Institution: UNIVERSITY OF BIRMINGHAM

Unit of Assessment: C17 – Geography, Environmental Studies and Archaeology

a. Overview

Our Geography & Environmental Studies (UoA17) contributions are embedded within the School of Geography, Earth & Environmental Sciences (GEES), which is part of the College of Life & Environmental Sciences (LES). UoA17 research is organised primarily around the themes of ***Society, Economy & Environment*** (SEE; including the ***Centre for Urban & Regional Studies,*** CURS), and ***Water Sciences*** (WS), with further contributions from ***Environmental Health Sciences*** (EHS, including meteorology and climatology) and ***Geosystems*** (GS). Themes are aligned with major environmental and societal challenges: ***urban resilience and living, transitions and cultural economies, water and energy security, living with environmental change, sustainable use of natural resources, biodiversity***, and ***data acquisition technologies***. Boundaries between themes are permeable to promote interdisciplinarity.

The research environment within GEES is coherent and inclusive, but presented as 2 REF submissions (UoA17 & UoA7). Institutional aspects of our environment apply to the entire School, although evidence (e.g. metrics such as income) presented herein refer to UoA17 specifically.

b. Research strategy

i. Our vision and strategy

The School's UoA17 research vision is founded on ***understanding the space-time dynamics of the interconnected processes that shape our planet to address natural and social sciences questions of international significance***. In turn, this ***fundamental understanding creates impact through application to real-world problems*** (REF3a).

The vision behind GEES, as a School, is to create and sustain an environment where cognate disciplines work synergistically to enhance research and education. Thus, the School's strategy focuses on ***nurturing disciplinary leadership while challenging traditional mindsets with new perspectives linking across cognate disciplines***. Our strategy maps onto the University's Strategic Goals, which cascade down to the College of LES Strategic Priorities; and it is delivered by investing in people (Section c), income generation and infrastructure (Section d), and our contributions to the wider research base (Section e). The following UoA17-related activities were targeted for 2008-2015 (with specific theme details provided further below):

1. capitalising on our ***culture of interdisciplinarity*** - (i) to set international agendas (Section e) (ii) to drive and secure funds from major, cross-cutting thematic programmes (Section d), and (iii) to lead in developing the University's Institute of Advanced Studies (IAS, founded 2012 as vehicle for interdisciplinarity) with inaugural themes fronted by geographers (Section e);
2. extending and reinforcing ***international partnerships*** to access world-class facilities (in USA, Europe and Australia), broaden our global reach (in Brazil and south-east Asia) and co-author papers with other internationally leading groups (REF2);
3. sustaining and growing ***strengths in recognised areas of excellence*** through appointments and infrastructure (see below plus Section c and d).

The 5-yearly Vice Chancellor's Review (September 2012), which included external assessors, demonstrated clear progress towards these strategic targets (as evidenced by examples below).

ii. School and UoA17 progress since RAE 2008

Our RAE2008 Future Strategy proposed: growing interdisciplinarity; infrastructure enhancement; and strengthening excellence in urban geography, environmental sustainability and energy, and water sciences. Since RAE2008, the School has aggregated themes and CURS colleagues have joined. Rationale for theme reorganisation was threefold: (1) to create ***interdisciplinary clusters***, which are more agile in responding to emerging issues of global significance and thematic funding calls; (2) to enhance and highlight our distinctive strengths identified in RAE 2008, and internal and external research reviews; and (3) to implement the School strategy to invest in our recognised areas of excellence in urban geography, water sciences and environmental sustainability and energy over the current REF cycle. Our strategy to grow ***urban geography*** research was the impetus for integration of CURS (formerly in the Business School) into GEES. This added urban regeneration, economic development, communities and the governance of public policy to our existing portfolio of urban expertise that includes ecology, hydrology, and impacts of climate change on people and infrastructure in cities. Our objective to enhance ***water sciences*** was to

expand our core strengths (flagged in RAE2008) in fluvial/ hydrological and ecological processes by adopting a wider catchment perspective (spanning surface and ground waters) and linking expertise in the atmosphere-land-hydrology-ecology process cascade with societal responses. Developments in the ***environmental sustainability and energy*** were driven by the post-RAE2008 award of the Energy Technologies Institute to the University of Birmingham (in collaboration with 2 other institutions) and establishment of the Energy, Society & Place Research Unit (ESPRU) within SEE to advance debates on social justice and resilience as related to energy use. These activities were backed by strategic new staff appointments (Section c). Future strategies are articulated *via* theme activity (Section b iii) and emphasise emerging global issues (Section a).

