Institution: University of Abertay Dundee

Unit of Assessment: 7

a. Overview

Benefitting from the relative compactness of Abertay we have developed the Abertay Centre for the Environment (ACE) focused on inter-disciplinary environmental research. ACE is housed in a purpose built facility to enhance interactions between discipline experts, experimentalists and theoreticians. New ways of thinking, notably in the emerging disciplines of computer games technology, the interface between life and physical sciences, and emergent behaviour of complex systems, are interlinked across disciplines. For example, common approaches to emergent behaviour are applied to soil science and cancer research. This interoperation provides augmented, reciprocal benefit and has driven the development of innovative inter-disciplinary approaches which have been transferred, applied, adapted and specialized across disciplines. Thus, the application of GP-GPU in systems modelling has supported our interactive visualisation research, spatial statistical analysis of complex geometries developed in soils research is being used to analyse the growth of cancer cells, and model biological systems looking at evolution and adaptation of bacteria are guiding our research into the response of soil systems to environmental change. The new 5-year pan-University Research Strategy aims to further develop our research strengths by integrating research activities under a single University-wide leadership to drive our discipline strengths and propose strategic, research focused appointments, to create support for early career researchers, to fund proof-of-concept projects and staff training, and to create a Graduate School to inculcate inter-disciplinary working (see below).

Making a difference to the environment matters to researchers at Abertay. To counteract human activities that cause significant changes to the environment, endangering natural resources, we created in ACE a research environment with knowledge exchange partnerships to identify solutions and create major economic opportunities to contribute to a more sustainable society. ACE's guiding philosophy links quality research to end users as is evidenced by our wide range of intellectual and industrial partners. The UoA7 submission includes 16 staff (14.45 FTE) from two research groupings within ACE: the Scottish Informatics Mathematics Biology and Statistics (SIMBIOS) Centre and the Urban Water Technology (UWTC) Centre.

The UWTC was established in 1993 with an original mission to provide a service to the water industry. It retained this strong reputation and developed growth in new areas including sustainable technologies and sustainability assessment, building on the successful combination of academic skills with commercial expertise and KE partnerships.

The mission of the SIMBIOS Centre (established in 2000) is to provide research leadership in system approaches to solving complex ecological, biological and environmental problems. Its multi- and inter-disciplinary research enabled it to develop generic approaches across disciplines with specific strength in the emergence of (i) sustainable soil functioning from the microscopic complexity of soils (submitted to REF UoA7) and (ii) tumours in tissue from cell processes and interactions (submitted to REF UoA5).

Our open plan office area and inter-disciplinary approach to research ensures that the two groupings are interlinked by transferable skills specifically in mathematics and visualisation drawn from Abertay's strength in computer games technology. For example, one such collaboration has resulted in an innovative approach to real-time visual simulation of sustainability, integrating complex interactions among environmental, economic and social factors (case study 2).

b. Research strategy

The UoA7 submission is underwritten by the University's Research and Knowledge Exchange (RKE) strategy and approach, which is driven by interconnections across its research base. In particular the University has committed to maintaining our world-leading role in aspects of environmental sciences, and developing emerging groups in policing, forensics and criminal justice and in inclusive technologies for sustainability, wellbeing and security.

Staff members in ACE are driven to make a difference to the environment through innovative research and the development of close interactions with stakeholders. Their collective vision is to

grow strength in multi- and inter-disciplinary research and to play an international leading role in developing: **(i)** a systems approach to inform sustainable exploitation of soils, **(ii)** technologies that provide innovative technical solutions for water and waste management; and **(iii)** a framework for assessment, visualisation and communication of sustainability technologies in order to address societal barriers to their uptake.

This focused strategy enabled ACE to enhance research esteem over the assessment period delivering against the strategic objectives outlined in the RAE 2008. In brief these stated that we would: **1**) build strength at the physical-life-science interface, **2)** invest in strategic partnerships, **3)** invest in world-class infrastructure aligned with our research strength, and **4)** optimise dissemination and increase Knowledge Transfer Partnerships.

