Flexible Working Arrangements policy. • 10% of staff work part-time hours.

Remuneration, recognition and conditions	• Annual remuneration review process, including comparing our remuneration data against market data to ensure fair and equitable remuneration for our staff. • Project is under way to revamp our Career, Performance Development and Remuneration Framework. • Worked closely with staff, managers and the Public Service Association (PSA) to manage change programmes, develop policies and improve our practices as a good employer. • Pay and Employment Equity Review project scoped with the PSA. The purpose of this review is to ensure pay, conditions of employment and experiences in the workplace are not affected by gender.
Harassment and bullying prevention	• We are committed to maintaining a safe working environment that is free from bullying, harassment and other undesirable behaviours. We promote a culture where staff experience mutual respect, trust and dignity. Activities this year include: – Preventing and Responding to Bullying and Other Undesirable Behaviours policy and Quick Reference Guide developed and implemented in consultation with staff, managers and the PSA – reviewed and updated the Code of Professional Practice to provide clearer examples to staff and managers around what is and is not appropriate behaviour – Creating a Respectful Organisation workshops were run organisation wide.
Safe and healthy environment	• Our commitment to health, safety and wellbeing was evidenced in our Staff Survey results, which showed an achievement above IBM Best Workplaces benchmark for the statement "GNS Science is committed to the health and safety of its people". • Our strong focus on health, safety and wellbeing is supported through the provision of support services such as: – Employee Assistance Programme – additional support in the event of heightened stress, such as response to an event, change process support and resilience training – flu vaccinations – ergonomic workstation assessments – eye examinations – regular medicals for all field and laboratory staff – Step Challenge – Health and Wellbeing lunchbox sessions. • We have tertiary ACC accreditation for our workplace safety management practices.
Equal employment opportunities statement	We are committed to being an equal employment opportunity (EEO) employer through our organisation-wide EEO good employer practices relating to recruitment and selection, development, promotion/career progression, management and retention of all staff.

WORKPLACE PROFILE

Full-time equivalent (FTE) staff	Our FTE count at 30 June 2016 was 361 (368 in 2015).
Annual staff turnover	Resignations and retirements in the year to 30 June 2016 amounted to 7.4% of the workforce (5.6% in 2015).
Gender profile	We have a 38:62 **female/male** ratio (39:61 in 2015).
Age profile	The average age of our staff as at 30 June 2016 was 47.4 years. Average age of **females** 44.9 years. Average age of **males** 48.9 years.
Ethnicity of recruits 2015/2016 (self-identified)	
Disability (self-identified)	This information is gathered at recruitment. Over the past 12 months, two staff have selected this category. We are committed to valuing the diversity of our people and recognise, respect and value differences and do not discriminate.

GNS Science Excellence Awards 2015

2015 was the inaugural year of our Staff Excellence Awards. They celebrate staff for conspicuous achievement in science and outstanding contributions to the organisation. Staff are nominated by their peers, and finalists are selected by a representative internal panel for ratification by the Executive.

Ursula Cochran
Excellence in Science Communication

Te Kura Whenua Team (Chris Hollis, Richard Levy, Kyle Bland, Diane Bradshaw, Fiona Coyle)
Excellence in Science Communication

