Institution: University of Sheffield

Unit of Assessment: 14 - Civil and Construction Engineering

a. OVERVIEW

Research in the Department of Civil and Structural Engineering (CSE) at the University of Sheffield takes place in three broad areas: *Structures, Ground* and *Water.* Researchers are encouraged to operate across disciplines, underpinning and enabling an interdisciplinary approach to research.

Since 2008 two major strategic developments have taken place: (i) significant growth in academic staff numbers, with an emphasis on new blood and vitality; and (ii) an on-going programme of laboratory infrastructure investment, upgrading and expansion. Our vibrant and effective research environment means that we have many fine achievements to celebrate, such as three EPSRC platform grants, a NERC consortium grant and two prestigious personal awards.

b. RESEARCH STRATEGY

Vision and Strategic Plans

The vision of CSE is to carry out and be known for internationally excellent research across the areas of *Structures*, *Ground* and *Water* engineering. We aim to lead interdisciplinary research which can make transformational change.

The strategy of CSE is to achieve: (i) a balance between fundamental and applied research; (ii) a balance between capitalising on existing strengths and exploring new areas; and (iii) greater interdisciplinary and collaborative research. This is in order to address the grand challenges of climate change (and the uncertainties it brings), population growth, resource demand and increasing urbanisation, and society's dependence on ageing and deteriorating infrastructure (and the need to maximise its sustainable future use and service delivery with minimal investment). These drivers span across and will influence our activity in all areas.

Over the next 5 years CSE will strategically target increased research activity in:

i. *Resilience and sustainability of civil infrastructure in the urban environment*, aligned to and influencing international, governmental and RCUK priorities. Research to help secure the services that a growing and increasingly urban society requires, including further integration of interdisciplinary research and collaborating locally, nationally and internationally.
ii. *Energy & sustainable building engineering,* including low-energy buildings, subsoil CO2 storage, green infrastructure, offshore geotechnics, and environmentally friendly construction materials, requiring interdisciplinary research activities. This activity will build on initiatives since 2009, including RAEng support, and is in response to the future needs of the profession and the wider community.
iii. *Geotechnical engineering and global soils*, taking full advantage of our investment in unique research facilities, reinforcing this crucial activity in the Department and linking it to activities in structural and environmental engineering, and in environmental and social science.

We will also target the following specific areas for enhancement:

iv. *Career and professional development* for all our research staff, recognising and valuing equality and diversity, to maintain healthy work life balance, and helping staff to develop either academic or industry careers.
v. Commitment to ensure that our research delivers *maximum impact* through both academic and non-academic channels.
vi. Upgrading and expansion of our *laboratory and other experimental infrastructure,* to clearly position ourselves with internationally unique and leading capabilities.

The above strategies drive our objectives for our research environment, which are reviewed annually and inform the staff review and development process. Specific objectives include:

- Develop and promote a vibrant research culture, and to enhance our international research reputation for excellence.
- Publish research work regularly in quality journals and otherwise maximise the impact and visibility of our research outputs.
- Encourage colleagues to develop cross-institutional and cross-disciplinary research links with world-leading research groups and individuals in the UK and other countries.

- Make credible and significant research grant applications regularly, enabling contributions to knowledge and to develop the research profiles of staff.
- Encourage the transfer of knowledge generated through research to practical use in industry and otherwise to maximise impact.
- Provide our postdoctoral researchers and research students with leading research facilities and supervision, as well as the opportunities to develop their profiles for successful careers.

Evaluation against RAE08 position and strategy

New appointments have been made across the career stages and research groups, taking the total pool of research-active academic staff from 28.7 in 2008 to 34.8 in 2013. We have invested £9.4 M from Departmental, Faculty and University funds in our research infrastructure (see Section d), including major new pipe research facilities, a new geotechnics centrifuge modelling centre and new facilities in the area of human-induced vibrations. We have helped foster the success of three EPSRC platform grant groups, including a unique third consecutive platform grant in urban water engineering research, one entirely new platform grant in structural vibration engineering, and the successful completion of the internationally renowned Ground Water Protection and Restoration Group's second platform grant. The Department has also developed and supported two new prestigious personal awards.