Review of our performance against strategic objectives.
The SIMBIOS Centre has grown its reputation in soil science by building on the expertise of a group of inter-disciplinary researchers. The Centre, comprising **9 researchers in environmental sciences**, combines strengths in Soil Ecosystem Modelling (Baveye, Chair), Soil Biophysics (Otten, Chair), Microbial Ecology (Spiers, Reader), Modelling and Visualisation (Falconer, Lecturer), Biogeochemistry (Foereid, Lecturer), Statistics and Mathematics (Hapca, Lecturer), Soil Physics (Schmidt, Lecturer), Contaminant Transport (Morales, Marie Curie FP7 Incoming Research Fellow) and Mathematical Modelling (Houston, Research Fellow). The Centre has world-leading facilities in two X-ray CT machines that allow for the microscopic examination of the internal structure of objects, including soil. Our strategy is for researchers to develop their own research programme, but also to contribute to a joint research focus in order to maximise the impact of our unique facilities and generate sufficient capacity to be recognised as world-leaders in the field. This focus enabled the Centre to develop novel methodologies to characterise soil structure; a paradigm shift in soil research from examining the solid phase (such as aggregates) to examining, non-destructively and at a scale relevant to micro-organisms, the pore-solid-water-air interfaces and pore geometry within which microbial life in soil resides. Combined with our experimental and mathematical skills we have become leaders in biophysical processes in porous media, underpinning food security, carbon sequestration and microbial response to environmental change. To underpin this programme, Abertay University invested >£225K in growth and maintenance of our world-leading X-ray CT facilities, expansion of our computing capacity, and in equipping our Microbial Ecology lab to underpin our biophysical modelling program and develop strength in microbial adaptation.

SIMBIOS played a leading role within SAGES (Scottish Alliance for Geosciences, Environment and Society), which pools world-leading expertise in geoscience and environmental science from across Scotland's research base (£22.2 M), partnering the Universities of Aberdeen, Abertay, Dundee, Edinburgh, Glasgow, St Andrews, Stirling, SAMS UHI, SUERC, and the West of Scotland. Over the reporting period, SIMBIOS has published over 120 papers in refereed journals (versus 77 during the period covered by RAE2008), including contributions to papers in leading journals such as Nature, Nature Biotechnology, Lancet ID, Genome Biology, and Coordination Chemistry Reviews. Authoritative reviews were written, including prestigious invited visionary reviews for the Centenary issue of Advances in Agronomy (advocating biophysics and scaling as major issues in soil research), the 75th celebration of the American Society of Soil Science (evidencing that soil is a Frontier of Science), and volunteered reviews on topics of great societal importance such as the role of the environment in the rise of antibiotic resistance (Lancet ID). Members of SIMBIOS were regularly convenors at major international conferences (including Eurosoil, Soil Science Society of America, EGU), established a bi-annual international workshop series (Micro-soil: focusing on integration of techniques, statistics and modelling in soil science, attracting on average 70 researchers world-wide), developed training courses, delivered >75 invited and keynote presentations, and continue to be key players in national and international research networks as is evidenced from our research output. We further extended our strengths in life sciences: 5 staff members from SIMBIOS are now part of the University's first submission in Biological Sciences (UoA5).

The Urban Water Technology Centre drives forward the University's agenda in environmental and

water technologies to provide solutions to environmental pollutants and advance bioenergy production, and to develop an integrated framework to enable the assessment, visualisation and communication of the sustainability of technologies. The Centre combines the work of 7 researchers with expertise in (i) anaerobic digestion and biofuels (Akunna, Reader), (ii) wastewater and waste treatment (Akunna and Bremner, Chair), (iii) sustainable urban drainage systems (Jefferies, Chair, and Tota-Maharaj, Senior Lecturer), (iv) sustainability research (Blackwood, Senior Lecturer, and Gilmour, Lecturer), and (v) ecosystem value (Wade, Lecturer). UWTC has expanded from its original focus on the Water Industry by drawing from research strengths across the University, and by implementing a strategy to replace retired staff with more research active staff. This enabled growth from 5 (included in the last RAE) to 7 researchers and an output in refereed journals of 73 (48 in previous RAE). Through developing a strong industry focused research strategy supported by a further 5 (not REF returned) staff members to underpin our KE and consultancy, the UWTC has been particularly successful in establishing national and international networks (7), impacted on policies and advised UN-Habitat on drainage matters. A second noticeable strength is our expertise in anaerobic digestion and transforming waste into energy, which has led to the use of new biomass pre-treatment methods, and greater understanding of inhibitory compounds and the biochemical pathways associated with the reduction of nitrogen oxides in anaerobic digestion systems.

