Institution: University of Strathclyde

Unit of Assessment: 14 Civil and Construction Engineering

a. Overview

The Department of Civil & Environmental Engineering prides itself on research that is truly interdisciplinary. We are a young and dynamic Department, with a strong upwards trajectory in research income, PhD student numbers and output quality. In the last 5 years we have benefitted from sustained investment in academic posts, lab space and office space that has transformed our research capacity. We work as a single multidisciplinary research group, and have used this investment to ensure critical mass in 3 themes aligned to international and UK research priorities: Energy; Material & Structural Performance; Environment & Health.

b. Research Strategy

The Department of Civil and Environmental Engineering (CEE) has an overarching vision to achieve international leadership in three key interdisciplinary engineering research challenge areas informed by University, RCUK and Royal Academy of Engineering "grand challenges": Energy; Material & Structural Performance; and Environment & Health. To achieve this our strategy is to integrate cutting edge research skills from a deliberately wide range of fields (civil, environmental, chemical and electrical engineering, geosciences, physics, chemistry, microbiology) to develop innovative solutions to engineering problems. In 2012, we changed our name to include Environmental Engineering, to better reflect our strategic priorities.

The Department's 5-year research strategy stated in RAE 2008 was to: develop world class environmental laboratory facilities; support the laboratories through staff recruitment; develop a new geo-materials lab through the Science Research Investment Fund (SRIF) and RCUK funding; continue to increase PhD student numbers; and achieve a substantial rise in departmental research income through national and international consortium bids. Since 2008, additional departmental objectives are: recruitment/promotion of talented staff; the growth of research excellence in key challenge areas; demonstrating national & international research leadership; influencing national and international research agendas in areas of research excellence.

To achieve these research strategic aims we used 5 key *facilitation mechanisms*. For each of these we give an exemplar below and refer forward to the appropriate section for more details.

(1) *Recruitment.* CEE has co-invested with University, Faculty and external pooling initiatives to fund 12 new academic posts in areas of research strength. We have pursued a strategy of attracting outstanding staff by winning matching research enhancement funding, e.g. £300k of SRIF funding for the geomechanics laboratory, competitively awarded to *Lunn*, was used to secure a world-leading researcher for the Chair in Experimental Geotechnics (*Tarantino*) - see section c.

(2) *PhD Awards*. Since 2008, we have been awarded 52 studentships through co-investment by the University and Faculty, 23% of which included an industry contribution - see section d.

(3) *Pump-priming for new staff.* All new posts are supported by a start-up package and ECRs in particular are provided with funding for networking activities and conference attendance. CEE has been successful in obtaining from the University 29 Research Development Funding (RDF) and Bridging the Gap awards (BTG, originally funded by EPSRC but maintained by the university) supporting pump-priming to underpin RCUK grant applications - see section c.

(4) *Mentoring* is vital for staff development at all levels. All staff have academic mentors from a related research field with whom they meet regularly on an informal basis. All new staff have successfully passed probation within the University-specified 3 year period - section c.

(5) *Glasgow Research Partnership in Engineering* (GRPE) is a Scottish Funding Council pooling initiative that has provided a platform for collaboration (e.g. £1.3M SAFE Barriers EPSRC consortium, with Glasgow University) and funded new posts and laboratories - section d.

Since 2008 we have achieved or exceeded our strategic aims. We have published high-profile and award-winning research (examples in section e). We have participated in, and led large multi-institutional research awards e.g. 3 national and 5 EU consortia (see section e). In 2013, CEE opened new state-of-the-art laboratories funded by £6M of University investment providing an operational platform for £1.1M of advanced environmental analysis instruments (e.g. GC-GC

TOFM, GC-IRSM) funded by the GRPE and £350k of geomechanical testing facilities funded via SRIF and RCUK research projects. We have grown research excellence in industry challenge areas via 12 new academic appointments (see section c). An increase in research income through a varied grant portfolio has been achieved by staff at all levels, including ECR (e.g. *Pytharouli* EPSRC First Grant), and by bringing together multi-disciplinary teams to contribute to large consortium applications (e.g. EPSRC-funded BANDD and SAFE-Barriers). Industrial funding has been awarded to each of the industrial challenge areas (e.g. *Energy:* Nuclear Decommissioning Authority, Midland Valley, Total UK, GeoChemico; *Material & Structural Performance:* Plaxis BV, Ideal Standard International, 2H Offshore Engineering; *Environment:* Parsons Brinkerhoff, SiREM, Environment Agency).