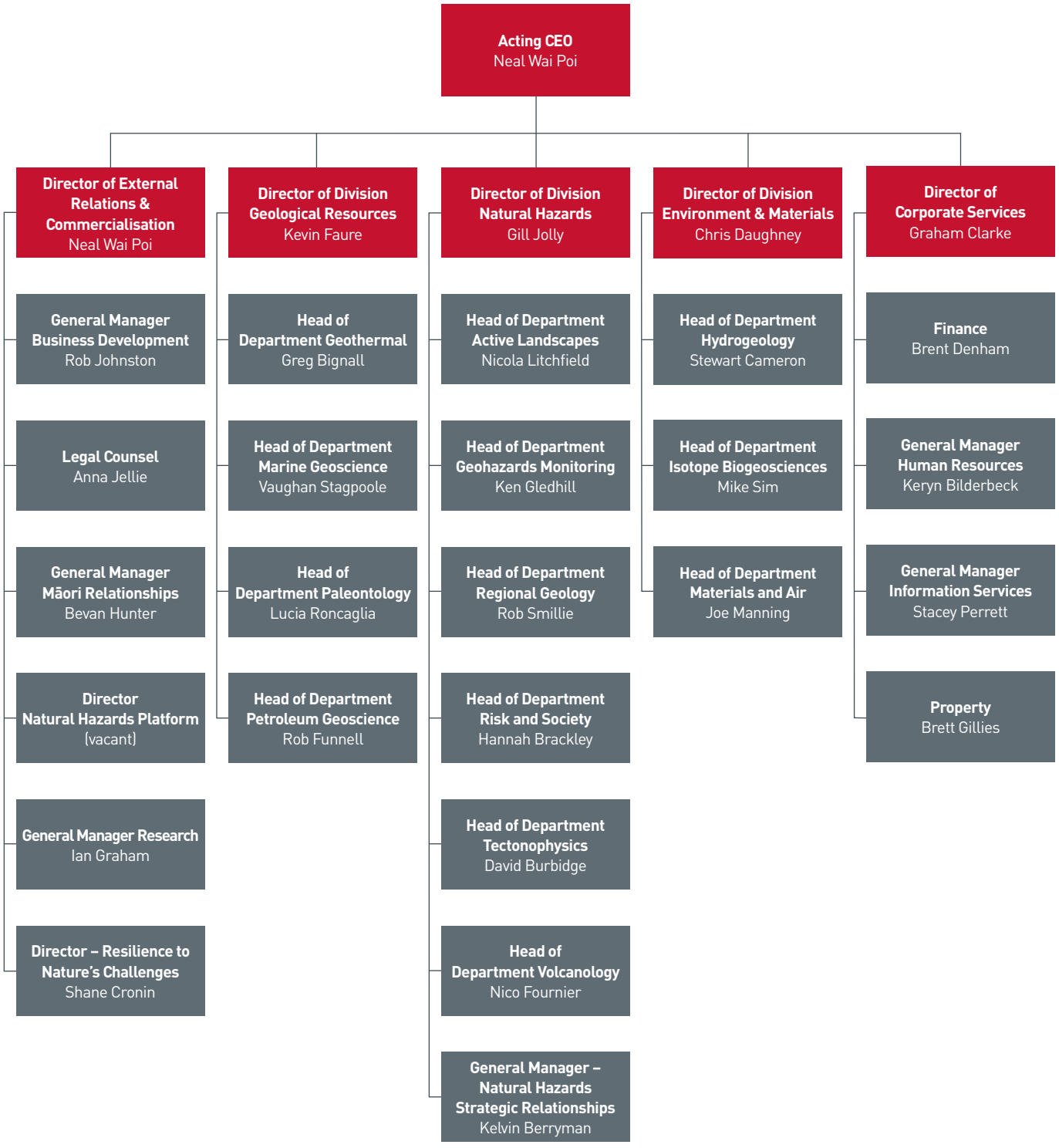
Jamie Howarth
Excellence in Science

Peter King
Excellence in Making a Difference

Chris Massey
Excellence in Commercial Services

ORGANISATIONAL STRUCTURE

(AT SEPTEMBER 2016)



STRONG GOVERNANCE

DR NICOLA CRAUFORD[1]

Chairman
BSc Hons, PhD, FIPENZ, CPEng, FAICD, CMInstD
Wellington
(Appointed 1 July 2015)

Nicola has extensive management and governance experience gained in private and state-owned companies. She is a director of Watercare Services Limited, Orion New Zealand, the Environmental Protection Authority and Wellington Water Limited and is Deputy Chairman of the Fire Service Commission. Nicola is a member of the Local Government Risk Management Agency Establishment Board. She was formerly a member of Transpower's executive team and a director of Genesis Energy.

SARAH HAYDON[2]

Deputy Chairman
BSc, ACA, CMInstD
Auckland
(Appointed 1 July 2014)

Sarah is a director of Ports of Auckland Limited, The Co-operative Bank Limited and a Council member of Unitec. She is the Chairman of Cavalier Corporation Limited and New Zealand Riding for the Disabled Association Inc. She is a chartered accountant and has worked for BP in the UK and also on international project work, and was CFO at OfficeMax New Zealand. Sarah has an extensive background in strategic planning, finance, general management and organisational development. She has led large teams of people and has strong HR and people skills.

BELINDA VERNON[3]

BCom
Auckland
(Appointed 1 July 2011)

Belinda is a consultant with a background in accounting, shipping and conservation. She is a Member of the Maritime NZ Authority and has previously worked in senior accounting roles in the shipping industry. She was a Member of Parliament between 1996 and 2002 and is Chair of the Auckland Philharmonia Foundation. She is an active volunteer with the Motutapu Restoration Trust.