Close collaboration between the two centres has enabled development of further strengths, linking the expertise in computer games-based 3D visualisation (Falconer, SIMBIOS) with predictive models of land use and sustainability based on environmental and socio-economic factors (Blackwood and Gilmour, UWTC). Collectively, ACE offered consultancy in a range of areas including waste treatment, landfill, gas analysis and X-ray CT. ACE supported 5 KTP's, which is a remarkably high number for such a small unit, filed world-wide patents (remineralisation of calcified tissue (WO2009/130447) apparatus and method for mineralising biological materials (WO2010/020769), and method for generating hydroxyl radicals (EP 1 868 945 B1)), and established a spin-off company (Carbon Filter Technology).

Strategy to develop research.
The University has established R-LINCS (Research-Led Innovation Nodes for Contemporary Society) offering internal research funds (c. £1M over 3 years) to grow the research culture across the University in the next 5 years focusing on innovative solutions to societal problems through four cross-University themes: Environment, Security, Society, and Creative Industries. The Strategy aims to integrate research activities into a single University-wide leadership to drive our discipline strengths and propose strategic research focused appointments; to support early career researchers, to fund proof-of-concept projects and staff training, and to create a Graduate School (£10M) in a new building (1500 m^2) to inculcate inter-disciplinary working (see below).

The future development of ACE aligns with this strategy. Specifically ACE will aim to:

- Grow our research esteem in industry-informed research and our research income stream from RCUK and EU councils (target >£1 M/year). We have already started to grow our income and will continue this trend through staff training and mentoring in grant writing, and investment in national and international research networks.
- Expand our portfolio of interactions with stakeholders and KE activities, align them with Innovation Centres, and expand our 'distinct method for sustainability assessment' to national and international applications across disciplines.
- Act as an inter-disciplinary hub for the rest of the University notably through linkages with research groups focussing on the social sciences and the food and drink industry.

Invest in new environmental engineering and life science laboratories (1200 m^2; £ 4.1 M).

c. People, including:

i. Staffing strategy and staff development

University wide staffing strategy:

The University is implementing all 7 principles of the Concordat to Support the Career Development of Researchers. Equality and Diversity is supported through the implementation of Equality and Diversity policies, and the monitoring and evaluation of staff data through the Equality

and Diversity Sub-Committee. All members of staff are required to complete an e-learning module on Diversity in the Workplace. The University has made a further commitment to enhancing equality through an objective to achieve Athena Swan Bronze Award status (by August 2015) and subsequently to progress to Silver. The University's staff appraisal system and workload planning align personal objectives with the University's research objectives and enable an appropriate balancing of teaching, research, administration and external engagement activities to develop both personal careers and the strategic priorities of the unit. Thus, early career researchers are given more opportunities to develop their research, and probationary lecturers have a lighter teaching and administration load to free up more time for research-intensive staff development. In December 2012 the University's human resources department conducted an audit of the University's recruitment and staff development policies to ensure that these were in line with the recommendations and guidance provided in the Concordat to Support the Career Development of Researchers (2008).Training and staff development, supported by approximately £20,000 p.a. for the Unit, has included annual workshops on grant writing, statistical methods, European Framework funding and Knowledge Transfer Partnerships. The University has also offered courses provided by the University of Dundee, through membership of the inter-University research pools, and VITAE and Leadership Foundation courses targeting both experienced managers and young researchers trying to develop a research team.

Unit specific staffing strategy:

The Unit's strategy towards staffing has aimed to retain our recognized position as leaders in soil science and environmental technology, and to retain a mixture of experienced and early career researchers. Reduced teaching commitments have been used to assist new staff to build a research career and to attract strong researchers (using contracts >60% research where appropriate). Our international reputation enabled us to recruit researchers from the USA (Cornell), UK (Cambridge), Norway, and Germany, and to be awarded a Marie Curie Incoming International FP7 Fellowship. UWTC have been able to retain established staff. Their strategy has been to grow in research strength by replacing retired staff with established researchers. In the SIMBIOS Centre, two Professors took up posts in Australia, and one an Endowment Chair in the US (maintaining a joint position at Abertay). Both of our 5-yr RCUK Fellows were offered posts elsewhere prior to completing their Fellowships. This churn in staff has enabled the Centre to develop in new areas including biogeochemistry and root-soil research, thereby strengthening our position to contribute to climate change and food security research, whilst retaining our inter-disciplinary approach.