Research organisation: CEE's research committee oversees strategic departmental funding for pump-priming, equipment and conference support, provides feedback on proposals, and monitors and informs staff on the funding landscape (in collaboration with the University research office). The three research themes overlap, and many sub-topics span two or more themes (e.g. monitoring technologies, computation modelling). The themes are reviewed during our annual research away-day. Research meetings are organised around a theme or a topic and all members of the Department are invited to attend. Most staff are, therefore, members of more than one research theme/sub-topic. Although there are senior staff in each theme, there are no formally assigned leaders; decisions are made by consensus and event/meeting organisation is rotated between staff and research students. This approach is designed to achieve an inclusive and supportive atmosphere for staff and students and to engender a strong research and leadership culture.

Our research strategy for the next 5 years is built on using our new world-leading labs to underpin income growth, staff development and promotion, PhD and PDRA recruitment, and international collaborations. We have set ourselves the following research targets, which we believe are attainable based on the progress we have made over the past 5 years :

- Double our research spend in 5 years,
- Recruit at least one new PhD per FTE staff member per year and double the number of post-doctoral research staff in the next 5 years,
- Internally promote academic staff members' careers via mentoring and training for future research leaders: aim to promote all staff at earliest possible opportunity
- Engage with university strategic recruitment initiatives for new staff investment
- Use the new business development officer to grow our international reputation for excellent lab facilities: self-sustaining in next 5 years
- Be responsive to, and exert influence on, national and international research agendas: win at least three large research agenda-driven grants in next 5 years

c. People

Sustained investment in staff since 2008 means that over half our academic staff (12) are new: 5 Lecturers, 5 Senior Lecturers, 2 Professors. Two University initiatives supported recruitment of excellent staff in strategically important areas: John Anderson Research Lectureships (JARL) and the Strategic Academic Investment Scheme (SAIS). CEE was competitively awarded matching university funds for a JARL Professor in Geological Engineering (*Shipton*) and a SAIS senior lecturer (*Lord*). CEE has successfully worked with the Engineering Faculty to secure 8 more academic posts, developing interdisciplinary critical mass in the key industry challenge areas. We have engaged with the Faculty to bid for positions on the basis that the first 4 years of salary are supported between CEE and the Faculty, after which the post moves onto central university funding. *Switzer* and *Knapp's* posts were funded by GRPE, providing the first five years of salary. *McKee*'s post was funded by the Scottish Funding Council Marine Alliance for Science and Technology pooling initiative (2011). All new positions have also been supported by a financial package for research enhancement of up to £50k and at least 1 PhD studentship, jointly supported by the department and Faculty.

All three research themes have benefited from appointment of new staff:

Energy: *Shipton* (2010, Professor, geological engineering) has a leading reputation in carbon storage and hydrocarbon production/exploration; *Pytharouli* (2009, ECR, Lecturer,

geotechnical/geological monitoring) designs innovative monitoring technologies to characterise rocks and soils for geological and slope failure applications; *El Mountassir* (2012, ECR, Lecturer, experimental geotechnics) harnesses natural phenomena, such as biomineral precipitation, to create novel technologies for geological disposal of radioactive waste. *Lord* (2012, Senior Lecturer, environmental geochemistry) investigates growth of energy crops on brownfield / contaminated land for sustainable energy production.

