British Geological Survey

Year 3 progress report for the BGS International Geoscience R&D programme

NERC NC International

Internal Report IR/25/017

BRITISH GEOLOGICAL SURVEY

NERC NC INTERNATIONAL

INTERNAL REPORT IR/25/017

Keywords

International Geoscience; BGS National Capability; Monitoring, Evaluation and Learning.

Bibliographical reference

UPTON, K, MCKENZIE, A, MITCHELL, C, SARGEANT, S, WILLIAMS, J & WATTS M 2025.
Year 3 progress report for the BGS International Geoscience R&D programme. *British Geological Survey Internal Report*, IR/25/017. 49pp.

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Editor: Maggy Heintz

Keyworth, Nottingham British Geological Survey 2025

BRITISH GEOLOGICAL SURVEY

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2 Executive Summary

Purpose of this report

This report provides a progress review of Year 3 of the NERC National Capability (NC) funded BGS International Geoscience Research and Development (IGRD) programme. The IGRD programme runs from 2022-26 and had an initial budget of £11.929M; following a mid-programme revision, the budget has been reduced to £8.3M.

The IGRD Programme

The intended impact of BGS' IGRD programme (see Section 3) is to facilitate the sustainable use and secure supply of Earth's natural resources and increased community resilience to natural and anthropogenic hazards. The programme's multifaceted pathways to impact are outlined in a Theory of Change (ToC) (see Appendix 1), which defines how the programme aims to transition from a series of outputs, through to outcomes and, ultimately, the long-term impact that the programme seeks to contribute towards. This ToC provides the basis for a logical framework (Logframe) against which progress is monitored and evaluated (see Section 7 and Appendix 3).

Progress and outcomes in Year 3

During Year 3 of the programme, there have been significant scientific advances and a clear shift along the project pathways to impact. The **research evidence base continues to expand** through data collection and analysis in collaboration with partners, providing new insights across the scientific challenge areas. There were 19 new papers and reports, 41 presentations, 10 new data products and tools, and 104 external stakeholder engagements made by the programme. **Section 5.3 of the report** provides a full breakdown of the number and types of outputs delivered in Year 3.

There is growing evidence of **research uptake by partners and external stakeholders,** including the application of models and tools, interpretation and integration of evidence, and influence on national policy. Several projects are demonstrating **influence and outcomes at a global scale**, i.e. beyond an individual country of interest, including the translation of BGS tools and expertise to different global contexts and provision of expert advice through participation in global networks and international events. **Section 4 of the report** provides a synthesis of the key outcome successes in Year 3, with more detail in Section 6 of the report.

BGS have helped to leverage >£12M of **new funding to grow and extend aligned research** activities with partners globally (principally in Africa, Asia, Europe), with several more proposals currently in progress.

3 Aims and objectives of the IGRD Programme

The IGRD programme is funded from the NERC NC International initiative from 2022-2026. The initial budget for the programme was £11.929M, however this has been reduced by 50% for 2024/25 and by a further 15% for 2025/26 (see Section 7 for further details). The programme aims to facilitate the sustainable use and secure supply of Earth's natural resources and increase community resilience to natural and anthropogenic hazards by addressing three global environmental challenges: (1) adaptation and resilience to natural hazards; (2) sustainable and secure resources for the future; and (3) sustainable land management and climate change adaptation.

To respond and deliver solutions to these challenges, the programme is organised into three corresponding Research and Innovation Challenges (RICs), each with clearly defined objectives:

- RIC 1 Living in multi-hazard environments: Geoscience data, information and knowledge are used to improve the detection and forecasting of hazards, and understanding of multi-hazard environments, to support disaster risk management (DRM).

- RIC 2 Resources for the future: Geoscience data, information and knowledge are used to determine how global demand for resources (water, food, energy, minerals) can be met with minimal environmental and social impact, while addressing the energy transition to net-zero.

- RIC 3 Sustainable land management and climate change adaptation: Geoscience data, information and knowledge are used to provide solutions to counter the negative impacts of land use change and urban development and help communities adapt to climate change.

Each of the RICs comprise several projects, each with their own research questions, novel research methodologies and geographical focus, which will contribute to the objectives outlined above. Projects were co-designed with partners in the most appropriate country for that challenge to generate outcomes for local practitioners while also providing the basis for translation to global impact where appropriate. Several projects explicitly build on previous initiatives delivered during BGS' precursor 'Geoscience for Sustainable Futures' (GSF) NC programme, which ran from 2018 to 2022. GSF had an explicit focus on Official Development Assistance (ODA), whereas IGRD seeks to undertake research excellence that can be nationally/internationally translatable to deliver global public good outcomes, while also responding to NERC's ODA commitments. The rest of the projects were based on BGS staff collaborations and/or existing commissioned projects, all with varying degrees of in-depth collaboration and shared history. All projects aligned to the BGS strategy and to the 2021 UK Government review of international priorities (Global Britain in a competitive age, 2021).

Recognising the inherent synergies and overlaps across the three RICs, mechanisms are in place to facilitate cross-programme exchange and learning. During Years 1-3, this was achieved through biannual in-person workshops, supported by a team of experienced Co-Investigators with expertise in particular geographical settings or areas of science that was cross-cutting the RICs described above.

Pathways towards achieving the aims and objectives described above are outlined in a programme Theory of Change (ToC) - see Figure 1 and Appendix 1. The ToC defines how the programme intends to transition from delivering a series of outputs, to a series of outcomes, whereby programme outputs are used by partners and external stakeholders to inform decision making and practice, whether at a sub-national, national or international level. These outcomes are one of many prerequisites for achieving the desired impact and will be the primary focus for evaluating success of the programme, recognising that impact is likely only measurable over much longer timescales and is dependent on a wider array of interventions (political, socio-economic, environmental etc) than can be delivered by BGS. The chance of achieving lasting impact will be maximised by activities designed to translate findings and outcomes to a wider audience, building on our links to international initiatives, overseas governments, supported by key links to UK Government, e.g. Foreign, Commonwealth & Development Office (FCDO) and Department for Business & Trade (DBT); global financial initiatives, e.g. World Bank and Bill & Melinda Gates Foundation; and long-standing involvement in multi-lateral organisations, e.g. Coordinating Committee for Geoscience Programmes in East and Southeast Asia (CCOP), Food and Agriculture Organization of the United Nations (FAO-UN), and the African Ministers' Council on Water (AMCOW).

Staff from across BGS contributed, to varying degrees, in the first three years of the IGRD programme, spanning the full breadth of BGS capability. It was designed in consultation with staff and the BGS senior leadership team with activities that complement and support the BGS strategy. A leadership team manages the finances, staff resourcing and project activities within three Research and Innovation Challenges (RICs). A small group of Co-Investigators (Co-I) assisted the management team in the programme design and during the first two years of the programme to identify synergies between projects and effective ways to achieve outcomes in the wider geoscience community. Resource for the Co-I role was removed for Years 3 and 4, as a result of the mid-programme budget review.

Monitoring, Evaluation and Learning (MEL) for the programme is a continuous process (explained further in Appendix 2), guided by the ToC. The ToC forms the basis for a Logframe (see Appendix 3), which defines a series of indicators against which qualitative and quantitative evidence is collected. This is used to measure progress, highlight successes, identify areas for improvement, and guide year-on-year resourcing. In 2024/25, two programme-wide workshops were held: the first in May 2024 aimed to regroup following the 50% cut to funding and assess the impact on project delivery, explore the tension between research, impact and need to leverage additional funds. This was an opportunity to familiarise researchers with the ToC and Logframe again, encourage projects to think about how their own pathways to impact given the new funding environment, and discuss synergies and new ways of working more efficiently across the programme; the second in January 2025, preceding business review and planning in February, provided a review of emerging success, outcomes and challenges to a BGS audience and invited guests (BGS Board/Advisory Committee) and facilitated a programme-wide discussion on how geoscience research can be useful, useable, and used (see Appendix 4 for further details).

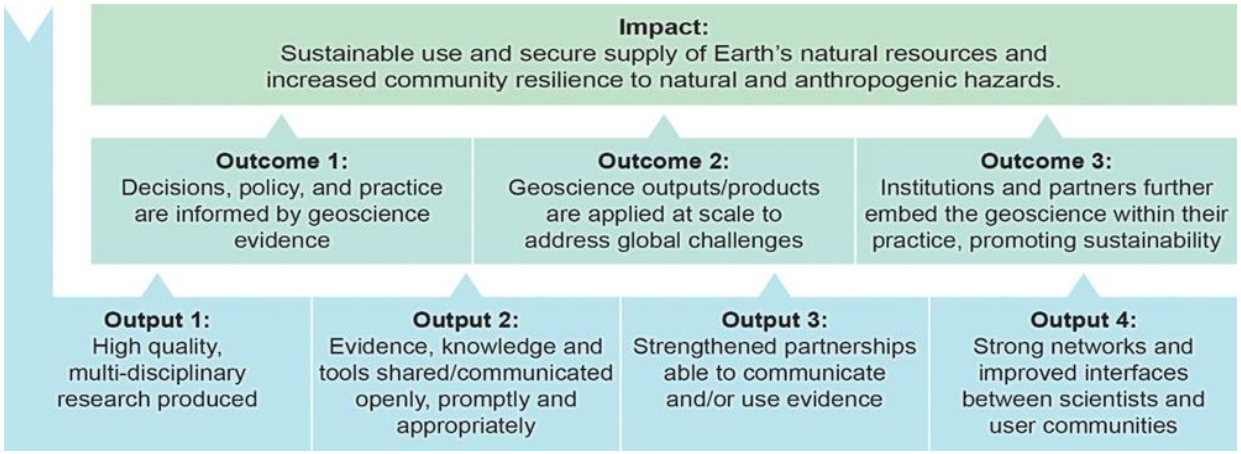


Figure 1 IGRD Theory of Change.

4 Year 3 highlights

During the first year of the IGRD programme, much of the emphasis was on developing partnerships, establishing ways of working, co-designing research methodologies, and data collection. During Year 2 of the programme, while new partnerships continued to evolve, there were significant scientific advances and a clear shift along the project pathways to impact. Despite the funding cuts for year 3, the majority of projects were able to adapt having built a strong platform of partnerships on whom they could rely for local engagement. In addition, with much of the new data collection completed in Years 1 and 2, projects moved to a process of write-up, development of models and other user-focussed outputs, and stakeholder delivery and engagement. The budget cuts did create tensions, in that more emphasis was placed on developing and pursuing funding opportunities, however, this was one of the original requirements from NERC.

Outputs

The **research evidence base continues to expand** through the development of new observational methodologies, data collection and analysis, in collaboration with partners, to provide new insights across the scientific challenges of multi-hazards, natural resources, and land management and climate change adaptation. This is evidenced by a significant increase in high-quality academic outputs across the three RICs, including:

- The publication of 19 new journal articles and reports (bringing the total to 55), which have been cited >1000 times within the wider academic literature.
- 41 presentations at conferences and workshops (bringing the total to 130).
- The release of 10 new products and tools (bringing the total to 16).
- An additional 104 external engagement activities (bringing the total to 230).

Section 7 of the report provides a full breakdown of the number and types of outputs delivered in Year 3.

Outcomes

Most projects have transitioned along their pathways to impact and are now seeing tangible outcomes, with around 35 evolving stories of change to partner capacity and stakeholder decisions, policy, and practice – both in the country of focus and beyond. There is demonstrable evidence of **research uptake by partners and external stakeholders**, including: the application of models and tools to inform decision making; the interpretation and integration of evidence to inform practice; and influence on national policy. Examples include:

- Installation of BGS' PRIME system on a critical slope above one of the largest hydroelectric dams in Malaysia, allowing risk assessment and mitigation of slope failure to protect power generation and downstream populations.
- Development of a scenario planning exercise for FCDO and the Ascension Island Government to enable planning, preparedness, and effective response and recovery to volcanic hazards in the UK Overseas Territories.
- Influence on the Zambian National Critical Minerals Strategy, which was published in mid-2024.

