Institution: University of Strathclyde
Unit of Assessment: 14 Civil and Construction Engineering
a. Context

Our Unit's key strength is our inter-disciplinary and multi-disciplinary applied research, blending aspects of engineering geoscience with environmental engineering and science. Our research is organised into 3 industrial challenge themes, each relevant to the Royal Academy of Engineering's (RAE) "grand challenges" and with specific audiences and user groups:

- **Energy:** Geological disposal of radioactive waste, CO_2 storage, shale gas, geothermal energy and hydrocarbon exploitation (*impacting: the economy, society*, *public policy, practitioners*).
- **Environment & Health:** Environmental engineering solutions for resilience, contaminated land, water and soil, eco-toxic or persistent organic pollutants, sustainable remediation, bioremediation, phytoremediation, and sustainability (*impacting: business, environment, health, society*).
- **Material & Structural Performance:** Geotechnical engineering**,** sustainable structures, structural health and performance in fire, water engineering, and transport (*impacting: professional practice*).

Thus our research has reach, significance and impacts on and beyond business and the economy, extending into areas such as health (e.g. water & sanitation), public policy (e.g. radioactive waste disposal safety), society (e.g. informing the shale gas debate) and the environment (e.g. soil remediation), as our case studies and members' publications demonstrate. This capability and approach to engineering in its broadest sense is echoed in our decision in 2012 to include Environmental Engineering in the Department's name.

b. Approach to impact

Our unit's challenge-led research strategy and commitment to useful learning and international technological development follows 4 priority activities to ensure impact:

(1) Industry-driven, technologically-focused, applied and directed research which is informed and disseminated by Knowledge Exchange (KE). All unit staff conduct applied research for industry or Government to some extent. We share the ambition to be "a leading international technological University" and we follow the "Triple Helix" innovation approach of a symbiotic University-Industry-Government partnership (a theme of the David Livingstone Centre for Sustainability). So, our research has intrinsic links to end-users enabling impacts within the economy, policy and society (e.g. by our Energy "challenge" theme activities above), and impacts on the environment and health derived from the emphasis on environmental engineering. Our research is underpinned by a commitment to KE as a facilitation mechanism to achieve research impacts with reach and significance (see Strategy and Plans). Our ambition is for seamless integration of research and enterprise, with user-driven research and research-led KE activity. In this regard, our researchers are expected and encouraged to engage fully with business-facing activities (e.g. through appraisal of KE activities and by internal funding to stimulate KE).

The Technology Strategy Board's (TSB) Knowledge Transfer Programme (KTP), the benchmark standard for industry engagement, is used extensively to facilitate KE from our research: Strathclyde is consistently in the top five in the UK in terms of the number of KTP awards, led by the Engineering Faculty and the West of Scotland KTP Centre (hosted by the University). Our departmental approach is to follow this institutional lead, using KTPs to embed activity resulting from the application of our Unit's research with our industrial partners. Successful KTP partnerships (*Lord*) concern navigational dredged sediments (with Scottish Canals) and (previously) reuse of water treatment residues (with Northumbrian Water).

A clear strength is the extent of industrial investment and involvement in our PhD studentships, into which the Department, Faculty and University have co-invested strongly. This provides an excellent interface for KE activity and indirect impacts. Examples are: CASE awards - Midland Valley Exploration (*Shipton*), Nuclear Decommissioning Authority (*Lunn & Shipton*); Industry funding and co-funding of PhDs - Total Oil (*Shipton & Lunn*), Plaxis BV (*Karstunen*), Geochemico/Chesser Gold (*Shipton and Lord*), Ideal Standard International and 2H Offshore Engineering Ltd (*Tarantino*), and Parsons Brinckerhoff (*Kalin*).

At postdoctoral level the Unit holds two Marie Curie Industry-Academia Partnerships and Pathways (IAPP) consortium projects (each funded 50:50 by the EU and by industry): "Monitoring systems to Assess Geotechnical Infrastructure subjected to Climatic hazards (MAGIC), total value €1.85M (*Tarantino & Sentenac*, leaders); and the €230K Creep of Geomaterials (CREEP) project (*Karstunen*).

Consultancy is encouraged and the Department regularly hosts meetings from stakeholder groups, (e.g. Scottish Contaminated Land Forum, Chartered Institute of Water & Environmental Management, Scottish Geotechnical Group, Scottish Geological Society).

(2) Interdisciplinary and multidisciplinary disruptive research which is novel in scope and methodology. This approach has produced wide ranging impacts, with examples in each impact domain considered for REF, including those on:

- *Businesses and economics* – e.g. ***Karstunen's*** novel constitutive models for soft clays used as subroutines for Plaxis (http://www.plaxis.nl/), the most widely used and powerful commercial geotechnical finite element code (over 9000 licenses worldwide).
- *Public policy and service* – e.g. ***Keenan's*** research on emerging pollution issues (including persistent organic pollutants and mercury), through membership of United Nations GESAMP (Group of Experts on the Scientific Aspects of Marine Environmental Protection) since 2007, Chair of Working Group 37 on Hg, UN Industrial Development Organisation (UNIDO) and UN Environment Programme (UNEP) practical training on the Stockholm Convention.
- *Society, culture & creativity* – e.g. ***Lunn's*** research expertise resulting in membership of the Committee on Radioactive Waste Management (CoRWM, since 2008), and ***Shipton's*** research on fluid flow and faults contributing to the Royal Society & RAE's working group on shale gas extraction (from Feb 2012), informing public opinion and debate on key engineering issues.
- *Health* – e.g. ***Morse's*** application of Strathclyde's worldwide laboratory method for cryptosporidium detection, crucial to on-going public health and education initiatives to reduce diarrhoeal disease through the Scotland Chikhwawa Health Initiative (from 2006 on) and Strathclyde's Malawi Millennium Project.
- *Practitioners & professional services* – e.g. ***Tanyimboh's*** pressure dependent analysis of water networks developing an approach and function to improve the US EPA's benchmark EPANET software (2012 onwards), which is currently used worldwide by the water industry.
- *The environment* – e.g. ***Switzer's*** continuing research on smouldering remediation for the treatment of soils and materials contaminated with hazardous organic liquids (Self-Sustaining Treatment for Active Remediation – STAR) has supported technology development and field applications in the USA, Canada, Europe, and Australia. Research at Strathclyde is assisting the transition of STAR from the laboratory to the field by SiREM under licence from the patent holders since commercial launch in 2010.

(3) Setting national and international agendas through participation in expert panels

Staff are actively encouraged and supported to join external panels and expert bodies, resulting in national and international influences on policy, legislation and society e.g. *Lunn* (CoRWM), *Shipton* (Shale Gas Extraction Working Group), *Keenan* (UNEP/UNIDO/GESAMP), *Kalin* (Hydro Nation), *Shipton* (ClimateXChange).

(4) Internationally-facing research, especially in Malawi and sub-Saharan Africa. Trans-disciplinary energy, pollution and sustainability issues are inherently global: Our current research is now used and disseminated worldwide by our input to UN policy, expert panels and training programmes, following a 40-year tradition of international activity established by the David Livingstone Centre for Sustainability, named after one of Strathclyde's best known alumni.

Resourcing and enhancement: The University, Faculty and Department have invested heavily to support the development of impact from our research as illustrated by the following:

- *Knowledge Transfer Account* - a £2.6M EPSRC investment used to accelerate and enhance Strathclyde's strong links with industry (e.g. *Sentenac*, E. Ayrshire Council)
- *Research Exploitation Partnership,* and *Knowledge Exchange and Innovation Training* (e.g. *Keenan*, Parsons Brinckerhoff).
- *Impact Accelerator Account* - to provide research leaders of major EPSRC projects with a junior researcher to achieve impact (e.g. *Sentenac*, EML Group).

- *Bridging The Gap* - supporting cross-Faculty interdisciplinary research (e.g. gene transfer, *Knapp*; detection of brominated fire retardants, *Switzer*).

Strathlinks - internal support for SME engagement; a major component of KE activity for staff in this unit (e.g *Kalin*, CookPrior Associates).

c. Strategy and plans

Our forward **Strategy for KE and Research Impact** is to achieve excellence by building KE activities upon truly innovative research, thereby increasing income and raising our international impact. **Outreach** activities will continue to be an important part of impact development targeting the general public (e.g. through plays, schools competitions, online resources for educational social networks, and department lectures). The Department recently appointed a new Director of Knowledge Exchange (*Lord*) who has responsibility to enhance the KE profile, provide strategic direction, link new staff to the strategic themes, and mentor and support colleagues to ensure an agile response to opportunities.

An **"innovation pipeline"** approach has proved beneficial and will be built upon. This process takes initial relationships supported by funded enterprise activity (e.g. TSB's, Scottish Funding Council's (SFC) or Energy Technology Programme's Innovation Vouchers for SMEs, Encompass or the Scottish Environmental Technology Network) or from consultancy, as platforms for research student projects or internships, and then for escalation to longer-term KE partnerships, such as KTP. A key ambition is to increase the number of KTP projects, in line with the University's target to be ranked 3rd nationally by number of KTPs, so efforts are focussed towards identifying new potential partnerships.

Co-funding industry-sponsored research degrees will continue, following good results achieved during REF: for example, collaborative research with Parsons Brinckerhoff, in its 4th year of supporting our MRes and PhD programmes, led to the 2012 Brownfield Briefing award for Best Scientific (or Verification) advancement for work on coal tar forensics. Our target is to double industry support and the research student cohort, equivalent to one new PhD student per researcher each year.

The University has committed to "**increasing collaboration with industry, business, Government and the third sector**" in its Outcome Agreement with the SFC. KE is now assessed in the annual Accountability and Development Review with targets set for all academic and research staff. Research impact and KE is now included in guidelines for probationary lecturers and promotion. A specialist KE career path has been created by the University, matched to academic pay scales, and **mentoring** from KE active staff is used to develop KE activity by junior researchers. The £89M Technology and Innovation Centre will be a conduit for industrial partners to draw on our research in finding solutions to challenges central to economic regeneration (its core purpose).

d. Relationship to case studies

The "**Malawi water, health and sanitation"** case study (*Morse et al.)* illustrates the potential reach and significance of impacts for interdisciplinary combinations of civil engineering with environment and infrastructure. The "**STAR"** case study (*Switzer & Tarantino*) shows the fundamental importance of establishing links with industry to achieve impact through KE; the partnership with SiREM provides new challenges and trial opportunities while developing STAR for commercial roll-out. The "**geo-uncertainty"** case study (*Shipton & Lunn*) indicates how participation in networks and panels can lead to the impact of research on Government policy or society. We are confident that the strong research performance achieved during REF provides a wide range of opportunities to develop further impact in the three strategic themes.