Material & Structural Performance: Tarantino (2010, Professor, experimental geotechnics) is one of the world's top experimental researchers in soil mechanics, and testing and monitoring of geomaterials: *Hamilton* (2013, ECR, Senior Lecturer, material science) was appointed to a senior lectureship, despite being her first academic position, on the grounds of her outstanding publications on chemical degradation of building materials; *Saafi* (2010, Senior Lecturer, civil engineering) develops smart monitoring systems for structural health monitoring e.g. smart paint to monitor concrete cracking; *Xu* (2008, ECR, Lecturer, structural engineering) researches thin shell and membrane materials applicable to both conventional infrastructure and the aerospace industry (e.g. composites); *Yang* (2013, ECR, Lecturer, structural engineering) does computational modelling of concrete failure due to chemical erosion. *Saafi* (2010, Senior Lecturer, civil engineering) develops smart monitoring systems for structural health monitoring e.g. smart paint to monitor concrete cracking.

Environment & Health: *Knapp* (2009, Senior Lecturer, microbiology) is one of the first researchers to determine the fate and evolution of antibiotic resistant microbes in the environment; *Switzer* (2009, Lecturer, chemical engineering) pioneers the use of smouldering as a technology for clean-up of contaminated land (e.g. patent PCT/US2012/035248). *McKee* (2011, Senior Lecturer, physics) develops optical sensors and novel remote sensing algorithms for marine applications.

Career development support: All academic probationary staff complete the University's PG Certificate in Advanced Academic Studies over two years. We encourage researchers at all levels to engage with the University's extensive Researcher Development Programme developed for implementation of the Concordat to Support the Career Development of Researchers, which helps researchers to identify, plan and record their CPD. 67 CEE PhD students and research staff have attended 258 courses since monitoring started in December 2010. Strathclyde was shortlisted for the 2011 and 2012 THE Awards for Outstanding Support for ECRs.

CEE provides exemplary strategic support to researchers at all career levels recognised in our gaining an Athena SWAN Silver Award in 2013. Because of our recruitment success, we have a cohort of highly motivated multi-disciplinary talented young researchers at relatively early career stages, who we intend to develop into future leaders in their field. CEE's senior management have a clear mission to mentor early- and mid-career staff by advising on research proposals and papers, promoting colleagues' research via networks, collaborative proposal writing, and joint PhD supervision to provide a track record in research management. Mentors formally assess performance and develop annual strategic objectives for probationary staff. Faculty and department financial support is targeted to facilitate researcher success. At least one studentship, start-up funding and prioritisation for University RDF pump-priming grants are used to support new academic posts. The department supports staff applications for university and faculty PhD scholarships by co-funding (~23% of costs) and funds laboratory consumables to support initiation of research ideas. The Research Director's budget also provides support for networking and conference attendance for all staff.

We support research leave via funded and unfunded opportunities. After coordinating RAE 2008, *Lunn* took a 6 month sabbatical at Glasgow University. *Yang* has twice been awarded BTG international exchange funding, spending 3 months setting up collaborative research in China. On return from maternity leave in 2013, CEE supported 6 months' research leave for *Pytharouli*, partially funded by her EPSRC project (UKCCSRC C1-19), to trial her new nano-seismic monitoring method on a carbon capture and storage demonstration project in Canada.

A measure of the quality of our mentoring is in the career success of our staff. Former post-doc Yin is now a Professor at Shanghai Jiao Tong University; Marie Curie Fellows, Cordão Neto and Castro, have permanent academic positions in Brazil and Spain, respectively; PDRAs Gauchotte-Lindsay and Rezania have academic positions at the University of Glasgow and Nottingham, respectively. We have been highly successful at promoting within CEE; *Lunn* and *Karstunen* were

promoted from Senior Lectureships to Professorships within 6 years. *El Mountassir* and *Pytharouli* were appointed to academic positions from department postdoctoral posts in less than 3 years.

***Research Fellowships*:** CEE has hosted the following personal research fellowships:

- Zielinski was awarded an AXA Postdoctoral Fellowship (Jan-Dec 2010), an AXA Fellowship Extension (Jan-Jun 2011) and a Marie Curie International Outgoing Fellowship to the highly regarded Texas A&M University (Jul 2011-Jul 2014). Zielinski completed his PhD in 2010 under the supervision of *Sentenac*.
- *Gejadze* was awarded a NERC Advanced Fellowship in 2012. *Gejadze*'s success built on his previous 5-year GRPE-funded postdoctoral appointment. Research collaboration with the Department of Mathematics and Statistics is supported by a jointly funded and supervised PhD.
- *McKee* started a NERC Advanced Research Fellowship in 2007, and was appointed to a Senior Lectureship in 2011.
- Cordão Neto joined the department in 2007-2010 as a Marie Curie Incoming Individual Fellow, from Brazil. This collaboration contributed to the award of the GEO-EXCEL project, which funds geoengineering exchanges between Latin American and European Countries.
- We have held 6 other incoming and outgoing Marie Curie Fellowships: Karstunen, Patel, Rezania, Kamrat-Pietraszewska, Sivasithamparam, and Becker.