An increasing number of projects are demonstrating **influence and outcomes at a global scale**, i.e. beyond an individual country of interest, including: the translation of BGS tools and expertise to different global contexts; provision of expert advice through participation in global networks; and citation of IGRD research in global policy and practice documents. Examples include:

- BGS' groundwater mapping methodology, developed for basement aquifers in Africa through IGRD, is being extended and applied to map groundwater potential across East Africa under work funded by UNICEF, the World Bank and the German Federal Institute for Geosciences and Natural Resources (BGR).
- Strong collaboration across the programme is providing new opportunities for earth observation and hazards science to inform dynamic multi-hazard risk assessment across different geographies, including the Philippines and Malaysia.
- BGS staff and partners are members of numerous international advisory groups including the ARISTOTLE advisory group, which provides multi-hazard advice to the European Commission; UNESCO working group on urban subsidence; UNECE International Centre of Excellence on Sustainable Resource Management; and FAO-UN Global Soil Partnership.

The programme generated significant **media attention** around key events, such as the Santorini earthquake, the 20-year anniversary of the Boxing Day Tsunami, and international groundwater events in Davos and India. Brighid O Dochartaigh (now retired from BGS) was awarded the Younger Medal by the Geological Society of London for her outstanding contribution to the hydrogeological community leading the development of the Africa Groundwater Atlas, which continues to be developed under the IGRD programme.

Building on successes in years 1 and 2, the programme secured an additional ~£7M of external income, taking the total to just over £12M of additional funding leveraged to **grow and extend research** activities with partners, and for partners to expand their capacity. The source of funding was varied, from the UK Foreign and Commonwealth Development Office, to UK national grant

funding (e.g. UK Research & Innovation), International Development banks, United Nations Agencies and commercial services. Section 7 of the report provides a full breakdown of the range and level of outcomes achieved in Year 3.

5 Responding to NERC's Forward Look

5.1 GREEN GROWTH: AN ENVIRONMENTALLY RESPONSIBLE NET ZERO TRANSITION

This theme aims to generate understanding and information to optimise decisions for clean energy provision, supporting green growth through the placement of green energy and infrastructure. It also aims for efficient extraction and use of resources, and sustainable agriculture, optimising the use of land, water, the subsurface, and ecosystems, and the services they provide.

The IGRD programme is responding to this theme by generating evidence to inform the net-zero transition and clean energy technologies in different parts of the globe. In India, IGRD is facilitating research and development on the potential for Carbon Capture and Storage to support decarbonisation. Work on deep geothermal in the East African Rift system, aims to de-risk the net-zero transition by providing techniques to better identify zones of high geothermal energy potential. The programme is working to understand and mitigate the environmental impact and hazards of mineral extraction, including those critical for the net-zero transition, to improve the sustainability and safety of mining in parts of South America, Africa and South-East Asia.

The programme is also generating extensive evidence to support sustainable agriculture and food security using geochemistry to inform land and lake management to improve resilience to environmental change in the Lake Victoria catchment. Sustainable groundwater abstraction in Africa, South and South-East Asia to support green growth includes de-risking low-carbon groundwater abstraction technologies (solar pumping) through improved understanding of groundwater availability at different scales.

5.2 ENVIRONMENTAL SECURITY: CONTRIBUTING TO NATIONAL SECURITY, GLOBAL STABILITY AND SHARED PROSPERITY

This theme addresses climate risks and environmental change to increase the resilience of people, economic systems, and global supply chains, and to protect environmentally exposed infrastructure.

The IGRD programme is responding to this theme through research on the resilience of environmental systems (water and soil) to change. In the Philippines, the programme has developed a national-scale hydrological model to assess the potential impacts of climate and environmental change on future water availability. It has also leveraged additional funding to examine the impacts of severe flooding on groundwater quality and quantity in Northern India.

The programme is generating evidence and tools to help detect, forecast, and respond to multi-hazards, thus increasing preparedness for significant shocks associated with hydrological and other natural hazards.

5.3 RESPONSIBLE INNOVATION: EVIDENCE TO ENABLE NATURE POSITIVE INNOVATION AND EFFECTIVE REGULATION

This theme aims to unlock new insights through AI, data analytics and data technologies, ensuring adequate policy frameworks, regulatory approaches and governance.

The IGRD programme is applying a variety of AI (machine learning) approaches to better understand and predict the response of earth's natural systems to different stresses. This includes earthquake occurrence, soil erosion, landslides, and subsidence. These methodologies provide

powerful tools for using large volumes of environmental data to achieve the aims of green growth, environmentally responsible net-zero transition, and environmental security.

6 Emerging Thematic Narratives

While the programme is managed as a series of projects and activities within the three RICs, each of which is focussed on specific science questions and distinct geographies, there are several thematic hubs, which address multi-disciplinary global challenges, around which multiple projects coalesce. These hubs provide a useful framework for developing narratives, or stories of change, which describe how the programme is progressing towards outcomes and impact in response to the global challenges described above.

The budget for the IGRD programme was reduced by 50% at the start of 2024/25. The programme structure has therefore been reshaped and simplified, resulting in the merging of projects and activities where synergies were identified, and the curtailing of certain projects and tasks following an evaluation and prioritisation exercise. All projects were subject to budget reductions and have therefore reduced in scope to varying degrees; however, the programme Theory of Change, which represents an amalgamation of outcomes across all projects, remains valid.

6.1 RIC 1: NOVEL DETECTION AND FORECASTING OF HAZARDS

Forecasting of hazards including earthquakes, landslides and urban subsidence is extremely complex but offers the possibility of improving anticipation and planning for such hazards. It often requires huge quantities of data. Artificial Intelligence (AI)/Machine Learning (ML) is opening up the potential of these datasets by automating some of the analysis, allowing rapid detection and response to hazards.

IGRD is investigating the performance of ML algorithms for automatic data processing to produce rapid, high-resolution earthquake catalogues in regions of high and low seismic hazard, and the IT systems needed to support this. Deep learning, in earthquake detection and forecasting, presents a powerful tool for informing our process-based understanding thus potentially enabling improved warning to populations and civil emergency authorities in future. In 2023/24, the team implemented deep learning workflows for earthquake detection in a scalable, cloud-based environment and applied this to high (Italy) and low (UK) seismicity environments. In 2024/25, the project has established systems and processes to enable rapid processing of data within NERC's JASMIN facility, which provides computing and storage technologies for the environmental research community in the UK, and Amazon Web Services (AWS). Testing of the new ML workflow within the AWS system has shown that it is able to find 10 times more events than a human analyst could and in significantly less time. It is likely the team's work will lead to changes in UKRI policy and influence how other research disciplines engage with facilities like JASMIN and AWS. The project team continue to engage with scientists from national agencies with statutory responsibility for earthquake forecasting to establish pathways to impact for the future uptake of this new methodology.

ML approaches are also being used to process large volumes of Earth Observation data to detect changes on the Earth's surface, providing new methodologies to monitor and quantify rates of subsidence and to automatically identify areas where landslides have taken place. This ability to automatically analyse and interpret large datasets to understand the location and evolution of

natural hazards provides a novel tool for developing effective disaster risk reduction and response strategies. Analysis of InSAR data using ML methods has been used to model urban subsidence, providing an improved understanding of the potential causes of subsidence, e.g. from loading or groundwater abstraction, and a library of characteristic subsidence signals. In 2023/24, libraries of loading-induced subsidence signals were developed for Hanoi, Bandung and Kuala Lumpur. This was extended to enable automatic recognition of subsidence patterns over larger areas, allowing identification of subsidence hazards in rapidly expanding cities across the world. Ongoing engagement with continental and global stakeholders such as UNESCO and the European Environment Agency, led to BGS being appointed as an observer on the UNESCO Land Subsidence International Initiative (LaSII) in 2024/25. LaSII enhances the scientific understanding and technical knowledge required to identify and characterize hazards related to natural and anthropogenic land-level lowering, thus strengthening potential pathways to impact for this work, which could ultimately inform urban planning decisions and enable urban decision-makers to design appropriate mitigation strategies. The work also underpinned BGS' ability to secure funding for further subsidence projects in the UK (working with the Coal Authority), Northern Ireland (working with the NI Executive), and Cyprus. ML algorithms to automatically identify areas where landslides have taken place using satellite imagery, have been used to produce rapid landslide inventories following earthquakes in Morocco (as a product from the Disaster Charter activation) and Turkey-Syria (to support UNITAR's disaster response activities) in 2022. In 2024/25, the team were engaged by the Red Cross following a landslide in Kenya, providing further evidence of the use of these tools as a product of the Disaster Charter. The team are working with UK (including FCDO) and international stakeholders to explore how these EO data processing tools can be further operationalised to facilitate disaster response and have delivered training in the methodologies to other relevant organisations, for example PHIVOLCS in the Philippines. BGS are also continuing to develop the tools through ongoing PhD projects.

While AI is opening up new possibilities when it comes to analysing large datasets, fundamental research on physical processes is also vital. In Kerala, work to understand landslide trigger thresholds in tropical residual soils has been continuing with partners at the University of Kerala and Geological Survey of India. This approach intends to complement and enhance the reliability of the existing landslide forecasting operated by the Geological Survey of India. The project continues to develop a landslide domains map for the region and a model of how the landscape reacts to rainfall. An approach was also applied that enables landslide debris volumes to be estimated more accurately from the difference in pre- and post-event Digital Elevation Models. Major landslides in Wayanad (a district of Kerala) in July 2024 that killed over 400 people were a particular focus for the project team and their partners. Together they documented the landslide characteristics using field investigation, lab testing, and modelling, and developed a methodology for quick assessment of landslide runout features and impact using crowd-sourced data and numerical modelling. The BGS team in collaboration with Indian partners is actively seeking funding opportunities to investigate why the landslide had such an unusually long runout leading to greater impacts. Understanding these factors will better inform future planning by the Kerala State Disaster Management Authority. This study aims to complement the approach developed by University of Kerala and BGS which predicts the landslide pathways based on their volume. The Geological Survey of India are also keen to expand the collaboration for national-scale landslide forecasting and in 2024/25 the project team also leveraged additional funding from FCDO to expand this work to Malaysia.

6.2 RIC 1: UNDERSTANDING AND MANAGING MULTI-HAZARD INTERACTIONS

This hub centres on geoscience for disaster risk management. Through global research and partnerships, including focal work in multi-hazard environments such as Indonesia, the Philippines and the UK Overseas Territories (UKOTs), this hub aims to make geoscience useful, useable, and used for decision-making to support disaster risk management.

In Indonesia, high quality, collaborative, multi-hazard science is contributing to improved understanding of hazards and their management, local capacity development, and influence on local and national policy. In 2023/24, the project carried out research with partners into the seismic hazard from the Lembang Fault, which led to partners adopting an improved approach to undertaking GNSS (Global Navigation Satellite Systems) campaigns on active faults. It also led to the team being approached for official advice after an earthquake emergency and the project co-lead co-authoring the new national seismic hazard model for Indonesia, which will be used for setting building design standards. Collaborative research on the 2018 eruptive event at Anak Krakatau led to the development of new hazard models to simulate volcanic flows over water. This understanding is being used to improve hazard communication to those communities most at risk to help improve their preparedness for future events. Efforts have also focussed on improving the representation of Indonesian experts from the Centre of Volcanology and Geological Hazard Mitigation within international advisory groups, such as the WMO Advisory Group for Volcanic Sciences, to ensure their knowledge and expertise is represented in global discussions. PhD students have been crucial to extending the reach of the project and what it is able to deliver, particularly with reduced budgets in 2024/25 (e.g. building a frequency-magnitude model for landslides in Palu). The project continues to catalyse new research proposals with local partners on different aspects of hazards and disaster risk. In 2024/25, there was a particular focus on the planning of a major symposium on geohazard solutions for Indonesia to be hosted by the British Embassy in 2025. This will bring nearly 50 UK and Indonesian experts together, with funders from both countries, to discuss pathways to address the research and implementation gaps for future disaster risk reduction in Indonesia.

In the Philippines, the team are working closely with PHIVOLCS (Philippine Institute of Volcanology and Seismology) to develop a deeper understanding of systemic multi-hazard interrelationships. In 2024/25, an MoU was signed with PHIVOLCS, which will support greater collaboration under a follow-on project for which £25K was secured from the UK Government Office for Technology Transfer to support multi-hazard risk assessment training in the Philippines. The project is extending the focus of the collaboration with PHIVOLCS, providing new pathways to impact for other areas of hazard research within BGS/IGRD, for example through training delivered on automatic landslide detection (see above) in November 2024. This builds on the existing strong collaboration with PHIVOLCS, which defined a framework for using case studies, developed through the IGRD project, in the Geovisionary visualisation software that aligns with HazardHunter PH. HazardHunter PH is the country's 'one-stop shop for hazard assessment' that allows users (including property owners, buyers, planners and other stakeholders) to generate indicative hazard assessments for a location and to prepare for and mitigate the effects of future hazards. Further opportunities to extend the scientific and geographical focus of this work are being explored with the UK Government (GOTT) and Asian Development Bank.