iii. Research themes: recent and future developments

The ***Water Sciences*** strategy has built on our well-established, core strengths (flagged in RAE2008; above) by broadening our outlook to whole catchment systems, and maintains high international visibility in the 5 priority areas: (1) hydroecology (hydrology-ecology interactions), (2) hydroclimatology (climate-water cycle processes), (3) sedimentology (large rivers, 3D modelling), (4) hydrogeology (groundwater-surface water interactions, flow and reactive transport modelling), and (5) urban ecology (landscape ecology, ecosystem function/service provision, impact of artificial light; Section e i). We are able now to quantify hydrological-ecological process interactions from the pore- to continental-scale by integrating hydrology, hydroclimatology, biogeochemistry, geomorphology and ecology. This has been driven by: (1) strategic appointments (Section c), (2) taking advantage of new University-led international links and (3) utilising the IAS to help develop new research agendas. A formal partnership with the University of Illinois at Urbana-Champaign (UIUC) has led to the building of a new pore-scale hydraulic experimental facility at UIUC, part funded by a RCUK grant (Sambrook Smith). The IAS provides a platform for a new initiative focussing on *Climate Change and Arctic and Alpine Environments*, following-up successes in the 6.5M€ EU-FP7 ACQWA project (Hannah, Milner). Beyond this REF period, we will reinforce our position by the newly awarded grant *Adaptive governance of mountain ecosystem services for poverty alleviation enabled by environmental virtual observatories (MOUNTAIN-EVO)*, part of the NERC-ESRC-DFID funded EPSA programme (Hannah, Clark). In addition, we will develop two further priority areas. Firstly, we aim to quantify of the importance of 'interfaces' (e.g. groundwater-surface water) as 'hot spots' for environmental processes. This builds on past successes; but a step-change will be enabled by the Birmingham-led 3.8M€ Marie Curie-ITN *Ecohydrological interfaces as critical hotspots... of ecosystem exchange fluxes and biogeochemical cycling* (starts 2013; Krause, Hannah). Secondly, we will prioritise research on impact of hydrological extremes on ecosystems and people, gathering momentum from recent NERC awards (>£1.6M; Ledger, Sambrook Smith).

Society, Economy & Environment-CURS conducts research to understand how social practices and relations are conditioned by space and place. The theme maintains an internationally-leading profile in 3 research areas, organised around shared conceptual issues and empirical challenges: socio-political and socio-economic transitions; critical urban geographies; and environmental and energy inequalities. Since RAE 2008, our strategy has been to complement and enhance these established strengths by targeted staff recruitment (Section c) and pursing 3 sets of activities. First is to build strong relationships with cognate schools and departments in the University as the basis for positioning Geography as a pivotal interdisciplinary research focus (e.g. Andres with the School of Sport and Exercise Sciences; Bryson - Business School, Engineering; Clark, Ramadan - Political Science; Fregonese - ICCS; Jones - Law; Moran - Psychology; Round - European Research Centre). This has enabled SEE-CURS researchers to lead IAS initiatives on *Regenerating Economies* (2013) and *Urban Resilience* (2011), and ESF workshops on critical water management issues and utilisation. Second is to focus SEE-CURS research on societal grand challenges, with theme members leading and contributing to multidisciplinary, large-scale partnerships with public and private enterprises regionally, nationally and internationally (e.g. Jones AHRC on cultural intermediation and urban regeneration; Mykhnenko EU-FP7 on city shrinkage; Day EPSRC on energy inequalities and environmental justice). Our third action is to build critical partnerships with policy practitioners to enhance research impact (REF3a), demonstrating University engagement in improving quality of life in a diverse society (Bryson on economic geographies of the Midland; REF3b). Depth and breadth of SEE-CURS research is evidenced by funding from AHRC (Jones), British Academy (Clark, Golubchikov, Round), ESRC