International staff and visiting scholars: Our staff have global backgrounds and conduct joint research with many international institutions. Out of 20 academic staff, 12 (61%) are non-UK nationals and 8 (40%) are non-EU nationals. Out of 76 outputs submitted to REF, 19 have EU co-authors and 30 have other overseas co-authors. Staff who have left the UoA have gone on to academic jobs in Africa, USA and the EU. Funded exchanges for staff and students to and from international research institutes have been an integral part of the EU consortia. For instance, Geo-Excel, an International Research Staff Exchange Scheme EC/FP7 project, involved secondments from 1 week to several months. 11 researchers from 4 Latin-American universities were seconded to Strathclyde, and 10 Strathclyde researchers (PhD students and senior staff) benefitted from secondments to Latin America. Two EC IAPP projects have funded several industrial secondments: *Karstunen* at Plaxis BV in the Netherlands, *Tarantino at Tecnopenta in Italy, Sentenac at GImpuls in Czech Republic El Mountassir* UMS GmbH, Munich *comprising a total of 10 months.* IAPP funded projects and the EC-Latin American European Exchange project have also supported a total of 42 months of incoming and outgoing staff, postdoctoral and PhD researcher secondments.

Equality and Diversity: CEE was awarded an Athena Swan Silver Award in Sept 2013 for our impressive equality and diversity track record and our inclusive culture that values all staff; we are one of only three civil engineering departments in the UK to hold a Silver award. We have the highest percentage (45%) of female academic staff of any UK civil engineering department, 43% of our research staff are female and 48% of PhD students. CEE also takes a wider view of supporting women in engineering: *Lunn* was invited onto a Royal Society of Edinburgh working group on Women in STEM, reporting to Government in April 2012. The report highlighted the loss of female graduates from the STEM employment sector and made wide-ranging recommendations to Scottish and UK Government, industry, funders and investors, universities, and learned and professional bodies. In 2013, *Lunn* was long-listed for a WISE Leader award for championing female talent in STEM (result announced Nov 2013).

Research students and training: CEE has seen a major upturn in PhD numbers, despite the challenging funding climate and competition from industry for talented graduates. PhD recruitment has increased every year since 2008/09: quadrupling from 5 new students in 2008/9 to 21 in 2013/14. Improved recruitment is reflected in the increase of awards in 2012/13. The overseas student population more than doubled from 14% in 2007/08 to 33% in 2013/14.

We believe in problem-driven research and aim to give our PhD students a thorough grounding in KE. In the last 5 years 25% of our students have had a component of industry funding (a total of £650k). We have significantly increased industry support for PhD studentships, with >£200k industrial PGR funding in 2012/13, including NERC CASE awards, EPSRC DTA funding, and projects 100% funded by industry (e.g. Total Oil, 2009-2012; Parsons Brinckerhoff x 2, 2012-2016). We are partners in the NERC Oil and Gas Doctoral Training Partnership (DTP) that has just been

announced (Nov 2013, first students starting Oct 2014). University and Faculty PhD scholarships are a key tool in encouraging industry engagement. For instance in 2012, 50% funding from the Faculty of two separate PhDs leveraged a further 50% plus project costs from Parsons Brinckerhoff and GeoChemico. Membership of the NERC Oil and Gas DTP was conditional on Faculty providing 50% funding to leverage the first three NERC studentships to Strathclyde. As of October 2013, PhD student funding is from: Research Councils 28%; University of Strathclyde 34%; Overseas Government 18%; Industry 14%; Self 5%; UK Charity 1%.