The UKOTs project is focussing on Tristan da Cunha and Ascension in the South Atlantic and is providing scientific evidence for disaster risk management on the islands. Through multiple field campaigns, significant work has been done to characterise recent volcanic deposits on Ascension

Island, which has improved understanding of eruption styles, individual eruptive events and the extent and severity of potential eruption scenarios. In 2024/25, this informed the first phase of a volcanic activity scenario planning exercise, which was designed by the project team at the request of FCDO London and the Ascension Island Government. Alongside this, FCDO-commissioned research on Tristan da Cunha has been conducted to establish baseline data for landslides that may pose a risk to people and infrastructure here. The team are working with local and UK government, and in 2024/25, increased collaboration with FCDO UK has confirmed BGS's critical role in the provision of scientific advice on volcanism and related hazards in the UKOTs to enable planning, preparedness, effective response and recovery. The project's activities have led to numerous papers and reports, due for publication in 2025/26, and discussions are underway with other UK agencies regarding setting up operational monitoring of the UKOTs to facilitate hazard preparedness and response (UK Met Office, NCAS).

The disaster recovery project in Malawi conducted two visits to disaster-affected communities living in Karonga in the Northern Region. Working in collaboration with the Malawi Geological Survey Department, the University of Malawi and the Ministry of Water and Sanitation, and through engagement with responding humanitarian organisations, the project team have developed an improved understanding of what recovery means for people affected by disasters, and their priorities and barriers for recovery (particularly relating to the physical environment, water supply and access to geoscience knowledge). The project has identified areas where the use of geoscience could be strengthened (e.g. in raising awareness of earthquake hazard) and ways in which it could be made useful (e.g. capitalising on existing communication channels to provide geoscience information to communities in a very simple way that is easy to understand and use). It has also highlighted institutional challenges that need to be overcome to ensure geoscience can support people when they are recovering, e.g. raising the profile of geoscience in general and strengthening the pathways for passing geoscience information and expertise from the national and regional levels to the district and community levels. The project has raised awareness of the potential for geoscience to support humanitarian and development activity, which led to BGS being invited by Catholic Relief Services to contribute expertise to the development of two multi-million pound recovery and resilience-related proposals. In 2024/25, the project team also carried out a scoping visit to the Southern Region of Malawi to explore potential future research opportunities around homemaking after disasters with social scientists from the University of Malawi. The disaster recovery project concluded at the end 2024/2025 with a visit by the members of the local research team to present our initial findings to Karonga district council, the communities who took part in the research and the local media. This was greatly appreciated by them because it is rare for researchers to return to share their findings and receive feedback. Our findings will also be presented to the Malawi Department of Disaster Management Affairs and the Global Shelter Cluster Recovery Community of Practice so that they may inform future decision making and research on this topic.

Working at a global scale, IGRD aims to enhance the capture, analysis and reporting of data and information about volcanic activity and its impacts for local to global use. It has a wide view and focuses on four areas. These include the need to enhance understanding of hazard systems and assessment of hazard and risk, and forecasting; compiling data, analysing trends and developing tools at all scales; understanding good practice for scientists and authorities working together and evidence-based decision making; and greater harmonisation of data and reporting to support disaster risk management. The project has been active in bringing people and organisations from around the world together to discuss and work on these topics and has contributed to numerous

high-level workshops and reports. For example: the team initiated a European network of institutions responsible for responding to natural hazards with civil protection and aviation authorities; they were invited to present on Global Data and Reporting at a Best Practice workshop in Chile; and they co-led a workshop with USGS on harmonisation of volcano observatory reports and moving toward global daily reporting. The Global Reporting project has been extracting data from operational hazard reports to inform global understanding of volcanic activity and associated hazard for aviation. This is also leading to a greater understanding of explosive eruptive activity. An MoU has been signed with the UK FCDO to provide ongoing support/response to support decision making in disaster responses, with £2.3M awarded recently.

6.3 RIC 2: STRATEGIES FOR SUSTAINABLE MINING AND RAW MATERIAL SUPPLY

The first RIC2 hub is focussed on geoscience informed decision making for resource development that aims to help secure the continued supply of raw materials, particularly for the energy transition to net zero, and ensure minimal environmental and social impact.

As part of the drive to ensure responsible sourcing of mineral resources, the critical and technology metals-related research in the Philippines is focused on the whole system understanding of nickel laterite deposits and geophysical imaging of copper mine tailings storage facilities (TSFs) as well as the geochemistry of copper-cobalt mining waste, respectively. In the Philippines, we have piloted for the first time BGS geophysical monitoring technology (PRIME) as a means of non-invasively and volumetrically monitoring subsurface changes within the body of a tailings dam – for the purpose of producing a new decision support tool for TSF management. The monitoring station was installed in 2022 and has provided resistivity data that has enabled modelling of subsurface seasonal moisture dynamics. This will inform the development of a hydrogeological model and provide the basis for monitoring geotechnical stability. This is the starting point for an early warning system for tailings dam slope stability. The results from this research have already stimulated significant interest from stakeholders (mining companies and consultants) in the UK, Philippines, and Australia. On the other hand, the nickel laterite project in the Philippines is providing new insights into the metallogenesis of the ore minerals and the distribution of other mineral phases that might be harmful to the environment. The robust field and lab-scale characterisation of the ores is key to optimising the sustainable extraction of other critical metals, including cobalt, magnesium and platinum group minerals that, along with nickel, are needed to support the energy transition. This knowledge has the potential to support future development of processing plants in the Philippines and collectively develop measures to avoid the negative environmental impacts of mining.

The global awareness of the impacts of consumption of sand and construction materials, which is second only to water in terms of anthropogenic flows of material, continues to increase. The sand and sustainability project team continued to engage with this by presenting at the United Nations Economic Commission for Europe (UNECE) annual conference in Geneva. The project team is collaborating with the newly formed UNECE backed UK International Centre of Excellence on Sustainable Resource Management (UK ICE-SRM) to promote sustainable mining practices. This has considerably raised the profile of the IGRD research. A second successful visit to Gambia hosted by the Geological Department of the Ministry of Petroleum and Energy took place. Gambia has an acute shortage of sand for construction which has led to environmentally damaging mining practices. The BGS team provided training and technical assistance to enable better resource governance in the Gambia. The outputs and recommendations from the initial phase of work have

now been published. Based on stakeholder engagement the project added additional illustrations to the good practice guidance published in 2023. These extra illustrations focus on good practice around marine dredging for sand and the effective processing of sand. The project continues to engage with UNEP GRID-Geneva to raise the profile of BGS work and explore potential collaboration opportunities; through this BGS has been asked to contribute to UNEP's next report into international sand governance, to be presented at UNEA 7. Implementation of this good practice by regulators and industry will improve resource management and policy, enabling secure and responsible sourcing of construction sand. The project also made progress on science research goals in developing new methodologies to use earth observation to quantify sand consumption. The outputs of this work are currently being finalised for peer review.

The continuing and growing demand to supply the critical and battery raw materials needed for the energy transition to a low-carbon society has led to increasing pressure to find these resources. The BGS support of the Zambian Geological Survey Department (GSD) is one example of the work of the BGS to support African governments' engagement with the exploration and development of critical raw materials. The geological understanding of resources, reconnaissance exploration, laboratory characterisation and freely accessible publication of minerals information and maps are ways in which national geological surveys in Africa can play a valuable part in the discovery and development of these critical and battery raw material resources. The Critical Mineral Resources – Zambia research combines the past BGS graphite and mineral waste research in a project that aims to develop a better understanding, of the critical mineral resources of Zambia in support of the Zambian Government. The IGRD research was pivotal to leveraging two phases of FCDO funded (~£550k) research in Zambia since late 2023. This ongoing BGS research activity, including graphite fieldwork, training and critical minerals workshops, has helped to inform the development of the Zambian 'National Critical Minerals Strategy' (published in mid-2024) of the Ministry of Mines and Minerals Development (MMMD). The current FCDO-funded project "Supporting Capability for Critical Minerals in Zambia" supports this strategy. The focus being on developing the critical raw materials capacity of the Zambian GSD. The BGS are working with the GSD on the 'Critical minerals potential of Zambia' guide that will cover copper, cobalt, coltan, graphite, lithium, manganese, Nickel, Rare Earth Elements (REEs), sugilite, tin and uranium in Zambia. The GSD Museum has yielded many samples that will be used to illustrate the guide to help educate exploration companies, academia, decision makers and the public on the resources of these critical minerals in Zambia. Other BGS teams are working in Zambia with the GSD to support the laboratory capacity and to enable archived Zambian minerals information to be more accessible. The BGS also continue to support PhD research in collaboration with the Copperbelt University (CBU) into the environment health impact and critical raw material potential of the abundant copper refinery slag/mine tailing across the Copperbelt. Success for the Critical Mineral Resources – Zambia research would be an increased understanding of critical raw material resources in Africa, active reconnaissance programmes by geological surveys, and mineral promotion leading to junior mining companies exploring for critical and battery raw materials in Africa.

The high Andean resources research project is focusing on understanding the provenance and determining the responsible sourcing of lithium from brines exploited from salars in Argentina, Bolivia and Chile alongside catchment functioning in Peru. The IGRD research builds on the outputs from the Lithium for Future Technologies (LiFT) and SIN TACTICAL fund project "Responsible sourcing framework to enable up-scaling of lithium production and supply". Environmental, Social and Governance (ESG), Life Cycle Assessment, in particular examining

existing frameworks and certification, stakeholder engagement and communication of the issues around salars are key aspects. Lithium extraction from salars forms one of the case studies in the UN Resource Management System (RMS) as part of the Centre of Excellence of which BGS is a part, enabling decisions, policy and practice to be informed by geoscience. Co-operation with the USGS and Rio Tinto (operators of a lithium mine at Rincon) allow new understanding of lithium provenance in salars and process understanding developed through IGRD research to be applied at scale. Further work is on-going in bofedales (wetlands) in Peru to understand how changes to glaciers affect mountain hydrology and water resources. The project maintains regular communications with stakeholders in all four South American countries and internationally, including geological survey organisations, government officials, operators and NGOs, promoting sustainability and translating geoscience knowledge into practice. Our expertise is sought by the International Lithium Association as part of a commission to write an article summarising salar processes based on the expertise developed in part by the IGRD supported work.

6.4 RIC 2: ENERGY RESOURCE EVIDENCE FOR TRANSITION TO NET ZERO

The second RIC 2 hub examines the way geoscience is harnessed to help develop the potential of the subsurface, particularly for geothermal energy and Carbon Capture, Utilisation & Storage (CCUS), for the energy transition to net zero.

The superhot geothermal research project has demonstrated the use of rock physics modelling techniques to estimate geothermal gradient using passive seismic and magnetotelluric (MT) surveys of Aluto, a stratovolcano in the Central Main Ethiopian Rift, part of the East African Rift. This will assist in better identification of zones of high geothermal energy potential that might be economically useful for renewable energy production in the Ethiopian rift and elsewhere. The research project methodology will enable future collaboration with the Institute of Geophysics, Space Science and Astronomy (IGSSA) at the University of Addis Ababa in Ethiopia to promote engagement with energy companies to further develop the geothermal potential of the East African Rift. This is a challenging research space due to a lack of temperature data which is typically only available in boreholes down to a few hundred metres but is required to a depth of several kilometres to validate the modelling. Success for the geothermal research would be to de-risk geothermal drilling and give investors a greater degree of certainty for hitting good geothermal yields.