PROFESSOR STEVE WEAVER[4]

BSc Hons, PhD, DSc, FGS, FNZIC, FRSNZ
Christchurch
(Appointed 1 July 2010)

Steve was formerly Deputy Vice-Chancellor (Research) and Head of the Department of Geological Sciences at the University of Canterbury. He has also held academic appointments at Birmingham, London and Nairobi Universities. He is a Fellow of the Royal Society of New Zealand and is a board member of Research & Education Network New Zealand (REANNZ) Limited and a member of the Governance Group of the Resilience National Science Challenge. Steve has published extensively on the geology of New Zealand, Antarctica and East Africa, specialising in igneous petrology, volcanology, isotope geochemistry, tectonics and environmental science.

CHRIS BUSH[5]

BE (Chem)(Hons), CMInstD
New Plymouth
(Appointed 1 January 2016)

Chris is an experienced oil and gas professional with 30-plus years spent in both upstream and downstream sectors including roles in New Zealand and overseas. He runs his own consultancy providing strategy and risk management advice to the energy sector and other capital-intensive industries, and has particular expertise in health and safety in major hazard facilities.
He has held a number of director roles and was previously Chair of the Petroleum Exploration and Producers Association (PEPANZ) and of the Be Safe Taranaki Trust.

BOARD OF DIRECTORS

Our experienced directors are committed to enhancing the organisation and its reputation. Their diverse backgrounds ensure that there is sound oversight of all aspects of our operation.

EXPERIENCED LEADERSHIP

DR NEAL WAI POI[1]

Acting Chief Executive and Director, External Relations & Commercialisation

PhD, The University of Auckland

Neal leads External Relations & Commercialisation at GNS Science and was appointed in May 2015. He has over 20 years' international experience in industry-focused research and development and commercial technology transfer, with skills in negotiation and strategic management. Before coming to GNS Science, he worked with CSIRO, most recently as Group Manager Strategic Alliances. He also worked at Simonsen AS as commercial manager and Rio Tinto Aluminium as a research and development manager.

DR KEVIN FAURE[2]

Director, Geological Resources Division

PhD, The University of Cape Town

Kevin leads the Petroleum, Geothermal, Paleontology and Marine Geoscience Departments. He specialises in stable isotope geochemistry and has researched and published on ore deposits, submarine volcanoes, gas hydrates and geothermal springs. He joined GNS Science in 1997 and has previously worked as an exploration and mining geologist in South Africa, and as a research scientist at the Geological Survey of Japan.

DR CHRIS DAUGHNEY[3]

Director, Environment and Materials Division

PhD, McGill University, Montreal, Canada

Since 2012, Chris has led the Environment and Materials Division, which includes research teams and commercial service units in hydrogeology, air quality, isotope biogeosciences and materials science. Chris joined GNS Science in 2002 and specialises in aqueous environmental geochemistry. His areas of interest include the chemical evolution of groundwater at the catchment scale, geomicrobiology and the use of tracer methods for evaluating in situ rates of water-rock interaction.

GRAHAM CLARKE[4]

Director of Corporate Services
Chief Financial Officer

Chartered Accountant

Graham leads the Corporate Services Division, which provides the full range of functions to support the Company's internal operations including finance, human resources, information services, property, procurement, health and safety, risk management and internal audit. A chartered accountant, Graham has been with the Company since 1994, having previously worked for KPMG in New Zealand and the UK.

DR GILL JOLLY[5]

Director, Natural Hazards Division

MA (University of Cambridge), PhD (Lancaster University) FGS, CGeol

Gill has led the Natural Hazards Division since August 2014. It consists of 130 staff who undertake research and consultancy in earthquakes, volcanoes, landslides, tsunamis, geological mapping, engineering geology, earthquake engineering, risk modelling and social sciences. Gill is a volcanologist and joined GNS Science in 2006. Her background is in magma physics and lava flow dynamics, but she has had a diverse career including mineral exploration, environmental geochemistry and 3D geological modelling of ore deposits. She was formerly a director of the Montserrat Volcano Observatory in the West Indies.

EXECUTIVE TEAM

GNS Science's leadership team brings a wide range of skills to the management table. They are committed to maintaining the highest standards of professionalism to enable us to meet our business and science objectives.