The increase in student numbers has been aided by a successful MRes programme and a dedicated PGR administrator. Our MRes programme, offered since 2008 in partnership with Parsons Brinckerhoff, supports academic research, and provides a route into PhD projects: 22% of our MRes students have moved into year 2 of a PhD. The success of collaborative MRes research over the last 5 years was instrumental in Parsons Brinckerhoff's decision in 2012 to support 2 full PhD scholarships and one MRes scholarship, including project costs. Our dedicated PGR Administrator (appointed 2008) provides support for marketing and recruitment through to graduation. Students are recruited via project advertising (CEE website and FindaPhD.com) or by applying directly to the Department. The administrator guides students through the application and registration process, particularly for overseas students. The administrator has developed promotional material for research degrees including updated webpages and course flyers. In 2009, we introduced more robust progress reviews: 6 monthly reports, with a major report due at the end of years 1 and 2 accompanied by a talk at the Department's annual research day, followed by a "viva-style" interview with a non-supervisor staff member on the panel. The aim of these reviews is to provide the most constructive guidance possible, to ensure that students consider their work is part of a vibrant department research culture, and to ensure the maximum completion rate.

Internal funding for conference travel is awarded by a committee of PhD students, chaired by the Research Director (*Shipton*), who peer-review applications and award funding. A dedicated PhD SharePoint site was set up in 2012 for students to share funding opportunity information, and PhDs have since secured national and international research awards, travel grants and BTG funding for interdisciplinary projects. These awards significantly enhance the CV of each student and gives them confidence and experience in proposal writing. International exchanges and research training have also been facilitated through GEO-INSTALL & GEO-EXCEL (section e), and industry sponsorship. CEE is a core member of ALERT Geomaterials, a European "School of Thinking" in the Mechanics of Geomaterials with 30 top European member universities (*Karstunen* is an elected Board Member). CEE PhD students regularly attend the ALERT Geomaterials annual conference and summer school, and Scottish Environmental Technology Network and Scottish Contaminated Land Forum annual conferences.

In 2013, the UK's first 60 credit Postgraduate Certificate in Researcher Professional Development, aligned to the Researcher Development Framework, was launched across the whole University (previously all Engineering PhDs were required to take 15 credits). The programme will enhance the career prospects of our doctoral students, ensure a high quality of research outputs, and support the PGR experience. All students present at the annual Faculty Research Presentation Day (held as a mini-conference arranged by the students) and the annual Departmental Research Presentation Day.

d. Income, infrastructure and facilities

Income: Research spend has more than doubled, from £516k in 2008-9 to over £1.1M in 20012/13. Industry income for research has also more than doubled to £412k in 2011/12. EPSRC spend is up from £108k to £426k and, reflecting the interdisciplinary nature of our Research Council grants portfolio, we have maintained annual NERC spend at over £160k. We anticipate research spend continuing to rise substantially, since new staff appointed during the REF period are highly research active and research spend associated with retiring staff was low. As a consequence, research spend per FTE is not yet reflective of our current staff profile. As an illustration of this, in the first quarter of 13/14 we have already been awarded £940k EU, EPSRC and NERC DTP funding.

Infrastructure and facilities: We have enjoyed significant investment in the Department's infrastructure during the last 5 years. At the start of the REF period, the Department's offices and

labs were housed within three separate buildings, with a legacy of *adhoc* expansion. In January 2014, staff, PDRAs and PhD students will relocated to purpose-built premises in the refurbished James Weir building (£10M university investment), providing an excellent growth platform for a fully integrated department. Staff have been fully involved in the design of facilities, which includes common space, meeting rooms and a dedicated Knowledge Exchange hub.