The Indian CCUS research project has been actively collaborating with partners in India, namely the Indian Institute of Technology Bombay (IITB) and CSIR-National Geophysical Research Institute (NGRI) to address some of the fundamental research required to understand the potential to deploy CCUS technologies in India. In March 2024, BGS co-chaired a three-day symposium in Mumbai on the role of geosciences in carbon storage, organised by the Society of Exploration Geophysicists. BGS presented IGRD research on CO_2 trapping by mineralisation in Deccan Trap basalts, CO_2 storage containment risks in the onshore Cambay Basin, and the application of CO_2-storage monitoring in India using seismic reflection methods. The research has led to the establishment of new partnerships with commercial companies operating in India, enabling the application of geoscience knowledge at scale and further embedding geoscience research into practice. In November 2024, BGS built on previous studies by hosting a faculty member from IITB to initiate a formal storage risk assessment process. Whilst further progressing the research, this collaborative initiative facilitated our partner institute in adopting best practice methods in geological site characterisation for CO_2 storage, which were subsequently applied to industry

projects in India. As a result of IGRD research, project partners in India and their funding agencies consider BGS as a trusted partner. Consequently, in February 2025, BGS attended a CCUS policy workshop in Delhi, where the British High Commission announced their aspiration to launch a UK-India joint innovation centre on CCUS, co-funded by the Department of Science and Technology in India, which would be led by BGS and IITB. BGS also attended a launch meeting in Hyderabad, for a new research project focussed on CO_2 storage monitoring, led by NGRI. This new research project will enable BGS and NGRI to build on previous IGRD research.

*** Note that following the programme reshaping, the groundwater sub-theme has moved from RIC 2 into RIC 3.

6.5 RIC 3: UNLOCKING THE POTENTIAL OF GROUNDWATER

This hub provides evidence and partnerships to support sustainable groundwater use, management and protection for improved water security in Africa and South and Southeast Asia.

In sub-Saharan Africa, this hub is centred around several key areas of research: (1) improving our understanding of basement aquifer typologies across SSA and their potential to support sustainable groundwater abstraction, alongside an understanding of key groundwater quality challenges; (2) identifying the key hydrogeological, social and engineering controls on the functionality of rural water points; (3) working with the solar pumping community to ensure that groundwater data and knowledge informs the anticipated shift to solar-powered groundwater abstraction in SSA.

A draft map of basement aquifer typologies was presented at the 50th Congress of the International Association of Hydrogeologists in Cape Town (September 2023) which stimulated much debate; the continental-scale map and paper will be fully published in 2025. The groundwater mapping methodology being developed under IGRD, which has fostered new ways of interdisciplinary working between the geologists, hydrogeologists and environmental modellers in BGS, is building the foundation for a new approach to characterising aquifers in Africa. The approach, which has advanced our thinking about aquifer productivity, is being recognised and taken up by stakeholders at a continental scale and has been key to leveraging further work (>£0.5M) at a sub-national, regional and continental scale. BGS' groundwater mapping capability was a key factor in BGS' success in winning funding from UNICEF, with whom we have a long-standing partnership, to carry out groundwater resource assessments in Southern and Eastern Africa under their More Water More Life programme. This was extended in 2023, under a new two-year framework agreement with UNICEF to carry out hydrogeological mapping in Ethiopia and is likely to be applied by UNICEF in other regions of SSA in the coming years. This mapping informs UNICEF's water supply infrastructure investment decisions to provide resilient water sources for rural communities. In 2024/25, the mapping approach is also being applied in projects across Ethiopia, Kenya, and Somalia under the World Bank's Horn of Africa Groundwater for Resilience programme; at a continental-scale, it will underpin a new decision-making tool, being funded by BGR (German Federal Institute for Geosciences and Natural Resources), which will inform investment decisions by stakeholders working on water supply projects at different scales in sub-Saharan Africa.

The work on waterpoint functionality was widely cited by Phase 1 of the Waterloo Foundation-funded Stop the Rot campaign. This is aimed at reducing issues of handpump corrosion and failure. As a result, in 2023/24, BGS were invited to act in an advisory capacity to Phase 2 of this continental-scale initiative, enabled by IGRD. In 2024/25, our ongoing engagement with this

initiative allowed BGS to leverage additional funds under Phase 3 of the initiative to undertake further work to identify and quantify determinants of corrosion risk to rural water supply infrastructure and to develop handpump borehole diagnostics that can be implemented at different points in the rural water supply life-cycle, from construction to ongoing maintenance. Through this initiative, BGS' functionality work is informing discussions with other partners within the campaign (e.g. Rural Water Supply Network, World Bank, WaterAid, UNICEF) about the role of handpumps in rural water supply under SDG6 and decisions about the future of standardisation for handpumps and handpump components.

BGS' contribution to work on solar pumping in Africa continues to influence the narrative on this important topic, which is receiving increasing attention from donors and investors at a global scale. In 2023, BGS, along with partners, contributed to a World Bank publication on the economics of groundwater in times of climate change, which highlights the opportunities and potential risks of maladaptation associated with the expansion of solar pumping in Africa. In 2024/25, the solar work continued through a PhD jointly supervised by Paris Saclay University. This allowed BGS to place the issue high on the agenda at the 2024 World Groundwater Congress in Davos, resulting in an Opinion Editorial by Alan MacDonald in the Guardian (September 2024).

The Africa Groundwater Atlas, which continues to be developed under the IGRD programme, pulls together much of the evidence being generated by IGRD and is a primary source of information on groundwater in Africa. In 2023, downloads of the country-scale hydrogeology maps surpassed 10,000 with users from academia, government agencies, non-governmental organisations, and the private sector. In 2024, a new version of the Africa Groundwater Literature Archive (AGLA) was launched, allowing the African Ministers' Council on Water (AMCOW) to link their online knowledge hub to AGLA for the first time. This provides a new entry point to AGLA, potentially increasing the number of users, and providing more visibility for groundwater to a wider range of users. BGS continue to engage with AMCOW as a recognised partner to their continental strategic groundwater programme. At a series of continental consultations on the post-2025 Africa Water Vision (Dec 2024 – April 2025), the Africa Groundwater Atlas was highlighted by AMCOW as an important and strategic resource that should continue to be developed in support of groundwater's contribution to socio-economic transformation on the continent.

BGS continue to provide input as co-author on a new global manual on natural water chemistry. This will be a high-impact successor to a well-known book used by many stakeholders, "Study and interpretation of the chemical characteristics of natural water" by John Hem (USGS, 1985).

In South Asia, the Indo-Gangetic Basin (IGB) is one of the world's most important transboundary water resources, and one of the most heavily exploited aquifers in the world (c. 25% of global withdrawals). Under the IGRD programme, BGS are working with key partners in the region, including the World Bank, Indian, Pakistani and Nepali water research organisations and the Australian government, on 3 objectives with important implications for management of water resources: (1) assessing the accumulation of groundwater salinity across the Indus Basin, quantifying groundwater salt stocks and salt fluxes; (2) quantifying the effects of abstraction, surface water inflows and groundwater capture on groundwater resources in the Upper Indus; (3) investigating groundwater residence times and resilience in the Kathmandu valley, Nepal.

The international dimensions of data access have been key to project success in the Indus basin and, building on the work of identifying data sources carried out during the first year of the project, data was collated on over 20,000 sampling points where salinity information is available. This was

used to prepare maps of existing salinity and salt accumulation rates, and a linear model was developed to test the relative effect of groundwater abstraction, canal irrigation, climate change, spatial distribution of rivers, canals and agriculture on salt accumulation. This research transformed our understanding of the dominant controls on groundwater salinity in this region and work is ongoing with our established partner networks to translate this understanding into policy and practice recommendations to address salinity issues in a region heavily dependent on groundwater. Natural tracers have also been used to determine rates of groundwater recharge in the Kathmandu valley to assess the resilience of an aquifer that is an important water resource, yet highly vulnerable to climate change impacts. This work led to further funding from FCDO to examine water quality in the upper parts of the Gangetic basin where exceptional flooding during 2023 introduced a pulse of recharge with distinct chemical signatures that can be used to trace flow through rivers, canals, soils and aquifers. This work is highlighting the importance of dams and reservoir management in controlling the propagation of floods downstream. Discussions are ongoing with partners and donors about future work to better characterise flood processes to inform future flood mitigation.

Work in **the Philippines** focused on developing national-scale hydrological models able to better prepare society and decision-makers for future change. Calibration of the models was completed in 2023/24, and a series of future scenarios were run in 24/25 and delivered to non-specialists through a newly designed web-platform to help in-country stakeholders understand and quantify the susceptibility of water systems to future hydrometeorological and urbanisation extremes, for instance on islands subject to environmental pressure from tourism. The project provided a strong foundation for ongoing and future work on water scarcity in the Philippines and played a role in raising groundwater up the agenda at a national level. Through close engagement with the National Water Resource Board and Department of Science and Technology, the project has placed a strong emphasis on network development and identifying pathways to extend activities and fund partners. This led to DOST (Philippines science funding body) adopting the IGRD programme as a basis for a national funding call in 2023/24 and the BGS team, alongside partners securing additional funding from the British Council in 24/25 to continue engagement through development of a Hydro Hub.

In 2023/24, a final project meeting was held in **Mexico** to present the results of the 2-year IGRD project that has developed tools for stakeholders to assess the socio-hydrological resilience (SHR) of their city, and the potential impact from climate change and blue-green infrastructure (BGI). Presentations to senior regional administrators in Mexico have aimed to improve integration in the allocation of funding for marginalized communities and funding for BGI implementation. An MSc project at Oxford University is aligned with the project (Optimising blue green infrastructure in Oaxaca) and an MSc and PhD at UNBC has also been aligned with the project (Uptake of blue green infrastructure amongst First Nations in British Columbia). In the **South American Andes** a small IGRD project has supported the investigation of the potential of using mountain groundwater stores as natural infrastructure for water supply to improve population resilience to climate change. The project is allied to a $15m USAID Natural Infrastructure project in the region, and students from the University of Birmingham and Imperial College London are focussing their PhD research on supporting the project and its principal partner INGEMMET, who have produced regional hydrogeological maps and aquifer property datasets.

6.6 RIC 3: GEOSCIENCE SOLUTIONS FOR SUSTAINABLE LAND MANAGEMENT

The impact of land degradation from poor land management has consequences for food security – impacting both food production on land and in lakes, where leached nutrients result in ecological imbalance in downstream aquatic environments. This is a significant issue in the Winam Gulf of Lake Victoria, Kenya, which supports the largest freshwater fishery in the world, providing food security and supporting the livelihoods of ~4 million people across Kenya, Uganda, and Tanzania. Via aligned funding from the Royal Society, initial investigation was undertaken in the Winam Gulf of Lake Victoria, through academic, research institute and community/regulatory partnerships, to encompass agriculture, industry and urban changes that influence land-to-lake dynamics, with global relevance for settings experiencing rapid deforestation for conversion to agricultural use. Field experiments determined specific rates of soil erosion using tracers (e.g. Plutonium) across differing land-uses to inform intervention strategies to improve soil lifespan. Emerging findings contradict some existing assumptions in soil conservation, showing that small scale field interventions may result in less erosion than intensive terracing. Source apportionment modelling at catchment scale for land-to-lake transfers of soil/sediment connect the agricultural and fisheries sectors and their decision makers to develop holistic management practices e.g. working with nature in land and aquatic environments. The resulting model for land-to-lake dynamics in the Winam Gulf of Lake Victoria is being used to demonstrate a catchment scale approach to inform sustainable land/aquatic management by prioritising limited resources for mitigation (e.g. afforestation) to specific locations within a catchment. Our ambition is to explore the extension of this approach to a diverse range of environments, while continuing the development of tools to make the data and learning widely accessible to regional stakeholders. Initially, this will link through the Lake Victoria Advisory Group to a broader regional study, building on the success of the land and lake management stakeholders in government, private sector and communities in Kenya. There is further potential for translation of knowledge and stakeholder linkage to the African Great Lakes in East Africa through a developing partnership with the African Centre for Aquatic Research and Education.

The IGRD programme also builds on previous work from the CEPHAS project, which investigated the effectiveness of conservation agriculture (CA) in Malawi, Zambia, and Zimbabwe, while also looking at the impacts of CA approaches on groundwater. Conservation agriculture is employed to reduce soil erosion and degradation by improving water retention, retaining nutrients, and reducing acidification of soils. Through IGRD, a multi-country, African-led publication was produced, providing insights into the impacts of CA on groundwater recharge in subhumid drylands in sub-Saharan Africa. This has led to the development of a new project proposal to look at the role of dambos in collaboration with partners in Zimbabwe; it has also helped to establish a new partnership with Practical Action and supported preliminary groundwater monitoring in Senegal to understand the role of groundwater in contributing to and mitigating flooding in the city of Thies.