In our RAE08 submission we defined three areas of strategic emphasis:

i. *Increase wealth creation* (for stakeholders): We have developed broader and deeper links with industry, firstly with industrial funding and consultancy, representing 17% of our research-based income (see Section d), and secondly via impact, as described in the impact template and case studies.
ii. *Enhance researcher's career development:* We have helped our research staff progress to high level careers in industry, research and academia. For instance, since 2008 eight of our researchers have been appointed to lectureships in the Department, all through open competitive processes.
iii. *Expand interdisciplinary collaborations locally, nationally and internationally:* Leading examples of this are the EPSRC SUE2 £2.5 M URSULA project at the interface of engineering and social sciences, led by Lerner (http://ursula.group.shef.ac.uk/), and the EU FP7 €7 M SoilTrEC project with 16 partners in Europe, USA and China at the interface of geosciences and microbiology, led by Banwart (http://www.soiltrec.eu/).

In RAE08 we also identified four areas for increased breadth and activity:

i. *Socio-economic impacts and policies in Environmental Engineering:* this has been implemented through forging links with leading spin out companies such as SEAMS Ltd., secondments to DEFRA (Lerner), advisory roles in EA floods policy and to major infrastructure projects (Saul), and leadership of the Royal Society of Chemistry industry KT event on sustainable soils for agriculture (Banwart).
ii. *Interactions between biological and physical systems in water supply and sewer systems:* here we have enabled internationally leading research funded by industry, EU and EPSRC, including a prestigious EPSRC Challenging Engineering award and new facilities.
iii. *Extension of our capabilities in Vibration Engineering:* has been underpinned by a platform grant award, staff appointments, a doubling of lab space and diversification of activities.
iv. *Extension of our capabilities in Earthquake Engineering:* this has been achieved primarily through recruitment of new staff with expertise in this area (e.g. Hajirasouliha).

Position review and strategic vision statements for each of the three research groups

Structures. Existing strengths are in computational mechanics, structural fire engineering, blast and impact, and concrete engineering. Since 2008 the structures group has developed expertise in the field of fatigue and fracture mechanics and instigated new research in sustainable building engineering. We have diversified our activities in the field of vibration engineering to encompass human-induced vibrations, and new appointments have brought new impetus to earthquake engineering research. In the future the group will further strengthen its expertise in structural dynamics and the exciting new sustainable building engineering research theme will be fostered into a world leading position, including new staff appointments. We plan to lead in the development of new materials and reinforcement techniques for concrete structures.

Ground. Existing strengths are in groundwater protection and restoration and in geotechnical

engineering. Newly founded in 2008, the Cell-Mineral Research Centre has been highly successful in developing environmental engineering science in chemistry and biology and applications to soil and land use. The Catchment Science Centre (established jointly with the Environment Agency) has conducted novel science to underpin sustainable management to deliver good ecological quality in surface waters. In the future we will take forward a vision to be a leading centre of excellence for physical modelling (including major infrastructure investment) and to work across the geotechnical / soil science / soil interfaces. Key emerging themes will be energy-related research areas (thermal piles, offshore renewables, offshore oil / gas / transmission) and resilient infrastructure (landslide mitigation, blast effects, and climate effects on soil strength).

Water. Existing strength is evident through the achievements and activities of the third platform grant-supported Pennine Water Group (PWG), an interdisciplinary group led from the Department. Since 2008 the group has undertaken highly innovative research encompassing the interactions between biological and physical systems, green infrastructure and in fundamental fluid mechanics. The group's evolving vision for the future requires a transition to 'Sustainable Integrated Urban Water Systems' that moves beyond asset management to a broader system definition. We will also maintain the balance of our activities between applied and fundamental research, underpinned by our staffing strategy.

c. PEOPLE

Staffing strategy

In the future we will: (i) expand numbers of internationally excellent research staff; (ii) maintain a spread of career stages, both overall and within each group; and (iii) ensure there is critical mass in every research area that we target, with a balance between applied and fundamental research.