The Department's laboratories moved in June 2013 to new purpose-built space, representing a University investment of £6M. Staff were involved at all stages of the laboratory design resulting in a purpose-designed laboratory suite for our state-of-the-art research, which has already attracted commercial contracts. This move built on a period of significant laboratory investment. In 2009, a £300K SRIF bid was awarded (*Lunn*) for a new advanced geomechanics laboratory as part of the Faculty's £3M investment in the Advanced Materials Research Laboratory (AMRL). The AMRL includes scanning electron microscopy, mercury intrusion porosimetry, X-ray diffraction and atomic force microscopy. Relocation into the Weir building has also facilitated access to other co-located Department/Institute laboratories. In 2012, *Switzer* was part of a university-wide team awarded £71k BTG funding for an equipment-sharing initiative focussing on making equipment across the university accessible (through a database and booking system) and usable (through appropriate training and maintenance). The resulting ULAB management tool has subsequently been rolled out across the University facilitating CEE researchers' access to the full suite of University laboratories.

State-of-the-art laboratories are not only vital to underpin excellent research, but they contribute to attracting leading researchers into the Department. We have attracted outstanding staff by strategically winning matching funding for laboratory infrastructure investment prior to advertising a position. *Kalin*, *Knapp and Switzer* were supported by £1M of GRPE funding of state-of-the-art environmental analytical equipment (e.g. GC-GC TOFM and GC-IRMS). The award of the AMRL directly resulted in: the appointment of *Tarantino* to the Chair in Geomechanics (2010): the development of the successful proposal for a John Anderson Research Leadership Chair (JARL2) in Civil Engineering including £70k of University support funding for *Shipton*; and attracting a world-class material scientist *Hamilton,* with a £61k support package, including a £46k zetasizer for cross-Faculty use. In 2012, CEE was recipient of £40k of EPSRC small equipment funding as part of the University's grant to support ECRs (nanoseismic array, climatic chamber, etc.).

The Director for Labs (*Tarantino*) has oversight of all practical activities, supported by 7 laboratory and IT technicians. An academic convenes meetings of each laboratory's user group of staff, PhDs, PDRAs and technicians. A Business Development Officer with 20 years of industry experience was appointed in 2013 to provide expert technical support, and bring in commercial contracts to underpin continual future investment in the laboratories. The Department benefits from five well-equipped laboratory facilities:

Environmental Chemistry Laboratory contains a full suite of analytical equipment for the study of contaminants in soil, water and other matrices (containment-level 2). It was the first facility in the UK and is the only one in Scotland to provide stable isotopic & comprehensive two-dimensional GCxGC TOFMS analysis for environmental forensics & contaminated samples.

Microbiology Laboratory forms a nexus between environment, engineering and public health. The facility comprises containment-level 2 laboratories equipped to safely handle and analyse pathogens of concern in public health (e.g., viruses, Legionella and drug-resistant 'SuperBugs'). It provides a combination of microbiological and molecular genetic methods to recognise and understand the ecological role of microorganisms in the environment and engineered systems.

Geomechanics Laboratory focuses on micro-scale characterisation and testing at a range of scales. It has a particular strength in bespoke testing, and is one of only a few labs in the world to accurately measure negative pore-pressure (suction) in fine-grained materials using in-house designed high capacity tensiometers. The laboratory also has testing facilities for multiphase porous geomaterials, engineered barriers in geological disposal (part-funded by EPSRC), and nanoparticle-based technologies for concrete restoration and colloidal silica-based and microbial suspensions for grouting.

Constitutive and Numerical Modelling of Geomaterials features multi-user platforms for: advanced modelling of multiphase flow & elasto-plastic behaviour; state-of-the-art models for soils implemented in 2D & 3D; PLAXIS for advanced numerical analyses; COMSOL for finite element analyses of generic multi-physics based problems.

Field Investigation provides for field-scale monitoring of physical responses of materials: electrical resistivity tomography (*Sentenac*, new applications in soil cracking and water content), time domain reflectometry (local scale or diffuse), nanoseismics to monitor sub-surface deformation & flow (*Pytharouli*), and a profile probe (*Tarantino*).