Linkages between agriculture and geology have been further explored in Malawi, where earlier GCRF research was extended to understand how geological deposits containing potassium can be exploited to address the needs of the agricultural sector for fertilizers. GCRF funding of partners in Malawi consolidated links previously established between BGS and Malawi GSD, as well as new interactions between our partners in Malawi (Geological Survey, LUANAR university, Ministry of Agriculture) and industry connections (Mkango Resources). The project successfully brought

together representatives of the Ministry of Mining, and Ministry of Agriculture with a ministerial field visit.

6.7 RIC 3: GEOSCIENCE TO INFORM URBAN PLANNING

More than half the global population currently live in urban areas. This is projected to increase to nearly 70% by 2050, requiring effective urban planning to ensure safe and resilient cities. The IGRD programme, building on work under the previous international NC programme, aims to support and increase the use of urban geoscience knowledge by urban planners to optimize the use of the sub-surface and minimize the exposure of urban populations and infrastructure to geohazards. This work is largely focussed on Asian cities, where BGS has long-standing and developing partnerships with geological surveys, universities, and decision-makers. A key pathway to impact for the urban work within IGRD is the strong partnership with CCOP (a multilateral organisation representing Southeast Asian geological surveys), who have a well-established focus on urban geoscience. BGS remains a trusted advisor of CCOP, providing continued support and input to their annual workshops, resulting in an invitation in 2024/25 to draft the Terms of Reference for the CCOP advisory group, which BGS will chair in 2025/26. This partnership has enabled BGS research, tools, and methodologies to be taken up by urban geoscientists working across Southeast Asia. For example, In Malaysia, co-developed systems and workflows for managing urban geoscience data and urban geological modelling are being implemented by the Malaysian geological survey (JMG) through a £0.5M project, which will develop a 3D geological model of the greater Kuala Lumpur area, supported by BGS. Through this collaboration, BGS was invited to comment on new Malaysian site investigation standards. In South Korea, an ongoing collaboration with the geological survey (KIGAM), is allowing BGS' stochastic approach for lithofacies modelling to inform 3D geological modelling at a national scale.

The urban work within IGRD is facilitating collaboration across the programme to address urban geohazard risk assessment and mitigation. One example of this is a collaboration with UNITEN (a Malaysian university privately owned by the national electric utility company), which resulted in them purchasing a BGS PRIME system to be installed on a critical slope above one of the largest hydroelectric dams in Malaysia. This will allow UNITEN to assess and mitigate risk to power generation and downstream populations associated with slope / dam failure.

Work under IGRD instigated new engagement between CCOP and the EuroGeoSurveys Urban Geology Expert Group, which aims to promote further uptake and application of urban geoscience tools within Southeast Asia. BGS' prominent role within the CCOP advisory group also provides new potential pathways for the translation of BGS research, beyond urban geoscience, to new geographical contexts. One potential example of this is a new CCOP Research Centre in Urban Geology, established in Nanjing, China, which has proposed a two-year programme of research with a focus on cities where there is a significant legacy of historical mining. This offers the opportunity of collaboration on themes from the UKRI-funded UKGEOS programme (especially mine water heat), and the challenges of mine related subsidence and water quality.

Urban water quality is a multi-dimensional issue, affecting cities and populations in diverse ways depending on geology, climate and the history of infrastructure development and industry. Our projects aim to understand the relative importance of these factors. As an exemplar, working with UNICEF and Practical Action in Zimbabwe on shallow water points that are extensively used by

marginalised urban communities, where population growth has outstripped infrastructure development, the project and partners have installed monitoring technology to understand urban groundwater balances. A programme of analysis used eDNA as a tool to identify sources of pollution. This is an emerging technology, and as part of the project new protocols and policies for its use in Zimbabwe were agreed with the Environmental Management Agency (EMA). In 2024/25, the groundwater monitoring network was fully handed over to the EMA, and an expansion of the network is being planned. This is helping to leverage additional funding to continue the work under FCDO's Green Cities Initiative. In Kenya, measurements of organic pollutants in urban soils and sediments identified contaminant transfer through the urban environment. The data and interpretations have been delivered to the National Environment Management Authority and directly contribute to Kenya's Vision 2030 which aims to improve sanitation and waste disposal.

7 Logframe Report

7.1 IMPACT

In responding to the global challenges described above (see Section 3, the long-term impact that the IGRD programme aims to contribute towards is:

Sustainable use and secure supply of Earth's natural resources and increased community resilience to natural and anthropogenic hazards in: (1) the urbanising world; (2) resource rich emerging economies; and (3) communities on the climate change frontline.

This impact spans across BGS' capabilities within the geosciences, reflected in the range of projects and tasks within the programme, and across a broad spectrum of beneficiaries, reflected in the range of partners involved in the research. Narratives towards achieving the intended impact, where the IGRD programme is playing a significant role in effecting change, are developing in several key thematic areas, as described in Section 6 above. Progress towards impact will be monitored as part of the ongoing MEL process, however, evaluation will primarily be at the outcome level, recognising that impact is likely to happen over much longer timescales due to a wider array of interventions (political, socio-economic, environmental etc).

7.2 OUTCOMES

The IGRD programme is working towards three key outcomes that focus on the uptake and use of IGRD research by various stakeholders, providing multiple pathways towards achieving the impact described above. Further description of these outcomes within the context of the three RICs is provided in the ToC (Appendix 1). Within each outcome, progress is being monitored against a series of indicators, as outlined below. Detailed evidence for each indicator can be found in the full Logframe document.

Outcome	Indicator	Number delivered Year 1	Number delivered Year 2[1]	Number delivered Year 3[1]
O1. Decisions, policy and practice	O1.1. Number of citations of IGRD research (papers / datasets / tools	0	1	2

are informed by geoscience	/ reports) within policy or practice documents			
	O1.2. Number of media reports (written articles, TV, radio) mentioning IGRD research	7+[2]	19+[2]	77+[2]
	O1.3. Number of stories of change to stakeholder decisions, policy, practice, or public awareness / understanding of an issue influenced by IGRD research	0	2	8
	O1.3a. Number of *developing* stories of change to stakeholder decisions, policy, practice, or public awareness / understanding of an issue influenced by IGRD research	5 (5)[3]	19	10
O2. Geoscience research is applied at scale to address global challenges	O2.1. Number of citations of IGRD research (papers / datasets / tools / reports) within policy or practice documents *beyond project localities*	3	4	5
	O2.2. Number of academic citations	n/a[4]	330	1,150
	O2.3. Number of stories of change to stakeholder decisions, policy, practice, or public awareness / understanding of an issue *beyond project localities influenced* by IGRD research	0	5	12
	O2.3a. Number of *developing* stories of change to stakeholder decisions, policy, practice, or public awareness / understanding of an issue *beyond project localities* influenced by IGRD research	9 (4)	5	7
O3. Institutions and partners further embed the geoscience within their practice, promoting sustainability	O3.1. Number of partners who report a change in their capacity (e.g. stronger networks/additional funding success/position of responsibility/ research outputs)	n/a[4]	23 (100% of respondents)	n/a[4]
	O3.2. Number of instances of participation (by partners) in relevant stakeholder meetings / forums[5]	*1*		

O3.3. Number of stories of change to the capacity or working practices of institutions and partners as a result of IGRD research	3	8	15
O3.3a. Number of *developing* stories of change to the capacity or working practices of institutions and partners as a result of IGRD research	6 (2)	15	5

[1]note numbers are cumulative; [2]this evidence relies on project reporting and BGS media monitoring, but issues with monitoring for international media mean numbers are likely underestimated; [3]a(*b*): a is the number of *developing* stories of change with clear pathways to outcome/impact; b is the number of *potential developing* stories of change where the pathway to impact is less clear; [4]not monitored in Years 1 and 3; [5]indicator removed as project partners are generally involved in all project stakeholder meetings.

At the outcome level, most projects now have demonstrated pathways to impact, with an increasing number of outcomes already in progress and growing evidence of **research uptake by partners and external stakeholders.** Across all projects, partnerships and networks have continued to strengthen and in many cases additional funding has been leveraged to allow the expansion of work beyond IGRD. Some examples of research uptake by partners and external stakeholders are summarised below.

Application of models and tools to inform decision making

1) BGS continues to work in partnership with PHIVOLCS to incorporate BGS' TOMRAP workflow into PHIVOLCS Plan SMART Philippines tool for hazard assessment. This has leveraged additional funding from the UK Government Office for Technology Transfer, allowing the delivery of multi-hazard risk assessment training to PHIVOLCS and engagement with other government agencies, including the Mines and Geosciences Bureau and the Philippine Atmospheric, Geophysical and Astronomical Services Administration.
2) The first national-scale hydrological model of the Philippines (developed by BGS) continues to be used by the National Water Resources Board to address issues of population growth and increasing water scarcity. This has leveraged additional funding from the British Council to develop a Hydro-Hub for the Philippines, in partnership with the NWRB, academics and other government agencies.
3) BGS' PRIME system has been purchased and will be installed by UNITEN on a critical slope above one of the largest hydroelectric dams in Malaysia, allowing risk assessment and mitigation of slope failure to protect power generation and downstream populations.

Interpretation and integration of evidence to inform practice

1) BGS developed the first phase of a scenario planning exercise, based on IGRD research, for FCDO and the Ascension Island Government to enable planning, preparedness and effective response and recovery to volcanic hazards in the UKOTs.
2) IGRD research informed the design and implementation of a new Global Navigation Satellite System (GNSS) campaign for monitoring fault movement, and BGS staff contributed to the current National Seismic Hazard Assessment for Indonesia.

3) BGS supported the development of a new groundwater monitoring network to assess groundwater quality and quantity in Harare, which has now been handed over to the Zimbabwe Environment Management Authority and an expansion to the network is being planned.

Influence on national policy

1) Following specific reference to graphite (and BGS) in the UK-Zambia Memorandum of Understanding on critical minerals, and by President Hakainde Hichilema in his address to the Mining Indaba in Cape Town in February 2024, IGRD and related FCDO-funded research into graphite and critical minerals in Zambia informed the Zambian National Critical Minerals Strategy, which was published in mid-2024.

Several projects are demonstrating **influence and outcomes at a global scale**, i.e. beyond an individual country of interest, which has been enabled by strengthened collaboration across the programme. Examples are provided below.

Translation of BGS tools and expertise to different global contexts

1) Strong collaboration across the programme is developing new opportunities for earth observation and hazard science to inform dynamic multi-hazard risk assessment across different geographies. For example, novel methodologies developed under IGRD for assessing landslide hazards are now being incorporated into work in the Philippines and Malaysia, while the UK Mining Remediation Authority have requested training on the use of ground motion data to monitor coal field hazards.
2) BGS' groundwater mapping methodology, developed for basement aquifers in Africa under the IGRD programme, is being extended and applied to map groundwater potential across East Africa under work funded by UNICEF, the World Bank, and BGR.
3) Through engagement with CCOP, BGS tools, methodologies and workflows for 3D geological modelling are being applied in Malaysia and South Korea.

Provision of expert advice through participation in global networks and advisory groups, for example:

- European Volcano Observatory Network, which BGS helped to establish, to move towards harmonized reporting of volcanic hazards; ARISTOTLE advisory group; WMO Ash Advisory Group; and International Civil Aviation Organisation.
- UNESCO working group on urban subsidence
- UNECE UK International Centre of Excellence on Sustainable Resource Management (UK ICE-SRM)
- Lake Victoria Advisory Group
- Global Soil Partnership of the FAO-UN
- CCOP and the EGS Urban Geology Expert Group
- Global advisory group on groundwater capacity building; advisory group to GEF-funded Groundwater for Deep Resilience in Africa project and World Bank-funded Horn of Africa Groundwater for Resilience programme; and AMCOW's Strategic Continental Groundwater Programme.

Citation of BGS research in **global policy and practice, the wider academic literature** and **media reports**, for example:

- In their regional and continental consultations on the post-2025 Africa Water Vision and Strategic Continental Groundwater Programme, AMCOW highlight BGS as a key international partner and cite the Africa Groundwater Atlas as an important resource that should be maintained to support sustainable groundwater development on the continent.
- Academic publications from the IGRD programme have now been cited more than 1000 times in the wider academic literature.
- IGRD work was featured in numerous media reports, particularly related to the role of AI in earthquake forecasting.

Overall, there have been 38 successful **funding applications to grow and extend research activities**, leveraged from the IGRD programme – some of which are BGS-led, while others are led by partners – and examples of partners attracting their own funding, expanding their capacity to carry out aligned work. This equates to £12.3M overall and £5.3M directly to BGS.