Four staff members received internal promotion including promotion to a Chair and Reader. In addition, 6 staff members on temporary contracts have been transferred to permanent contracts. Early career staff members are mentored by senior staff to grow their publication record and esteem (e.g. through co-chairing conferences, co-authoring reviews, or inviting to editorial boards). In addition, we have developed 7 early career researchers through expert 1-week training by a leading Image Analysis Company (enabling them to build upon our international reputation) and supported finishing PhD students through internally funded short-term posts (5 short-term posts and 3 permanent posts over the reporting period). Our extensive international networks have created a research environment beyond the boundaries of the University. New researchers have been able to benefit from early career investment opportunities through the pooling initiative SAGES (4 staff). Over the reporting period the Unit has supported staff to undertake medium-term (minimum 2-4 weeks) research visits to the US (8), Spain (3), France (4), Germany (2), China, Russia, South Africa and Brazil, and hosted 21 international researchers for research visits (stay between 2 weeks and 9 months) bringing leading researchers to the Unit. All staff present work at a minimum of one conference per annum.

ii. Research students

Our programmes cater for a diverse range of students. We have introduced (2011) a Masters by Research, which can be transferred to MPhil or PhD (6 MRes students started in the Unit). The University also encourages staff to undertake part-time PhD's (2 staff members in the Unit made use of this opportunity), and introduced a PhD by publication route. The postgraduate research student community is overseen by the Research Degrees Sub-Committee (RDS) which approves registrations and examination teams, ensures that appropriate research support is in place, expects that at least 2 trained supervisors are allocated, offers generic training events (for staff and

students), and organises an annual Post-graduate conference. Progress is monitored through 6-monthly reports on progress and thesis planning. The RDS also monitors the implementation of personal development planning (PDP), recorded in the form of an evidenced based training record which is assessed by the RDS prior to submitting the thesis. The ELIR (2012) reported that Abertay's postgraduate research students (currently at 94 across the University) were positive about what they described as a friendly, supportive and integrated academic community. Nevertheless we have developed ambitious plans to invest in a Graduate School to grow our postgraduate research. The Graduate School will consist of approximately 1500m^2 open plan office/study space, meeting rooms, workshops and social space, new staff accommodation and laboratories (overall £10 M investment). For the coming 3 years, the University is committed to providing 18 fully funded studentships.

Unit Specific Approach to Research Students:

PhD students in ACE were embedded in an inter-disciplinary research environment working on a daily basis side-by-side with leading researchers with wide-ranging expertise in open plan office spaces. Students participated in weekly school seminars, and approximately fortnightly group discussions dealing with topics ranging from funding, KE activities or technical difficulties faced during their research. Students had the opportunity to enrol in the Graduate School of the research pool SAGES, which offered high-level graduate training in Geosciences. Students in SIMBIOS were also enrolled in the STAiR program, which is an international Research Education programme for Soil Technology And inter-disciplinary Research in Soil and Environmental Sciences in Denmark. STAiR offers advanced training courses, conferences, and possibilities to work in another laboratory. For example, we have hosted a PhD student from Denmark (6 months), resulting in a joint publication between PhD students. The Unit has developed strategic links with the James Hutton Institute through 4 joint studentships which offered access to world-leading facilities and graduate training at both institutions.

d. Income, infrastructure and facilities

Staff in SIMBIOS and UWTC are situated in two interlinked open office space areas with a shared social space suited for discussions and social activities. The same floor houses our laboratory facilities with discipline-based laboratories, shared by all but looked after by discipline experts. The University offers technical support in terms of maintaining laboratory equipment and ordering of consumables for all research staff. We invested £70,000 in facilities for anaerobic digestion research and in equipment for field gas analysis, and, as part of our commitment to the research pooling SAGES, invested £225,000 in support of research activities. Our X-ray CT and visualisation suite, which houses 2 state of the art X-ray CT machines and integrated powerful computing facilities, is world leading and combined with our theoretical modelling makes our research cutting edge. The University supported the maintenance of the facilities and software licenses (approx. £18,000 p.a). We have doubled our computing capacity and built a purpose designed network and fully automated back-up system capable of handling about 1TB of data/month. Two staff members are fully trained in maintenance and all group members receive facility training. We also encourage wider usage, offering consultancy scanning, training for long standing collaborators and promoting applications of X-ray CT through organising training courses and international conferences (4).