Structures Laboratory features nanotechnology for sustainable built structures with cutting edge equipment for the design and manufacturing of wireless graphene and carbon nanotubes, and MEMS sensor systems to monitor the durability and integrity of civil infrastructure systems. The Structures Laboratory is also equipped with a strong floor and medium/large capacity actuators to conduct static and dynamic tests on large structures.

e. Collaboration and contribution to the discipline or research base

Multidisciplinary research is a key strategic aim of CEE and the University. One exemplar of the transformative nature of our multidisciplinary collaborative research is collaboration across the Energy and Material & Structural Performance themes on the geotechnics of decommissioning and disposal of radioactive waste. Our research has delivered novel approaches to the design of bentonite barriers, non-invasive monitoring technologies, new technologies for rock mass characterisation, and new geomicrobial technologies for fracture sealing in and around a geological disposal facility. During 2007-2010, *Lunn* and *Shipton* worked on the simultaneous evolution of seismicity and permeability within geological faults (NERC Standard Grant £408k, £180k to Glasgow University) in collaboration with Universidade Federal do Rio Grande do Norte, Brazil. This work opened up the possibility of non-invasive monitoring of potential geological disposal sites, and together with ongoing work on characterisation of the geosphere (e.g. Total Oil and Carnegie Trust-funded PhDs, and consultancy for Statoil) attracted the Nuclear Decommissioning Authority (NDA) to fund an EPSRC CASE PhD on fluid flow through connected sub-seismic features in mudstone (2008). The NDA subsequently supported two EPSRC consortia: Biogeochemical applications in nuclear decommissioning and waste disposal (BANDD, 2009-2013, £1.9M); and Systems Approach For Engineered Barriers (SAFE Barriers, 2012-2015, £1.3M) (50% NDA funding). BANDD, a consortium of 6 universities and the British Geological Survey (BGS), has involved the development of microbially-mediated mineral grouts as barriers to radionuclide migration, including the development of field and lab scale demonstrations. This has attracted interest from the wider geotechnical industry with pilot field trials now planned for 2015 with BAM Ritchie. SAFE Barriers, a consortium of 4 universities and the BGS, integrates cutting edge structural health monitoring technology and geotechnical engineering to manufacture “smart” bentonite bricks. The SAFE Barriers award was supported by 3 EPSRC DTG PhD studentships. The relationship with NDA has developed in the last 5 years from acting as a supporting partner in BANDD, to a 50% contribution and steering group membership for SAFE Barriers. NDA are currently facilitating access to overseas underground research laboratories, so that our group can conduct a controlled field trial. We have recently been awarded a £6M EPSRC project (DISTINCTIVE, October 2013) led by Leeds University, with £435k to CEE *(Lunn PI)* on design of novel low-viscosity grouts as hydraulic barriers, and monitoring and controlling deterioration of contaminated structures on decommissioning sites. This award is supported by 3 Faculty-funded PhDs and an NDA CASE award (2013). Monitoring research is also being applied to geothermal energy systems (*Pytharouli’s* EPSRC first grant) and carbon capture and storage (*Pytharouli, Lunn and Shipton’s* EPSRC UKCCSRC RAPID grant).

Intersectoral research is another strategic aim. One exemplar of our problem-driven research is *Karstunen* and *Tarantino’s* 'fundamental' research on experimental behaviour and modelling of soft soils and unsaturated soils that aims to capture thermo-hydro-mechanical-chemical processes at multiple scales. This was initiated by two major European Marie Curie Research Training Networks (MUSE 2004-2008, AMGISS 2004-2009) involving institutions from Norway, Finland, Austria, France, Italy, Spain, Germany, and Switzerland. The outcomes of the two collaborations attracted the interest of industrial partners, who had bought into the network’s dissemination activities, leading directly to 'applied' research projects via European Marie Curie Industry-Academia Partnership Pathways (IAPP) coordinated by the University of Strathclyde (Geo-Install 2009-2013 €1.25M, MAGIC 2013-1016 €1.85M) to transform research findings into commercial products and services (software, instruments, design approaches). This inter-sectoral research includes industrial partners from Germany, Netherlands, Norway, Italy, Austria and the Czech Republic. The

IAPP projects involved secondments of PhD students and ECRs and, therefore, have a long-term strategic value in terms of building an inter-sectoral culture. This has led directly to the industrial partners co-funding PhD projects (Ideal Standard International, Plaxis bv, Environment Agency, Geotechnical Observations Ltd, Autonomous Province of Bolzano). Industry is keen to invest in fundamental research with medium and long-term impact in recognition of CEE's capacity to convert research into more effective and cost-saving design.