7.3 OUTPUTS

The IGRD programme is working towards four key outputs that build the foundation for achieving outcomes and impact, from the scientific evidence base to the partnerships needed to translate that evidence for uptake to effect change. Further description of these outputs is provided in the ToC (Appendix 1). Within each output, progress is being monitored against a series of indicators, as outlined below. Detailed evidence for each indicator can be found in the full Logframe document.

Output	Indicator	Number delivered Year 1	Number delivered Year 2[1]	Number delivered Year 3[1]
P1. High quality, multi-disciplinary research is produced by the IGRD programme	P1.1. Number of academic publications	9	36	55
	P1.2. Number of products and tools	2	6	16
P2. Dissemination of research	P2.1. Number of non-academic outputs (e.g. policy briefs, webpages, blogs)	1	14	25
	P2.2. Number of presentations at conferences / workshops	25	89	130
P3. Strengthened partnerships able to communicate and/or use evidence	P3.1. Number of collaborations and partners	tbc	59	No update
	P3.2. Number of co-produced outputs and activities (including partner meetings,	34	56	57

	training and capacity building activities)			
P4. Strong networks and improved interfaces between scientists and user communities	P4.1. Number of external stakeholder workshops and networks engaged with	46	126	230

[1]note numbers are cumulative

As is evident in the table above, the research evidence base expanded further in Year 3 with 19 new journal articles, whilst all 55 papers have been cited 1,150 times within the wider academic literature (as of 1st April 2025), a total of 130 presentations at conferences and workshops, and the release of 10 new products and tools, with a further three awaiting sign-off. The number of partnership meetings significantly reduced, with only one new meeting reported. This is likely due to a combination of factors: primarily that the research partnerships have matured and the focus within projects is generally on external stakeholder engagement – as evidenced by more than 100 new external engagement activities in Year 3, which are generally attended by BGS staff and partners; the level of reporting of internal partnership activities may also have reduced due to time pressures resulting from budget cuts in Year 3.

7.4 CHALLENGES

Several common challenges were identified by researchers within the IGRD programme during Year 3. These include: technical difficulties and data sensitivities; keeping momentum with partners, particularly where there is a high turnover of staff in partner institutions; the time required to manage complex stakeholder relationships; and addressing complex issues and working within socioeconomic and/or geopolitical contexts where geoscience is one (often minor) component. Many of these challenges were foreseen within the project pathway to impact plans and programme risk register; however, where unforeseen challenges have arisen, project leads were supported by the IGRD management team to manage and mitigate any associated risks. Due to budget reductions, some of these challenges became more acute during Year 3 of the programme – these are addressed in Section 7 of the report.

8 Partnership Survey

No partnership survey was undertaken in 2024/25. A survey will be undertaken in 2025/26 – the final year of the programme – and the results compared to the 2023/24 survey.

9 Forward Look

9.1 CHANGES TO THE PROGRAMME FOR 2025/26

In 2024/25, the IGRD budget allocation was reduced by approximately 50%. In 2025/26, the budget allocation will be reduced further. This resulted in a further reduced programme for 2025/26, including further withdrawal from some of the 15 countries engaged in collaborative

research. For 2024/25, the IGRD PI led an evaluation and prioritisation exercise of the 29 projects within the programme to determine how this reduction could be achieved whilst ensuring the optimum impact of the IGRD research programme. Reshaping of the programme was achieved through curtailing project activities completely and merging of projects and activities where synergies could be identified. A proportionate budgetary outcome is expected across the BGS science challenges, with an attempt to maintain the integration with ongoing research and commercial projects to maximise cohesive working across the full breadth of BGS science capability. Each of the project activities was reviewed through extensive information gathering according to the following criteria:

- Balance of programme across the BGS science areas
- Continued success in building hub of activities in SE Asia
- ODA relevant outcomes to meet NERC requirements
- Science excellence
- Ability to leverage external income and aligned in-kind resources
- Risk to reputation
- Quality of impact
- Shape and coherence of programme

The conclusion from the exercise was to end 5 projects and merge several others, resulting in 16 projects continuing for the final 2 years of the programme. The risk to reputation has been well managed so that the overall risk was low, however some residual risks remain with individual partners, particularly where projects have been curtailed, for which support will be provided to manage the relationship. This support is now cut for 2025/26 for several projects that were provided with ramp down funds to manage the relationship and link to new funding. In some cases, new funding was found, tasks had been completed, but there are activities that have had to be cut short, which put at risk their final delivery and link to new funding. A list of projects is provided in Table 1 in section 9.3. As in the previous year, this has been managed to reduce overall risk to reputation for BGS and best possible scenarios to deliver excellent science for NERC and leveraging of funds.

More detail on potential future risks is provided in Section 9.2.

9.2 POTENTIAL FUTURE RISKS

A number of residual risks following the programme reduction are identified, including:

- Reduced opportunity for cross organisational working.
- Reduced opportunities for overall leveraging of EI.
- Tension between science delivery and EI.
- ODA compliance is of minimal risk, as science delivery generally occurs across ODA countries – meeting requirement of ODA relevant outcomes (low risk likelihood).
- Risk to reputation with partners is largely managed through rearrangement of activities but not risk free. Curtailed projects will need assistance in managing their relationships to find a secure footing.
- Risk to reputation with FCDO is marginal, with continued positive engagement through projects and wider BGS network contributing large scale funding opportunities.

- Risk of managing wide ranging programme with reduced budget – smaller programme, fewer activities for oversight.
- Reduced internal opportunity to develop international science leaders – mitigation potentially through leveraged EI projects for the group developed in years 1 & 2.
- Risk of unfinished tasks by cutting off activities.

9.3 PRIORITIES FOR 2025/26

The programme will continue to work towards delivering the overall intended outcomes set out in the Theory of Change (Appendix 1), albeit shifting to a different delivery model where greater in-country science is achieved remotely via project partnerships rather than directly led or undertaken by BGS. The considerable progress made in years 1 and 2 to set a strong platform for delivery have helped to navigate the cut in budget for 2024/25, although opportunities to leverage EI have been limited due to reduced partner engagement in-country – balanced with cyclical funding. For 2025/26, the outputs and outcomes from the programme will continue to be managed and monitored through the well-established Monitoring, Evaluation and Learning processes. Whilst some projects may seem to have a small NC budget, they have been reviewed based on the existing leverage of EI resources to ensure continued delivery, as well as their potential to leverage future EI. As in the previous year, projects were reviewed by the Science Strategy Group based on their potential strategic location, strength of partnerships to deliver excellent science, quality of impact and for this coming year, most pressingly, the financial viability of a further reduction to budgets.

Table 1 provides a summary of the reduced project format for 2025/26 for each of the RICs, with comments highlighting where project activities were merged. All of these projects are expected to finalise delivery of excellent research in year 4 of the programme, supplemented with leveraged in-kind or competitively won resources. Research outputs are expected to be designed and delivered as public good with local/regional stakeholders. Whilst a tension was created with reduced budget in 2024/25, many of these projects have completed in years 1 and 2 the majority of their data gathering, whilst working through strong partnership foundations, moving to a phase of write-up, refinement of models/data delivery and testing with stakeholders on which to deliver these expectations in year 3. In year 4, with additional cuts, there will inevitably be unfinished outputs and a requirement from within BGS, perhaps via Business Development to support the leveraging of funding opportunities to maintain international presence of BGS staff.

Table 1: IGRD project activities for years 4 of the IGRD programme with reduced budget.

Project	Lead	Comment
RIC 1		
Using AI to transform Earthquake Hazard	Margarita Segou	
Geohazards & Risks in Indonesia	Ekbal Hussein / Sam Engwell	
Landslide Trigger thresholds for tropical residual soils	Nikhil Nedumpallile	
Subsidence and Landslide mapping	Luke Bateson / Alessandro Novellino	ALMEO and Urban subsidence merged

Global reporting of multi-hazards and impact for decision makers	Sue Loughlin	MHs Philippines, Recovery from Disasters cut
RIC 2		
Mineral mine waste evaluation	Jon Chambers	Levee stability cut
Sand and sustainability	Tom Bide	
Lithium Brines	Andrew Hughes	Peruvian glacial waters cut
Emissions reduction and enabling clean growth in India through CO_2 storage	John Williams	
Identifying superhot geothermal zones	Brian Baptie	Completed
Critical Mineral Resources – Zambia	Clive Mitchell	Mineral waste project cut, final output delivery through PhD student
RIC 3		
Land Use and Environmental Geochem.	Michael Watts	Agriminerals Malawi cut
Water Security in Africa	Alan MacDonald	CLANS and OPUS cut
Groundwater SE Asia	Dan Lapworth	Hydrology-Philippines cut
Urban Geoscience	Marcus Dobbs	MICP and OPUS sediments cut

10 Summary

At the end of Year 3, the IGRD programme was successful in its delivery of outputs: 230 external engagement activities, 55 academic publications, leveraging of >£12M of additional resources secured for aligned research with partners from a range of UK/International funding bodies or via direct commercial services. Through this, the research evidence base continues to expand while there is growing evidence of research uptake by partners and external stakeholders, both at a national and international level.

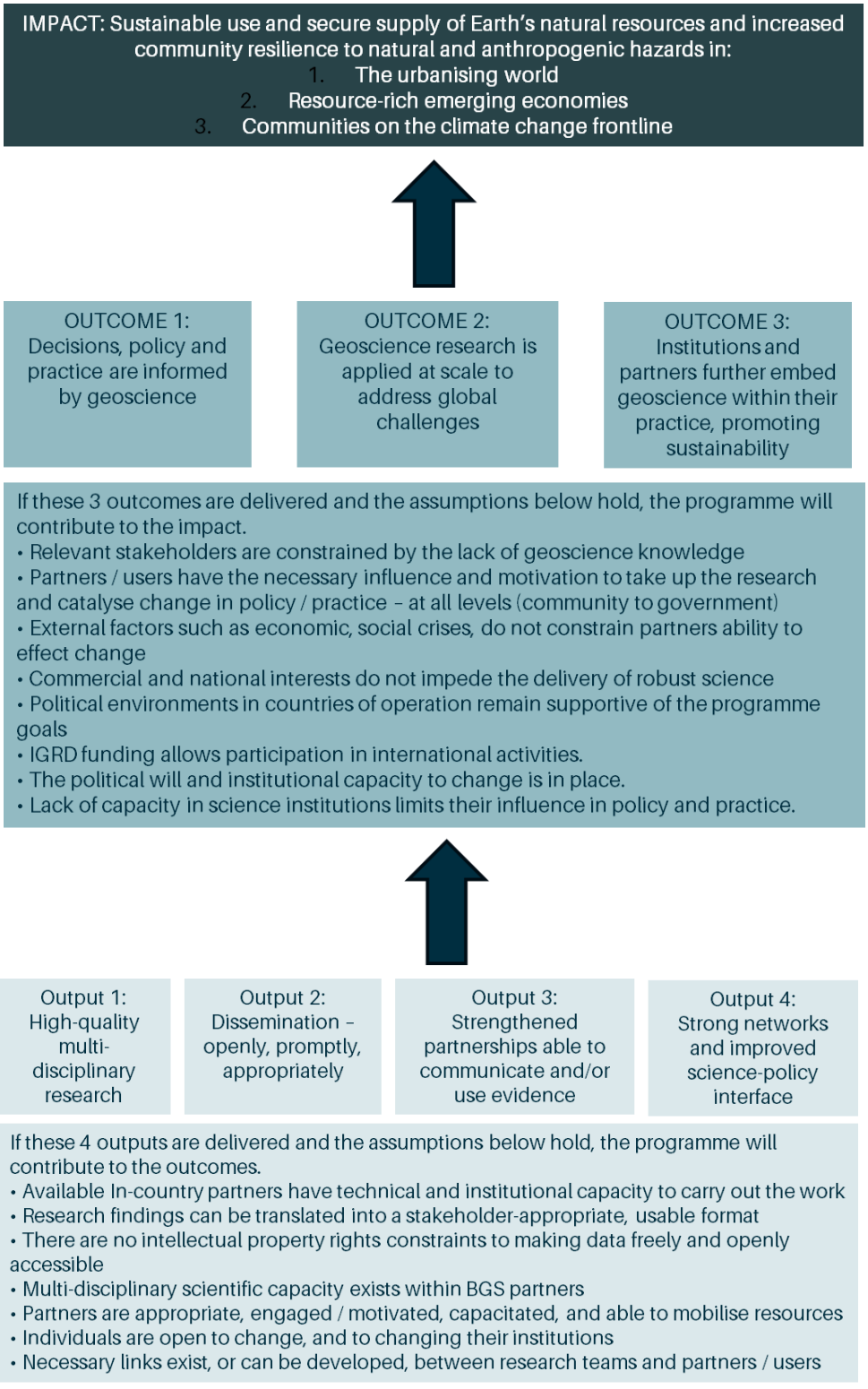
Through to year 3, the IGRD community of project leaders had developed pan-BGS working ideas with new funding proposals that may benefit future BGS international leveraging of resources, particularly with the FCDO for critical minerals research in Africa and the ISPF funding calls. The programme-maintained momentum as highlighted by the January 2025 workshop at which progress was shared with the rest of BGS. Key points have been highlighted in this report, utilising an effective MEL process to capture achievements and articulate a narrative for the positive influence of research in tackling global environmental problems. The reduction of overall budget to IGRD of 50% created obvious problems, although through a process of change management in the preceding six months of 2023/24, the impact to reputational risk was minimised by enabling project leaders to position their partnerships with sufficient time – advanced communication was critical. In the first quarter of 2024/25, a rebuilding of the sense of community developed through the IGRD programme was required to continue positive pan-BGS working to showcase the best of BGS research internationally that is translatable from their original location of research to other scenarios around the world. Further cuts to the budget for 2025/26 require careful management to close out the IGRD programme in year 4 to balance the tension between delivery of research and the higher priority to leverage additional funding to ensure the sustainability of BGS international research, alongside developing opportunities for BGS staff.