The staffing strategy since 2008 has been for growth, new blood and vitality. Appointments have been made across the career stages and research groups, taking the total pool of returned academic staff from 28.7 in 2008 to 34.8 in 2013. Since 2008, 12 academics have left the Department, including 5 retirements. We have recruited 18 new academics, including 12 early career and 4 international appointments. Our recruitment strategy has created a balanced, sustainable profile overall: 9.8 Professors, 2 Readers, 6 Senior Lecturers and 17 Lecturers.

The Faculty and University's strategy to create the biggest interdisciplinary urban water research group in the UK saw the appointment of six academics across three departments and two faculties (three appointments in CSE). This strategic growth was accelerated by capacity created following the move of three senior members of our vibration engineering research group to the University of Exeter in spring 2013, after 20 years of headline achievements at the University of Sheffield.

Structures (5 Professors, 1 Reader, 1 Senior Lecturer and 7 Lecturers): To underpin the strategic expansion into the area of fatigue and fracture mechanics, the international appointment of Susmel to a Chair was made. We have appointed Becque (international) and S.S. Huang (early career researcher, ECR) to strengthen our research in structural steel and fire engineering. In response to our strategy for sustainable building engineering, Hathway was appointed (ECR) and we have just appointed an industry-focussed chair. We have also diversified our activities in dynamics with appointments of Racic (ECR) in human-induced vibrations and Hajirasouliha (external, ECR) in earthquake engineering.

Ground (2 Professors, 1 Reader, 3 Senior Lecturers and 4 Lecturers): Driven by our strategy for new blood, vitality and infrastructure growth, we have appointed Menon (external, ECR) for interdisciplinary research in soil microbiology, Clarke (ECR) for modelling expertise, and Bowman (international) and Black (external, ECR) for excellence in experimental geotechnics, coupled with current infrastructure investment in a state-of-the-art centrifuge centre (see Section d). Our strategy for growth will be continued through the appointment of a new Senior Lecturer in ground water engineering starting in summer 2014.

Water (3 Professors, 3 Senior Lecturers and 5 Lecturers): Significant growth, driven by our strategy to balance fundamental and applied research, has taken place. Appointments have been made to facilitate the development of numerical modelling excellence, Keylock (external), Shao (external) and Kesserwani (external, ECR) and to reinvigorate our experimental hydraulics research, Tait (external), Shucksmith (ECR) and Brevis (international, ECR). Our applied water research activities, where we are world leading, have been grown through the recruitment of

Schellart (external, ECR) and Collins (ECR).

To support our research activities we have also had an active programme of expansion in our administrative support staff (15 total, excluding those dedicated to teaching only matters) and technical support staff (14 total), with net growth of over 30 % since 2008. Notable new roles, with direct positive strategic impact on our research environment, have included a research finance officer, an electronics and instrumentation officer, a business development manager, and research operations and/or clerical support to each research group. Additionally, CSE benefits from 9 FTE research support staff in the Faculty of Engineering Research & Innovation Hub. This hub has an annual budget of £0.8 M to raise awareness of developments in the research-funding and industrial-funding landscapes, and to develop external partnerships and funding proposals; this resource allows CSE academic staff to focus on the quality and sustainability of their research.

Staff Development

Probation and induction: We use a 3-year probation period for each new lecturer, for which ambitious targets are set. We support all our new staff through reduced teaching and administration load (especially for probationary lecturers), and we provide generous start-up packages (discretionary funds, fee waivers, laboratory/equipment funds, etc). DTA allocations are prioritised for new lecturers. Following our strategy for new blood we have had a particular focus and programme of mentoring and support to nurture the talent and promise of our new academics. Success is evident here with 8 out of 9 EPSRC First Grant submissions successful since 2008.

Annual review and mentoring: The performance of all staff is reviewed annually, with targets discussed and set with respect to our overall research strategy. Research targets include numbers of publications, target journals, conferences and research income. Performance is reviewed and feeds directly into promotions, exceptional contribution awards and workload allocation. Sabbaticals are planned and encouraged to enable staff to deliver exceptional contributions (e.g. bringing the Computing and Control for the Water Industry conference to Sheffield for the first time - Boxall). All probationary lecturers are formally assigned a senior colleague to act as a mentor; these are selected to have complementary skills and expertise, and are normally from a different research sub-group. Our success with EPSRC First Grants is testimony to the effectiveness of this.