Award-winning research: Staff in all 3 research themes have won prestigious awards. *Switzer* won the Combustion Engineering Association's 2009 Lord Ezra Award for Innovation in Combustion. *Shipton* won the Geological Society's 2010 William Smith fund for "excellence in contributions to applied and economic geoscience". *Lunn* was the first woman and first engineer to win the Geological Society's Aberconway Medal 2012, for "distinction in geology with special reference to work in industry". *Kalin,* NGRID and Parsons Brinckerhoff won the 2012 Brownfield Briefing award Best Scientific (or Verification) Advancement for "environmental forensic methods for characterisation of coal tars and coal tar contamination". *Lord* won an EC "Best of Life" award 2010 for his Life III Environment project "Biomass, Remediation, re-Generation: Re-using brownfield sites for renewable energy crops". *Karstunen* was invited to become a Fellow of the Institute of Civil Engineers in 2013. Staff have also won awards for research papers. *Knapp* authored one of the "Editor's choices" for best paper in Environmental Science & Technology, 2009. Pytharouli won 2008 best young researcher's paper at the 13th FIG Symposium on Deformation Measurements, and the Academy of Athens Lambadarios Prize 2009. *Shipton* co-authored the 2013 Tectonic Studies Group of the Geological Society of London, Ramsay Medal-winning paper (best paper arising from PhD research). *Sentenac* co-authored the 2012 Geometrics Scholarship award-winning paper (best research project in applied geophysics).

Contribution to the discipline: We have hosted major international conferences: for example, *Karstunen* ran the 2nd International Workshop of Geotechnics on Soft Soils in 2008 (3-day event) with 130 participants and published conference proceedings edited by Karstunen & Leoni. In 2010, Shipton convened a 3-day conference on "Stress Controls on Faulting, Fracturing and Igneous Intrusion" with 80 international participants; the conference papers were published by the Geological Society of London in 2012. We have given 8 plenary/keynote lectures at international conferences (*Tarantino*, *Lunn, Hamilton, Karstunen)* and *5* other invited talks at major international conferences (*Tarantino*, *Lunn, Pytharouli, Saafi, Shipton*). Members of the Department act as editors for 4 international journals and serve on the editorial board of 14 international journals. *Shipton* is chair of the Tectonic Studies Group of the Geological Society of London. *Lunn* is a ESPRC peer review college member, has sat on responsive mode funding panels and a Fellowship interview panel (2013). *Shipton* and *Knapp* are NERC peer review college members and participate in NERC standard grant panels. *Karstunen* acted as an expert evaluator for EC/FP7 Research Programmes (2010, 2013), and for the Swiss, Dutch and Austrian research councils. *Tarantino* has sat on panels for the Canada Foundation for Innovation and the National Sciences and Engineering Research Council of Canada. Staff have provided peer review for 11 other international research award-granting organisations.

Influence on national and international research agendas: Members of the Department hold positions on a number of influential Government advisory committees. *Lunn* has been the hydrogeologist on the UK Government Committee for Radioactive Waste Management since 2008, an independent scrutiny and advisory committee making recommendations, including on research and development, directly to the Department of Energy and Climate Change and Ministers. *Shipton* is an invited member of the Royal Society/Royal Academy of Engineering working group on Shale gas extraction in the UK, and the Scottish Government working group on unconventional oil and gas. *Keenan* is an invited member (since 2007) of the United Nations Group of Experts on the Scientific Aspects of Marine Environmental Protection and served until 2012 as Chair of Working Group 37, dealing with mercury and its compounds. *Keenan* has also acted as Vice-Chair of the Water Science Forum of the Royal Society of Chemistry since 2012. *Shipton* leads the Scottish Government Centre of Expertise on Climate Change workstrand on Perception and Communication of Risk and Uncertainty (£300k), providing research-based policy advice to Scottish Government on a call-down and horizon-scanning basis. *Kalin* advises Scottish Government on implementation of the climate change bill (2020 Group, to 2013) and water framework directive (HydroNation, 2013-present).