Appendix 1 Theory of Change

The purpose of this document is to lay out the pathways that link the outputs that the IGRD programme will deliver through to the long-term change that the programme seeks to contribute towards. It was compiled in a series of discussions with the leadership team of IGRD during 2022.

The theory of change is illustrated in a diagram overleaf, followed by a narrative description. The structure of the change pathways outlined in this document has also been used as the basis for a separate log frame. The log frame gives more details of how these changes will be measured. It shows indicators of change, as well as milestones and targets against which progress can be tracked.

The programme is sub-divided into three research settings, namely: living in multi-hazard environments; resources for the future; and sustainable land management and climate change adaptation.


IMPACT: Sustainable use and secure supply of Earth's natural resources and increased community resilience to natural and anthropogenic hazards in:
1. The urbanising world
2. Resource-rich emerging economies
3. Communities on the climate change frontline
OUTCOME 1: Decisions, policy and practice are informed by geoscience
OUTCOME 2: Geoscience research is applied at scale to address global challenges
OUTCOME 3: Institutions and partners further embed geoscience within their practice, promoting sustainability
If these 3 outcomes are delivered and the assumptions below hold, the programme will contribute to the impact.
• Relevant stakeholders are constrained by the lack of geoscience knowledge
• Partners / users have the necessary influence and motivation to take up the research and catalyse change in policy / practice – at all levels (community to government)
• External factors such as economic, social crises, do not constrain partners ability to effect change
• Commercial and national interests do not impede the delivery of robust science
• Political environments in countries of operation remain supportive of the programme goals
• IGRD funding allows participation in international activities.
• The political will and institutional capacity to change is in place.
• Lack of capacity in science institutions limits their influence in policy and practice.
Output 1: High-quality multi-disciplinary research
Output 2: Dissemination – openly, promptly, appropriately
Output 3: Strengthened partnerships able to communicate and/or use evidence
Output 4: Strong networks and improved science-policy interface
If these 4 outputs are delivered and the assumptions below hold, the programme will contribute to the outcomes.
• Available In-country partners have technical and institutional capacity to carry out the work
• Research findings can be translated into a stakeholder-appropriate, usable format
• There are no intellectual property rights constraints to making data freely and openly accessible
• Multi-disciplinary scientific capacity exists within BGS partners
• Partners are appropriate, engaged / motivated, capacitated, and able to mobilise resources
• Individuals are open to change, and to changing their institutions
• Necessary links exist, or can be developed, between research teams and partners / users

The impact that the programme seeks is the secure supply and sustainable use of the Earth's natural resources and increased community resilience to natural and anthropogenic hazards. The focus of the programme will be in three particular environments: i) the urbanising world; ii) resource rich emerging economies; and iii) communities on the climate change frontline. In order to achieve this long-term goal, there needs to be sustained action taken by many partners, together with a range of actors in the external environment. The external environment also needs to be conducive to such an impact. For example, economic and social crises do not constrain the partners ability to effect change. It is also important that partners and users of the products of this programme have the necessary influence and motivation to take up the research and catalyse changes in policy and practice at all levels, from community to government. It is assumed that the relevant stakeholders are currently constrained by the lack of geoscience knowledge.

One of the pathways towards this impact relates to **decisions, policy and practice which are informed by geoscience evidence** (Outcome 1). The programme and project partners, together with a range of external actors, articulate a voice of responsible advocacy through representative bodies and the leverage that they command through their networks of influence. This outcome will be developed by each of the RICs across the three key settings, as follows:

For Research and Innovation Challenges (RIC) 1 this relates to Disaster Risk Management (DRM) and/ or resilience-related decisions. The objective is that urban planners and infrastructure managers are informed by robust landslide hazard and risk analyses and by new evidence of subsidence rates. Responding organisations are able to act in a timely manner during earthquake sequences. DRM decisions taken by authorities and community decision makers are informed by new hazard analyses and scenarios. Geoscience knowledge and expertise supports people recovering after disasters in multi-hazard environments to become more resilient.

RIC 2 relates to sustainable natural resource supply decisions. In this case the objective is that decision makers in the public sector (including government ministries, resource licencing authorities and environmental agencies) and the private sector (including mining, power, and water supply companies) are using geoscience-based best practice to ensure sustainable development and use of natural resources. Informed policies and plans are put in place that assist the energy transition to net zero (including development of geothermal, solar pumping, carbon capture and storage and critical raw materials) and address environmental, social and governance issues including mine tailings safety and utilisation, groundwater utilisation, sand extraction and Li-brine mining.

RIC 3 relates to land and water use and climate change adaptation decisions. The objective is that farmers, local authorities and/ or national agencies (in Zambia and India) will adopt working with nature approaches to soil and groundwater conservation. Government agencies (in Canada, and Mexico) will use social and hydrological tools to assess the resilience of marginalised communities and optimise blue-green infrastructure solutions. Impacts of climate change on future soil and water resource will be quantified and incorporated into national resource plans and planning mechanisms (in Kenya, Philippines).

The second objective at the outcome level is that **geoscience outputs and products are applied at scale to address global challenges.** Providing global leadership and influence, alliances that share environmental and scientific ambitions meet the scientific challenges of the complexity and scale that require an international response.

For RIC 1, DRM and resilience stakeholders with a global presence (e.g., UNDRR, UN Global Shelter and WASH clusters) are informed by RIC 1 outputs. Landslide forecasting in tropical regions is informed by landslide trigger threshold workflow developed for India. Inventory maps for landslide-prone regions produced by the 'landslide tracker' tool are in use. The process for making subsidence forecasts is applied to rapidly expanding cities in different geological settings around the world. For example, the understanding of how multi-hazards interact with policy in the Philippines is applied elsewhere; approaches to integrating geoscience in DRM decisions in the UK Overseas Territories (UKOT) is transferred to other island settings. RIC1 will provide international leadership and influence through supporting the implementation of the Sendai Framework for Disaster Risk Reduction by developing mechanisms for reporting against its targets.

For RIC 2, the objective is that research outputs inform and influence natural resource stakeholders across the world. RIC2 research enables the application of: Ni-laterite waste monitoring to international mine sites and emerging areas such as landfill mining; the better understanding and best practice for sand mining to other areas of the world where active sedimentary environments are mined; new understanding from the Lithium triangle to other environmentally sensitive mining districts especially in arid areas where mining could exacerbate water scarcity; the knowledge gained through the CO_2 storage research in India to the Indian subcontinent and Southeast Asia; and the superhot geothermal research to volcanic settings worldwide.

For RIC 3 this will mean the development of digital platforms for data delivery on soils and geosciences, the African Groundwater Literature Archive and the African Groundwater Atlas. African policy makers in the water sector give increased attention to the groundwater sector influenced by bodies such as the African Ministers' Council on Water (AMCOW) and the APA Groundwater Programme. Geological Surveys in SE Asia prioritise urban geoscience issues, influenced by bodies such as the Coordinating Committee for Geoscience Programmes in East and Southeast Asia (CCOP) and the Research Centre on Urban Geology (RCUG). Tools developed for social and hydrological resilience, climate change impact, predicting future groundwater abstraction and urban typologies are adopted outside partner countries.

The third outcome on the path to impact has the objective that **institutions and partners further embed the geoscience within their practice, promoting sustainability**. This will vary across partners and partner types. It will include the ability to undertake research but also to network and connect the supply of evidence with the demand for it. The capacity of researchers and intermediaries will strengthen research uptake approaches.

RIC 1: Partners (in India) have capacity to carry out landslide trigger threshold modelling. Partners have increased 3D visualisation and modelling capacity that supports communication with people exposed to hazards in the Philippines. There is raised awareness among geoscience partners of what information is needed for making DRM decisions. Decision makers in the UKOTs are aware of geohazards and the need for

monitoring in the UKOTs. Humanitarian partners understand the role of water supply in recovery, and how geoscience can support their decision making. They design and implement strategies accordingly.

RIC 2: Partners and stakeholders have the knowledge and capacity to make natural resource decisions based on geoscience data and information. RIC2 research will enable the: multiscale observation of tailings storage facilities to mitigate the risks of failure and enable sustainable mining to recover critical raw materials; the improvement of sand and lithium mining practices; the development of CO_2 storage in India and beyond; the potential of groundwater in sub-Saharan Africa to be unlocked to help achieve water and food security; the provision of geoscientific data and geoscientific knowledge needed for geothermal resource development.

RIC 3**:** Support to AMCOW and BGS representation on the RCUG board and scientific steering committee will ensure that these partners integrate the latest research on groundwater and urban geoscience, respectively, into central government planning and action. Partners in academic sectors in Africa and Central America will have the capacity to support and extend the deployment of tools developed by IGRD projects in the long-term, and will demonstrate a capacity to win grants and access funding to support fieldwork and studentships.

Feeding into those outcomes are the outputs, the deliverables of the programme. The paragraph below describes these. In order for these outputs to contribute to the three outcomes listed above requires several enabling factors .These are listed below:

- Available in-country partners have the technical and institutional capacity to carry out the work and there is multidisciplinary scientific capacity in place. The partners are appropriate, engaged, motivated, capacitated, and able to mobilise resources.
- The necessary links exist, or can be developed, between research teams and partners, and users.
- The individuals involved in the programme are open to change and to changing their institutions.
- The research findings can be translated into a stakeholder appropriate, usable format and there are no intellectual property rights constraints to making that data freely and openly accessible.

There are four classes of outputs. The first is that **high quality, multi-disciplinary research is produced**. That is, responsible research that adheres to the ‘fair’ principles, that data should be findable, accessible, interoperable, and reusable. This research will be cross-disciplinary.

The second output is that **evidence, knowledge, and tools are shared and communicated openly, promptly and appropriately**. This will ensure that data, information, and knowledge will be openly available and easily accessible to a global audience, that it will be informed by a range of stakeholders to ensure that it is useful, usable and used.

The third output is **strengthened partnerships able to communicate and or use evidence**. These partnerships will be ethical and equitable, ensuring that there is relevance and informed consent.

The fourth output relates to **strong networks and improved interfaces between scientists and user communities**.

Appendix 2 MEL Strategy

MEL PRIORITIES

Monitoring, Evaluation and Learning (MEL) is a key pillar of programme implementation. The purpose of MEL is to increase the likelihood of the programme achieving its intended outcomes and impact, while maintaining key values of efficiency, integrity, equity, preventing harm (safeguarding), inclusivity and openness. Information gathered via monitoring is primarily for the purpose of enabling reflection and programme adjustments towards increased impact.

Official reporting requirements are through the UKRI ResearchFish platform, on an annual basis, but the programme will also prepare an annual report to highlight key achievements, progress and learning. This will help to inform the next corporate-level evaluation by NERC, which is likely to take place in 2026.

The reporting is guided by an IGRD Logframe reporting template. This is used to document the key outcome stories under each of the 3 outcomes. The template also collates aggregated data on the outputs and outcomes.