Workload management: A formal workload allocation model is used to moderate duties across CSE, recognising individual strengths and career ambitions, and providing our research leaders with reduced administration loads to focus on strategic initiatives. We support academics who are targeting particular calls for prestigious grants by making sabbatical-like arrangements. For example, Banwart when leading a prestigious SCOPE international rapid assessment process project. Twice a year we run a ‘red lining week’, where all staff are encouraged to work exclusively on research and all other administration and teaching activities are suspended.

Personal Research Fellowship and similar: The Department has achieved success in the following prestigious open and competitive schemes: EPSRC Leadership Fellowship and EPSRC Challenging Engineering. We also attracted a Faculty Prize Senior Lecturer to join CSE and two prestigious EPSRC Advanced Research Fellowships were completed since 2008.

Promotion: Recognising and promoting excellence is a key part of our research strategy and we are committed to rewarding and supporting all staff. Promotion cases are typically identified through our annual staff review and development process; this is also supported by active involvement of the Head of Department who targets and provides encouragement to the more modest academics (of whom women are a disproportionately large subset); staff are also able to self-submit. During the period, three staff were promoted from SL to Professor, two staff were promoted to Reader, and two staff were promoted to Senior Lecturer.

Research staff: In 2012 the University was awarded the HR Excellence in Research award from the European Commission and we remain committed to applying the seven principles of the UK Concordat for the Career Development of Researchers. Our research staff on fixed-term contracts have the same opportunities as all staff to undertake development, and undergo the same annual review process. Key successful researchers and experimental officers are recognised and awarded open ended research contracts; seven of these are currently in place, underwritten by the Department. A research staff society is in place in the Faculty of Engineering, the Engineering Researcher Society (ERS). The chair, secretary, treasurer and communications officer (focussing on international researchers & inclusion) are all researchers from CSE. ERS provides a voice for

all early career researchers across engineering, offers development opportunities (including mentoring) and promotes a community for networking. CSE research staff are represented on the University's standing group for research staff (which oversees the University's approach to enhancing provision for research staff). In addition, the 'Think Ahead' framework for research staff includes professional development, career training programmes and researcher mentoring.

Equality and Diversity

Equality: In September 2013, CSE was the recipient of an Athena Swan Bronze Award. The Department intends to seek a Silver Award by September 2014. As part of this process we have developed a comprehensive Action Plan that includes challenging but realistic targets for increasing the number of female academics and students in the Department. Actions include: ensuring a balance of male and females on decision-making committees; unconscious bias training for all staff involved with recruitment; and ensuring flexible working is highlighted and supported across the Department. The number of submitted female academics stands at 6 (up from 2 in our RAE08 submission).

Diversity: We pride ourselves in being an ethnically diverse Department. Of our 35 submitted individuals, 18 are from the UK, 7 from Europe and 10 from the rest of the World (in 2008 these figures were 18, 6 and 6, respectively). This has been achieved without pursuing particular targets. We guarantee an interview for all individuals who disclose a disability and who meet the essential criteria for the role.

Research students

As presented in REF4a, 76 PhD awards have been made over the assessment period; this is in spite of our large programme of staff renewal and rejuvenation. Of these completions 9 were supported by highly competitive Faculty/University scholarships. In recognition of their excellence, two of our PhD students were awarded EPSRC Doctoral Prize Fellowships (Bridge and Langford), to enable them to initiate independent research careers.

Recruitment: Our student recruitment strategy focuses on giving academics the responsibility and freedom to attract exceptionally talented individuals. We do not set quantitative targets.

Supervision and progress monitoring: Each student has two supervisors and is required to meet formally with them at least monthly. Between 9 and 15 months we have a formal examination process consisting of the submission of a progress report and a viva with two examiners.

Training: Sheffield has pioneered an innovative approach to doctoral training, noted positively by the QAA. An individual 'training needs analysis' is used to design a bespoke training programme, focussing not only on research skills but also on future employability in the research area or beyond. This is then used as a tailored, on-going, CPD plan that is an integral part of our research degrees. The Department initiated a PhD student conference in 2011; this was successful and is now an annual event. Many other research group led activities (presentations, paper groups, social activities) also supplement the scholarly atmosphere within the Department.