We have diversified our income streams, balancing consultancy, industry-focused and fundamental research. In doing so, we have secured a regular income sufficient to increase research impact. Over the assessment period, ACE reduced its reliance on consultancy income streams by focusing on directly funded research activities. This strategy was successful not only in maintaining the funding stream in an adverse economic climate, but has also encouraged staff to establish a research/KE profile. Our aim is to build upon our growing track record, and grow our research income from RCUK and EU funding bodies to >£1M/year.

The Unit promotes data sharing (via a dedicated server) and open access publication where possible, the latter supported through the University's ring-fenced open access publication fund. An author-approved copy of all research outputs is deposited in the publicly available University Research Repository. Staff members maintain personal web-pages in addition to the web-pages of

SIMBIOS and UWTC, which describe the overall aims of the groupings.

In terms of governance, applications for external research funding are reviewed by an ethics committee and for their contribution to full economic costs, with bids where the level of overhead recovery is low requiring a case to be submitted by the Head of School to explain how the bid is strategically important to the University. The University's Research Enterprise and Innovation Services (REIS) office provides advice and support on research related matters, including costing and approvals of applications for external funding, management of IPR and contractual obligations with funders. Bringing these services together ensures that a consistent approach is taken across the University and provides a single point of contact for all research related matters.

The University is committed to supporting high-quality research through our infrastructure, with a design philosophy that ensures new spaces are built to promote research-teaching links. We are planning to develop new facilities for the School of Engineering and Technology (where this Unit sits) together with the creation of the Graduate School (£10 M). We plan to develop specialist engineering laboratories, housed in a new engineering building for research and teaching in civil and environmental engineering (approx. 1200m^2 and the estimated cost is £4.1M). We have recently (2013) upgraded all ICT facilities (£2.8 M). In addition, the University is increasing its academic staffing by 35 (c.20%) in 2013/14.

e. Collaboration and contribution to the discipline or research base

Research collaborations and KE partnerships:

Research collaborations are an important part of the research strategy of ACE. All researchers are members of at least one research and KE network. Participation is actively promoted (e.g. supplemented by internal match funding and reduced teaching loads) and has had a strong influence on the output and development of the Unit. Exemplars of collaborations and our commitment, which are all sustained beyond the initial funding, include:

- **SAGES**, Scottish Alliance for Geoscience Environment and Society, an SFC funded Scottish Research Pooling initiative. We initially interacted with 2 new Abertay appointments and as the Theme leader of the terrestrial Carbon Theme. We shared our leading tomography and visualization facilities (>£ 2M in value) and developed growth with 4 Abertay funded studentships. We identified that our strength in sustainability assessment could contribute significantly to the development of the Society Theme and we now have 8 active members.
- **MEPSOM**, Multi-scale Modelling and Emergent Properties of microbial degradation of Soil Organic Matter, an ANR funded French research consortium (to date 9 papers; 28 conference contributions, 5 PhD's). As the only non-French partner we brought strength in biophysical modelling and our X-ray CT facilities. With 4 staff members, we were leaders of a working package on complex systems which funded PhD's, joint PDRA's, staff exchanges and meetings. Our research was important in the establishment of this consortium.
- **PMI UK-US Partnership**: We were awarded a grant by the British Council's Prime Minister Initiative to enhance UK-US partnerships in Higher Education. This enabled us to establish strong links with Michigan State University, Rensselaer University (NY, USA) and University Rio Grande do Sul (Brazil). Our links with US researchers were further enhanced through a joint appointment for part of the REF period of Prof. Baveye (chair at Abertay and the Kodak Chair of Environmental Engineering at Rensselaer University). This contributed to an increase in collaborations with bi-lateral staff exchanges (13 in total), and joint grant applications to DOE and NSF (3). Our increased reputation in the US resulted in an invited paper (reprinted in full colour in the CSA magazine) to celebrate the 75 year existence of the Soil Science Society of America, and co-chairing a platform debate on the future of soils research in the US.
- **SUDSnet**, originally EPSRC funded and coordinated jointly by Abertay and Coventry University, this provides a UK-wide network for researchers, practitioners, agencies and developers who are interested in Sustainable Urban Drainage Systems. The network has now over 800 members, with 70% practitioners and 30% researchers and has had influence on policy and professional training. Led by Prof. Jefferies at Abertay, the research informed the approach by the Scottish Environment Protection Agency (SEPA) to SUDS, changed the delivery of public service by Scottish Water, and has had an impact on EU storm-water and energy management. The SUDS design manual, orientated at practitioners, has been downloaded more than 40,000 times.