USERS

The primary users of the data are within BGS. The project leads and partners can share the information and reflect on progress, updating the workplan and budget to improve performance. The RIC leads can look across projects in that portfolio to share good practice and lessons, and to see patterns of change, or identify blockages. The programme lead can use the data and analyses to reprioritise projects or areas of work, to understand where there might be synergies or gaps and to pull together all the work done and benefits gained from the implementation of the whole programme.

DATA COLLECTION

There is data collection from each project at the output level using a 2-strand approach.

Information on the research outputs and engagement activities is uploaded to NORA with corresponding datasets uploaded to the National Geoscience Data Centre (NGDC). Engagement activities (including meetings, conferences, blogs, training, workshops, panel discussion, outreach events, media activity) are recorded on a separate form(s). Projects report on outputs as they happen, throughout the year– with data compiled for input to the Logframe in February/March of each year

The information from these sources can then inform ResearchFish.

Information at the outcome level is gathered primarily in the regular (quarterly) discussions with the RIC lead. These discussions review outputs that have been reported, linking back through the project impact pathway towards the outcomes. Impact stories collected in this way are recorded in

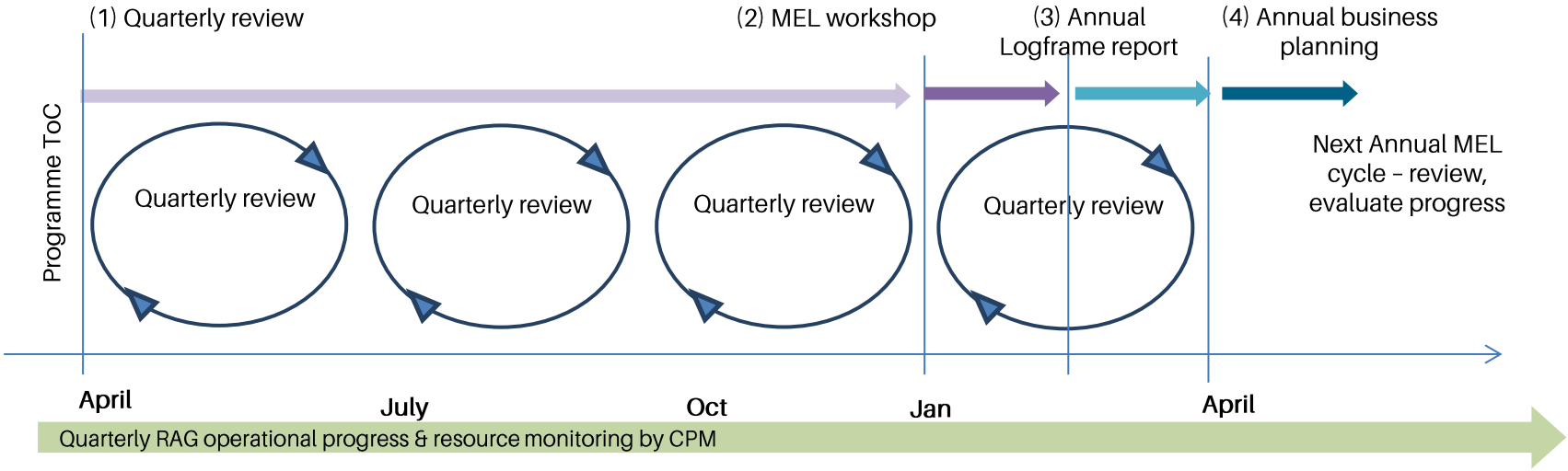
the Logframe. So, for example, if a project reports several engagement events, the RIC lead will probe to elicit further information on the consequences of those engagements, in terms of policies or practices that have been influenced. RIC leads will use a reporting template to guide their discussions and gather relevant information for the Logframe. Outcome data will be compiled for input to the Logframe in February/March.

The annual report will be completed in March/April.

The MEL process is supported by one or more workshops throughout the year. These provide opportunity for cross-project and cross-RIC exchange, allow progress towards outcome and impact to be discussed and evaluated at a programme level, and promote discussion of future priorities.

TIMELINE

IGRD Annual MEL Cycle



(1) Quarterly review cycle:

- RIC leads discuss progress along pathways to impact with project leads
- Logframe reporting template supports discussions
- RIC leads discuss with MEL lead to inform Logframe reporting

Outputs reporting:

- Ongoing by PLs via NORA and engagement activities form
- Annual metrics into Logframe (February)

(2) MEL workshop:

- Involves all Project leads and CoIs
- Review and assimilate progress over the year in emerging outcomes, constraints and opportunities

Focus workshop: MEL lead, RIC leads and CoIs:

- Synthesise key outcomes narrative
- Identify where outcomes / pathways could be amplified – these are followed through into business planning

(3) Logframe report

- Completed by MEL lead with input from RIC leads

(4) Business planning:

- Led by PI, CPM and RIC leads

Appendix 3 Logical Framework

IMPACT							
Sustainable use and secure supply of Earth's natural resources and increased community resilience to natural and anthropogenic hazards in: i) The urbanising world; ii) Resource rich emerging economies; and iii) Communities on the climate change frontline.							
OUTCOMES							
			Year 1		Year 2	Year 3	Year 4
Outcome	Indicator	Number delivered	Milestone	Progress against Milestone	Number delivered	Number delivered	Number delivered
O1. Decisions, policy and practice are informed by geoscience	O1.1. Number of citations of IGRD research (papers / datasets / tools / reports) within policy or practice documents	0	n/a	n/a	1	2	
	O1.2. Number of media reports (written articles, TV, radio) mentioning IGRD research	7	n/a	n/a	19	77	
	O1.3. Number of stories of change to stakeholder decisions, policy, practice, or public awareness / understanding of an issue influenced by IGRD research	0	n/a	n/a	2	8	

	O1.3a. Number of *developing* stories of change to stakeholder decisions, policy, practice, or public awareness / understanding of an issue influenced by IGRD research	5 (*5*)	n/a	n/a	19	10
O2. Geoscience research is applied at scale to address global challenges	O2.1. Number of citations of IGRD research (papers / datasets / tools / reports) within policy or practice documents *beyond project localities*	3	n/a	n/a	4	5
	O2.2. Number of academic citations	n/a	n/a	n/a	330	1150
	O2.3. Number of stories of change to stakeholder decisions, policy, practice, or public awareness / understanding of an issue *beyond project localities* influenced by IGRD research	0	n/a	n/a	5	12
	O2.3a. Number of *developing* stories of change to stakeholder decisions, policy, practice, or public awareness / understanding of an issue *beyond project localities* influenced by IGRD research	9 (4)	n/a	n/a	5	7
O3. Institutions and partners further embed the geoscience within their practice, promoting sustainability	O3.1. Number of partners who report a change in their capacity (e.g. stronger networks/additional funding success/position of responsibility/ research outputs)	n/a	n/a	n/a	23	n/a
	O3.2. Number of instances of participation (by partners) in relevant stakeholder meetings / forums	*1*	*n/a*	*n/a*		

	O3.3. Number of stories of change to the capacity or working practices of institutions and partners as a result of IGRD research	3	n/a	n/a	8	15	
	O3.3a. Number of *developing* stories of change to the capacity or working practices of institutions and partners as a result of IGRD research	6 (2)	n/a	n/a	15	5	
OUTPUTS							
			Year 1		Year 2	Year 3	Year 4
Output	Indicator	Number delivered	Milestone	Progress against Milestone	Number delivered	Number delivered	Number delivered
P1. High quality, multi-disciplinary research is produced by the IGRD programme	P1.1. Number of academic publications	9	n/a	n/a	36	55	
	P1.2. Number of products and tools	2	n/a	n/a	6	16	
P2. Dissemination of research	P2.1. Number of non-academic outputs (e.g. policy briefs, webpages, blogs)	1	n/a	n/a	14	25	
	P2.2. Number of presentations at conferences / workshops	25	n/a	n/a	89	130	
P3. Strengthened partnerships able to communicate and/or use evidence	P3.1. Number of collaborations and partners	tbc	n/a	n/a	59	n/a	

	P3.2. Number of co-produced outputs and activities (including training and capacity building activities)	34	n/a	n/a	56	57
P4. Strong networks and improved interfaces between scientists and user communities	P4.1. Number of external stakeholder workshops and networks engaged with	46	n/a	n/a	126	230

Appendix 4 Workshop Reports

10.1 MAY 2024 WORKSHOP

In 2024/25, two programme-wide workshops were held: the first in May 2024 aimed to regroup following the 50% cut to funding and assess the impact on project delivery, explore the tension between research, impact and need to leverage additional funds. This was an opportunity to familiarise researchers with the ToC and Logframe again, encourage projects to think about how their own pathways to impact given the new funding environment, and discuss synergies and new ways of working more efficiently across the programme; the second in January 2025, preceding business review and planning in February, provided a review of emerging success, outcomes and challenges and facilitated a programme-wide discussion on how geoscience research can be useful, useable, and used.

The agendas for both workshops are shown below.

Workshop Agenda May 2024

Time	Session title	Detail
9:30 - 9.45	Welcome & warm up	Introduction, aim & objectives
9:45- 11:45	Logframe - Outcomes	Plenary Explanation of exercise (5mins) One group for each of three outcomes i) emerging successes and outcomes? (ii) understanding of constraints? (iii) how can success be achieved in new funding environment? Answer the three questions within each outcome. 30mins per Outcome 1-3. Coffee at 10.20 for 20 mins.
11:45- 12:30	Report back on Outcomes	Plenary Report back on group discussions • Highlight key opportunities and challenges
LUNCH		
1:15- 2:45	Synergies and Opportunities	Synergies - are there already project concepts linking activities across IGRD projects or BGS Challenges? (Group Exercise) Opportunities - future priority (could be expansion of work to a new geography, upscaling, new area of research etc) •
2:45- 3:00	Wrap-up	*Plenary* • Programme-level priorities

		• Actions & next steps
3.00	Coffee and cakes	

Workshop Agenda Jan 2025

Time	Session title	Detail
		TUES 21st JAN
13:45 - 16:15	Project nano presentations: pathways to impact	• Each project presents 5 minute nano presentation • Nano template provides basis for log frame reporting
16:30	GROUP DINNER	
		WED 22nd JAN
09:00-10:30	Project poster presentations: science	• Time to circulate around posters
10:30-11:00	COFFEE	• Additional time to circulate posters
11:00-12:30	Outcomes to close out the programme	Challenges to what needs closing out/reporting Outputs to outcomes in Year 4 – reporting Report back on discussions
12:30-13:15	LUNCH	
13:15-14:45	TBC – Synergies and opportunities: continued discussion from May 2024 workshop	Synergies - are there already follow-on project concepts linking activities across IGRD projects or BGS Challenges? (Group Exercise) Opportunities - future priority (could be expansion of work to a new geography, upscaling, new area of research/problems to solve, stakeholder input etc)
14:45-15:00	Wrap-up and close	
15.00	Coffee and cakes	

Appendix 5 Thematic Synergies

	Multihazard Detection & Forecasting	Multihazard Management	Water Security	Urban Resilience	Sustainable Resources	Decarbonisation	Sustainable Land Management	Useful, useable, used
RIC1								
Philippines multi-hazards		x						x
Earthquake forecasting using AI	x							x
Self-recovery after disasters		x	x				x	x
Geohazards and risk in Indonesia		x						x
Landslide trigger thresholds	x							x
Landslide mapping using Earth Observation	x							x
Subsidence in developing urban centres	x			x				x
Global reporting of multi-hazards and impact		x						x
Geoscience for sustainable living in the UK Overseas Territories		x	x					x
RIC2								
Mineral mine waste: whole system approach (multiple tasks)	x				x			x
Sand and sustainability					x			x
Improving SEA of Li-brine mining from Lithium Triangle of South America					x			x
Food and water security Africa (multiple tasks)			x					x
Enabling clean growth India through CO2 storage						x		x

African geoscience data for improved geothermal assessment						x		x
Identifying superhot geothermal zones using geophysical methods						x		x
RIC3								
Land use and environmental geochemistry (multiple tasks)							x	x
Blue green infrastructure (multiple tasks)	x		x	x			x	x
Groundwater Futures (multiple tasks)			x				x	x
Groundwater in SE Asia (multiple tasks)			x					x
Urban Geosciences (multiple tasks)			x	x				x