Ethics and Integrity: Amongst the Russell Group the University of Sheffield is a leader in fostering research ethics and integrity that places good academic practice (rigour, respect and responsibility) at its core. We operate within and actively contribute to sustaining the University's research ethics and integrity framework, which applies to all research-active staff and students.

Facilities and support: Support funds are allocated to and managed by research groups to pay for conference attendance, travel, computers, software, etc. Students are made to feel valued and respected as part of an inclusive environment, and we organise regular social occasions (including a monthly coffee and cakes event for all staff and PhD students).

Following our active and successful programme of support and development for research students, these individuals often go on to become RAs, lecturers and beyond. Overall we provide the best possible PhD journey for the students as they progress from student to colleague, in line with the University of Sheffield's 'Research Student Proposition', praised by the QAA.

d. INCOME, INFRASTRUCTURE AND FACILITIES

CSE operates within the wider Faculty of Engineering. The Faculty now has the second highest engineering research income in the UK (2011/12 HESA; Times Higher Education 13-19 June, 2013), with turnover increased by 35% from £77.8 M in 2008/9 to £105 M in 20012/13. Since

2008/9 the Faculty has spent or committed £34.4 M of its resources to support research, in addition to a £154 M building programme. The latter includes a new Engineering Graduate School (£21 M), a new Engineering Teaching Building (£81 M) and a refurbishment programme for the existing estate (£53 M, 12,000 m^3).

The Department's annual turnover has increased by 24% from £10.6 M in 2008/9 to £13.1 M in 2012/13. We have invested £3.0 M of core funds in support of research: £0.6 M on PGR scholarships and maintenance; £0.6 M on research equipment; £0.1 M to support conference attendance; £1.7 M creation of reserves to support on-going investment in infrastructure and laboratory equipment over the next five years. In addition, the Department has benefitted from a total £6.4 M of Faculty resources to support strategic initiatives which, for example, funded the start-up cost of the relocation of members of the PWG from Bradford.

Income

Overall research income attributable to CSE since 2008 is £14.5 M (as presented in REF4b), and our consultancy income is £0.9 M, leading to a total income of £15.4 M. The three main sources of this total income are RCUK (56%; predominantly EPSRC and NERC), EU government (21%) and industry (17%) – such diversity is evident in all the individual research groups. This diversity provides resilience in an ever-changing funding landscape, enabling us to deliver and carry out the research that we have identified as being strategically important, and to maintain research activities which range from the theoretical to the applied.

Our ambition is: (i) to maintain a balanced income portfolio that will support and drive forward leading international research, both fundamental and applied; and (ii) to grow the volume of income in proportion to our increased staff numbers. An important mechanism in stimulating and supporting research income within the Department is the reinvestment of 25% of the departmental overheads associated with research grants (i.e. in associated studentship(s), higher risk added-value activities, equipment, etc.); this is evidenced in letters of support provided by the Head of Department. Between 2001 and 2007 (RAE08 period) our annual research income grew from just under £1 M to nearly £2.6 M. Since 2008 our annual research income has increased and been maintained at approximately £3 M – this has been achieved in spite of staff changes and in the context of the strategic recruitment of a large number of ECRs. We have made supporting and mentoring our new academics seeking EPSRC First Grant awards a priority; this has resulted in 8 out of 9 submissions being successful, as was reported in Section c. This early career success sets the standard and expectation for individuals and for the Department as a whole, and positions us to achieve further growth and excellence in the future.

All academic staff are also encouraged to undertake consultancy, where benefits accrue to research, reputation and impact. Most staff are active at some level, and total consultancy income since 2008 is £0.9 M across 86 different projects (see Impact Template for further details).

Infrastructure and Facilities

The new Faculty of Engineering Teaching Building will free up space in our existing buildings for new research laboratories, helping to facilitate our strategy for laboratory upgrade, renewal and expansion. Thus our existing specialist laboratories will be refurbished, expanded and dedicated to research. Notably, this will include complete modernisation of our Heavy Structures Laboratory. CSE has invested in our research infrastructure (including people), matching our expansion in staff numbers and activity. We have also expanded our strong associations with industry, providing vital access and facilities for field validation.