We have built close interactions with businesses to inform our research through Abertay-led KE networks, notably **LoCal-Net**, our Low Carbon Land Use Innovation Network (ERDF-funded), which coordinates R&D in low carbon activities for SMEs across Scotland; **ACE Eco-partnerships** (jointly funded by the Abertay and the EU to the value of £1.1M, 2008-2011), offering free assistance to SMEs to identify commercially viable environmental solutions to their products and processes; **Scottish Biofuel Program**, focusing on the development of the next generation biofuels from renewable resources with Abertay's expertise in anaerobic digestion and fermentation, and **CREW**, a partnership between higher education institutions and the James Hutton Institute (JHI) which ensures that water research and expertise is available and accessible to the Scottish Government.

None of these networks are funded at full economic cost (FEC) and all receive support from Abertay, and 6 members of staff, originally employed on temporary externally funded contracts, have now gained permanent posts. These networks to date have helped >300 SME's, bringing for example typical energy savings of £10,000, creating 12 new and securing 17 existing jobs. Through these networks above, ACE supported >40 bilateral staff exchanges, equivalent to mini sabbaticals lasting between 2 weeks and 9 months, aimed at strengthening our international research esteem. We acted as convenor and organiser of >15 major international conferences and established 2 regular international conference series directly related to our research.

Editorial Positions: The Unit considers editorial positions and reviewing as important contributions to research, acknowledged in the time allocation of staff. Members of the Unit edited 2 special issues on research related to the Unit, hold 13 positions on editorial boards of international Journals, including leading Journals in the field such as Journal of Hydrology (Editor in Chief and Associate Editor), Critical Reviews in Environmental Sciences and Technology, and Applied and Environmental Microbiology. We have also stimulated debate on peer reviewing and the publication process in various journal articles including a publication in Science.

Professional activities and advisory boards: Researchers have been called upon by 8 international councils and made contributions as Expert Evaluators for EC FP7, the EPSRC moderating panel, NERC Peer Review College (2), and NERC moderating panels (4). We hold six posts on advisory boards and steering committees, including the National Biotechnology Development Agency, and the EPSRC funded Porous Media Processes Mathematics consortium (Steering Committee). Our close interactions with local stakeholders are strengthened through steering group memberships including Tay Estuary Forum Steering Group, the Dundee Waterfront Evaluation Group (a £1 bln regeneration project), and City Council Recycling Group, and are further supported by part-time staff secondment.

Contributions to interdisciplinary research.
Inter-disciplinary research is a key attribute of the Unit and underpins much of its research esteem. Our output evidences our inter-disciplinary approaches, specifically at the life and physical sciences interface (e.g. the use of network theory for biological invasions in soil), society and environmental science interface, art and science interface (with an art exhibition on research and collaborations with the National Museum Scotland), and the computer gaming and environmental research interface (developing GP-GPU based modelling and visualisation interfaces). It has enabled us to develop industry funded research in dentistry as a spin-off from environmental research (Cadbury funded), and to develop similar approaches in environmental sciences and biological sciences. Our open plan offices, discipline based laboratory sharing and staffing and research strategy all aim at developing and maintaining an inter-disciplinary research team, ensuring that a range of disciplines are covered in the Unit. The mixed discipline research environment offers training for the next generation of researchers and a reduced teaching load is further deployed to allow for the increased time required to develop inter-disciplinary approaches. This approach ensures that ACE retains critical mass and has the capacity to respond quickly to emerging environmental challenges.