PERFORMANCE INDICATORS

These indicators include those specified in our Statement of Corporate Intent.	**Actual 2015/16**	Budget or expected range	Actual 2014/15
Financial performance indicators and targets			
Return on equity	**3.8%**	5.0%	5.9%
Revenue per FTE ($000s)	**228**	236	212
Profit[1] per FTE ($000s)	**19**	22	20
Equity ratio	**59%**	60%	56%
Capital renewal	**93%**	130%	106%
Operating margin	**8.4%**	9.3%	8.1%
Quick ratio	**1.5**	1.2	1.4
Interest cover	**n/a**	n/a	n/a
Profit volatility	**12%**	11%	11%
Forecasting risk	**(0.7%)**	(0.3%)	(0.6%)
Revenue growth	**5.6%**	10.0%	1.5%
Human resources indicators			
Full-time equivalents (FTEs):	**361**	375	368
Scientists and specialists	**257**	263	262
Science support	**63**	55	66
General support and management	**41**	57	40
Distribution of science effort (FTEs):			
Research	**174**	160	179
Commercial	**146**	158	149
Staff turnover	**9.2%**	6%–8%	5.6%
ACC workplace safety accreditation	**Tertiary**	Tertiary	Tertiary
Injuries, causing missed work days, per million work hours	**none**	<5	3
Staff engagement (% proud to work at GNS Science)	**86%**	>80%	73%
End-user collaboration indicators			
Commercial revenue ($000s)	**32,746**	>32,000	29,713
Commercial revenue per FTE ($000s)	**91**	85	81
Percentage of end-users satisfied with the way GNS Science sets their research priorities (Colmar Brunton annual survey)	**61%**	>75%	*
Percentage of end-users confident that GNS Science considers their sector's priorities when setting research priorities (Colmar Brunton)	**78%**	>75%	*
Percentage of end-users satisfied with the overall quality of their experience with GNS Science over the last three years (Colmar Brunton)	**71%**	>85%	*
Value of research contracts to other research organisations ($000s)	**12,776**	>14,000	9,800
Value of research contracts from other research organisations ($000s)	**2,472**	>2,500	4,525
Number of active advisory groups	**4**	6	4
Research collaboration indicators			
Peer-reviewed publications (calendar year):	**191**	250	261
Total publications	**79%**	67%	67%
International co-authorship	**15%**	23%	22%
Other New Zealand co-authorship	**94%**	90%	89%
Total co-authorship	**6%**	10%	11%
GNS Science only co-authorship			
Percentage of end-users that have confidence in GNS Science's ability to form the best teams to deliver outcomes (Colmar Brunton)	**82%**	>85%	*
Number of visiting researchers hosted	**82**	>80	89
Number of graduate scholarships funded	**13**	>25	16
Number of graduate students supervised	**113**	>100	115

PERFORMANCE INDICATORS

These indicators include those specified in our Statement of Corporate Intent.	**Actual 2015/16**	Budget or expected range	Actual 2014/15
Science quality indicators			
Peer-reviewed science papers and book chapters (preceding calendar year)	**245**	320	265
Other publicly available papers and reports (preceding calendar year)	**66**	70	78
Publication rate peer-reviewed papers/monographs/maps per scientist FTE	**0.8**	1.0	0.8
Mean citation score	**1.5**	1.4	1.3
Use of science – h_1-score (number of publications with at least this same number of citations)	**100**	80	90
Scientist visibility – h_2-score (number of staff with an *h*-score of least this same number)	**23**	20	22
Commercial indicators			
Commissioned reports (ca. 55% commercial revenue)	**214**	275	286
Reports scientist FTE	**0.7**	0.9	0.9
Geohazard reports (ca. 28% commercial revenue)	**514**	620	645
Reports scientist FTE	**1.6**	2.0	2.0
Laboratory analysis reports (ca. 11% commercial revenue)	**14,970**	20,500	20,821
Reports scientist FTE	**47**	64	63
Total reports scientist FTE	**49**	67	66
IP licensing (incl. technologies, products, services) in New Zealand and overseas:			
Number	**43**	20	33
Value ($000s)	**385**	800	402
Client feedback average score (out of 10)	**7.3**	7–8	6.5
Percentage of end-users that have adopted knowledge from GNS Science in the last three years (Colmar Brunton)	**85%**	>90%	*
Percentage of end-users satisfied with their experience of accessing knowledge or technology from GNS Science (Colmar Brunton)	**76%**	>90%	*
Projects achieving outcomes or creating opportunities for iwi/Māori	**9**	25	15
Database use:			
Number of databases accessible to the public via the web	**22**	26	29
Registered external users of GNS Science data	**3,836**	>5,000	5,479
Users accessing the GNS Science website:			
Total number	**594,577**	>450,000	541,531
Daily peak	**5,197**	>10,000	4,994
Number of users accessing the GeoNet website:			
Total number	**3,383,918**	>500,000	4,879,681
Daily peak	**288,185**	>30,000	294,209

[1] Profit is before interest, tax, depreciation and amortisation.

* Colmar Brunton survey not undertaken in the 2014/15 financial year.