Structures

Existing specialist facilities: We have well equipped structural engineering research laboratories for the mechanical testing of materials and structures. Our specialist equipment is focused on extreme loading conditions, including an internationally unique apparatus to carry out multi-axial compression at elevated temperatures and equipment to test the mechanical behaviour of steel connections under fire conditions. Furthermore, CSE has off-site laboratories at Harpur Hill with a wide range of facilities for blast, explosion and impact testing.

Investment in specialist infrastructure: New facilities that underpin our expansion into human-induced vibrations include a motion-capture treadmill (EPSRC funded) and a grandstand simulator (CSE funded). The operation of the Harpur Hill laboratories is now underpinned by an experimental

officer and a dedicated research technician (underwritten by CSE), whilst new facilities (an impulse measurement device funded by DSTL and on-site ammunition storage funded by CSE) have increased capacity, capability and efficiency.

Ongoing investment: We have recently embarked on a £2.4 M investment programme, funded by the University, for refurbishing our Heavy Structures Laboratory, which includes upgrading our facilities in concrete technology, testing steel joint robustness under elevated temperatures, fatigue testing and the mechanical testing of scaled concrete structural systems.

Ground

Existing specialist facilities: We have well equipped state-of-the-art geotechnical engineering experimental facilities. In the Kroto Research Institute we also have outstanding specialist environmental engineering laboratories facilities, including: inductively coupled plasma mass spectrometry, Raman and infrared microspectroscopy as well as gas chromatography mass spectrometry.

Investment in specialist infrastructure: Two Experimental Officers have been recruited on open-ended contracts, underwritten by the Department, to maximise the effective operation of our environmental engineering science research facilities.

Ongoing investment: Our strategy led us to invest £0.3 M of core budget to establish a Centrifuge Centre, for operation of up to 3 new centrifuges including technician support and associated space, including a new 4.0 m diameter centrifuge. The centre has already attracted funding from EPSRC (capital bid of £0.75 M) and industry.

Water

Existing specialist equipment: Our extensive and well equipped hydraulic laboratories include five open channel flumes (up to 17 m in length and 1.2 m wide), green roof facilities, a commercially funded full scale siphonic roof drainage facility, and state-of-the-art measurement equipment including Particle Image Velocimetry, Laser Doppler Anemometry and Laser Induced Fluorescence.

Investment has been made in new space to house new experimental facilities at the interface between biological and physical systems. We have invested in a 600 m long full scale, temperature controlled, potable water quality pipe test facility with funding from the University and industry. A 150 m long, full scale, dynamic leakage test facility has also been developed with funding from EPSRC and industry. A one-sixth scale flooding model has been established with Flood Risk Management (EPSRC, EA, UKWIR funded) and University funding. This is matched with a full scale facility for studying road gully performance.

Ongoing investment: We are investing in a 2 m diameter annular flume facility to be housed in a class 2 environmentally controlled laboratory; this collaborative facility with the Department of Chemical and Biological Engineering has been wholly funded by the University. A further £0.5 M has been allocated following the uniting of PWG to the University of Sheffield, which will be used for a new full scale, straight sewer pipe simulator and further upgrade of our instrumentation.

e. COLLABORATION OR CONTRIBUTION TO THE DISCIPLINE OR RESEARCH BASE

Collaborative and interdisciplinary research

Collaborative and interdisciplinary research is actively promoted at the University of Sheffield by the formation of research centres that span multiple faculties and departments. These centres are intrinsically interdisciplinary, have external collaboration and funding, and are recognised internationally for their high quality research. CSE currently hosts the Centre for Cement and Concrete, the Catchment Science Centre, the Cell-Mineral Research Centre and is an active member of the Green Roof Centre and the Kroto Research Institute. CSE is also the home of the Pennine Water Group, which is the largest interdisciplinary urban water research group in the UK, spanning engineering, physical and social sciences.

During the period, there have been numerous examples of national and international collaborations. We have active funded research collaborations with 64 universities and research institutes (34 UK, 18 European, 12 other countries) as well as 75 companies (such as Atkins, Costain Ltd and Shell Global Solutions). CSE carried out research which spanned across the Faculties of Engineering, Science and Social Science. Examples of collaborative and/or

interdisciplinary research projects are provided below:

- The concrete research group is currently leading the EU COST (research coordination) action TU 1207 on 'Next Generation Design Guidelines for Structural Composite Reinforcements in Construction' with 24 partner countries. In this same field the group is also co-convening the International Federation of Concrete task group TG9.3, comprising 50 international experts, has coordinated a series of three EU Marie Curie Networks (the latest of which 'Endure', has 14 partners from 12 countries) and has coordinated a series of International Round Robin Tests, with 23 laboratory and 12 industry partners.
- The Catchment Science Centre led the EPSRC-funded, £2.5 M, URSULA consortium to research the design of urban river corridors, integrating city planning, flood and water quality management and socio-economic issues. As well as 5 academics from CSE, the project had co-investigators from 6 other departments in the Engineering, Social Science and Science Faculties, and had the Environment Agency, Sheffield City Council and several consultancies and NGOs as external partners.
- The Pennine Water Research Group carried out several collaborative and interdisciplinary EU projects, such as: 'Flood Resilient City' (total funding €14.2 M, 11 academic and industrial partners from 6 countries); 'Managing Adaptive Responses to Changing Flood Risk' (total funding €4.4 M, 15 academic and industrial partners from 4 countries); 'Skills Integration and New Technology' (total funding €4 M, 7 academic and industrial partners from 4 countries).

How research collaborations have informed research activities and strategy

CSE has aligned its research strategy with national, regional and European government priorities in several areas. Research programmes have been shaped to support the strategies of the former local regional development authority (Yorkshire Forward), the Environmental Agency and the EU in particular. We are also heavily engaged in research tackling major UK and EU priorities such as sustainability, energy reduction and water for all. Three examples of end user collaboration informing our future research strategy as set out in section b are:

Resilience and sustainability of civil infrastructure: The PWG holds biannual meetings of an industrial advisory board that is chaired by and includes R&D managers of the leading water companies (including Yorkshire Water, Anglian Water, and United Utilities) and consultants (including the Water Research Company).

Energy & Sustainable Building Engineering: This is a prime example of our research strategy being informed by industrial collaboration – in this case developed in collaboration with major industrial partners and the RAEng. It was initially guided by the appointment of Johnston (founder of Cundall Johnston & Ptnrs) as Visiting Professor with funding from the RAEng, followed by the appointment of Mayfield (Arup) as Visiting Professor one day a week through flexible core funding from the Faculty, to be appointed as full time Professor of Sustainable Building Engineering in late 2013.

Geotechnical Engineering (linking to activities in Structures): Our blast and impact research activities based around facilities at Harpur Hill are aligned to the needs and questions of the Ministry of Defence and in particular the Defence Science Technology Laboratory. Notable recent developments have been a geotechnics led EPSRC First Grant and DSTL funded research with spin out company Blastech, both exploring the interaction of buried explosives with the ground.

Leadership in the academic community

All staff are active in leadership activities at a national level on a regular and on-going basis. Many staff are active internationally, setting research agendas and defining the grand challenges of the future. The following sections provide summary figures and key examples, indicating the breadth and depth of our leadership activities.

I. ***Leadership roles in advisory boards, industry, commerce, research councils, learned societies or professional bodies*** - 19 staff have been members/chairs/leaders of 40 councils and boards or committees of professional institutions. Examples include
   - *RCUK:* Chair of the steering committee for the NERC Facility for Environmental Nanomaterials Analysis and Characterisation (Banwart); invited member of EPSRC Water Advisory Group (Boxall).
   - *Governmental:* DEFRA Water Quality Professional Advisory Group member (Lerner).
   - *Industry*: member of the Steel Construction Institute's Advisory Council (Davison); external advisor for CONCAWE - EU Oil Companies Organisation (Thornton).

- *Policy:* Drafting EA/DEFRA policy of defuse urban pollution (Lerner).
- *Learned Societies:* Co-convener of fib TG9.3 (Pilakoutas).
- *Professional Bodies*: Secretary, European Assoc. Geochemistry, 2008-2011 (Banwart).

II. ***Conference organisation and programme chairs*** - 11 staff participated in the organisation of 29 international and national conferences, workshops or seminars. Examples of leading conference organisation are:
- *Sheffield 2009:* 10th Int. Conf. Computing and Control in the Water Industry (Boxall);
- *Gaeta, Italy 2012*: 4th Int. Conf. Crack Paths (Susmel);
- *Ispra, Italy 2013:* SCOPE Int. Workshop on Benefits of Soil Carbon (Banwart);
- *Prague, Czech Republic 2013*: 7th Int. Conf. Fibre Concrete (Pilakoutas);
- *Sheffield 2013*: 7th Int. Conf. Sewer Processes and Networks (Saul, Tait).

In addition, 20 staff acted as members of technical committees or chairman of over 90 conferences.

III. ***Invited keynote lectures and presentations*** - Over 370 invited keynote lectures and invited seminars were given at professional bodies, interest and trade associations, companies, universities, as well as at a vast number of conferences, seminars and workshops. Examples of keynote lectures include:
- *Rio de Janeiro, Brazil 2010:* 'The effect of edge support on tensile membrane action of composite slabs in fire', 3rd Int. Coll. Stability and Ductility of Steel Structures (Burgess);
- *Paris, France 2012:* 'Sustaining Soil at the Heart of Earth's Critical Zone', French Academy of Sciences (Banwart);
- *Perugia, Italy 2013:* 'What's in the Pipe Line?', 12th Int. Conf. Computing and Control in the Water Industry (Boxall).

Examples of invited seminars at prestigious universities and societies include:
- *Oxford University 2010:* 'Inertia penalties in computational dynamics' (Askes);
- *Japanese Geotechnical Society, Tokyo 2010:* 'Visualisation in geotechnical physical modelling research' (Black);
- *Columbia University, New York 2011*: 'Recent developments in limit analysis and limit state design of reinforced soil' (Gilbert).
- *Tsinghua University, China 2012:* 'Robustness of Composite Multi-Storey Buildings in Fire' (Burgess).

IV. ***Fellowship or membership of learned societies*** - 17 staff are fellows or members of 13 learned societies. Examples of fellowships are: Royal Academy of Engineering (Lerner) Geological Society (Lerner, Thornton) and Institution of Civil Engineers (Lerner, Saul).

V. ***Journal editorships and editorial board membership*** - 15 staff have fulfilled editorial roles, 12 have been guest editors, and 8 are members of the editorial boards of 28 different journals. Examples include Editor in Chief, Theoretical and Applied Fracture Mechanics (Susmel); Associate Editor of Ground Water (Thornton); Associate Editor of Drinking Water Engineering and Science (Boxall).

VI. ***Externally funded fellowships*** - EPSRC Advanced Research Fellowship (Gilbert, 2004-9, Pavic 2004-9); EPSRC Challenging Engineering (Boxall 2009-14); EPSRC Leadership Fellowship (Reynolds 2011-2016).

VII. ***Awards, prizes and honours*** - Examples include: IStructE Henry Adams Awards (Burgess, Davison); ICE Telford Premium Prize (Bowman); Water Industry Achievements Award, IWEX University Challenge Award (Boxall); Sensors for Water Interest Group Early Career Researchers Prize (Shucksmith); DEng degree (Askes).

VIII. ***Visiting professorships*** – Examples include Aalto University, Finland (Askes); Universitat Politecnica de Catalunya, Spain (Askes); Tun Hussein Onn University, Malaysia (Burgess); Chinese Academy of Science, Beijing Genomics Institute (W Huang); Beijing Normal University (Thornton); Peking University, (Lerner).

The ethos and environment that we create within CSE is focussed on people, providing the opportunity, culture and platform for our researchers to maximise their potential and deliver research excellence for themselves, the Department and the wider University. Thus we will continue and expand our position of international research excellence, delivering on our overall research vision and strategy.