(Clark, Jones, Moran, Pykett), EPSRC (Day), the EU-FPs (Clark, Mykhnenko), ESF (Clark), and a range of (inter-) government and charitable organisations across the World (e.g. World Bank - Round; Belgian SPO - Day; Nuffield Foundation - Day). SEE-CURS strategy is to advance strong policy and civil society links, with regard to urban spaces, renewable energy, energy poverty, community resilience and climate change mitigation.

UoA17 researchers in Environmental Health Sciences have a longstanding international reputation for ***pure and applied atmospheric research***, including significant knowledge transfer to the meteorological market place (REF3a). This research has 4 foci: (1) urban climatology (Chapman), (2) infrastructure meteorology (Chapman), (3) extreme events (Leckebusch), (4) past and future climate change (Widmann). Modelling is also a strength: from small-scale street-canyon turbulence models (Cai - UoA7) to global circulation models (Widmann, Leckebusch). During this REF period, the £0.7M NERC-funded Birmingham Urban Climate Laboratory (BUCL: the densest urban meteorology observing network on Earth; Section d) was established. BUCL (led by Chapman) is a centrepiece for current and future urban climatological research in the School. Recent grants (1.2M€ PLEIADES funded by the Volkswagen Foundation; Widmann) and appointments (Leckebusch) have reinforced and extended expertise on impact of climate change and extreme events on the environment and society, which will be pursued as a priority area.

Our overarching UoA17 future vision targets enhanced interdisciplinary research in two growth areas: (1) ***coping with uncertainty*** will focus on mitigating and adapting to environmental and societal change, including extremes (e.g. climate change, water and energy security, urban unrest, mega-events); and (2) ***reconceptualisation of living spaces, places and ways of doing*** will emphasise the importance of the individual and place in a dynamic world (e.g. city liveability, 'big data', economic networks, resource usage). In addition, GEES is co-leading (with Biosciences) the £15M ***Birmingham Institute of Forest Research*** (BIFoR) to be established in 2014. BIFoR will address initially two fundamental geographical challenges: the impact of climate and other drivers of change on woodlands, and the resilience of trees to invasive pests and diseases.

c. People, including:

i. Staffing strategy and staff development

Sustaining and enhancing research strengths form the basis of our people strategy. We were proactive in planning for a number of expected retirements after RAE2008. This succession planning took the opportunity to build leadership, while deepening and diversifying our expertise by recruiting outstanding individuals to complement existing strengths. Nurturing disciplinary leadership is exemplified by promotions to Chair (Hannah, Milner, Sadler), Reader (Chapman, Sambrook Smith) and Senior Lecturer (Barber, Clark, Jones, Ledger, Moran, Pemberton, Round, Widmann). When recruiting, we balance the need to attract the best applicants with the need to maintain a coherent research environment in which our facilities can be exploited fully and collaborations flourish. We have enhanced capacity in water sciences, meteorology and environmental change (Barrand - glacial systems; Kettridge - ecohydrology, wetlands; Krause - groundwater-surface water interactions, biogeochemistry; Leckebusch - extreme events and climate change impacts). In SEE, our focus has been on urban resilience and living, and transitions and cultural economies and natural resource usage (Arribas-Bel – 'big data' and spatial analysis; Emery - human-environment relations; Fregonese - urban unrest ; Golubchikov - urban energy infrastructures; Hadfield-Hill – urban sustainability and children's geographies; Leszczynski – socio-cultural implications of new technology; Müller - mega-events; Mykhnenko - regional transitions; Noxolo – cultural development geographies; Oldfield - Russian environmental histories; Pemberton - urban resilience; Pykett - socio-political transitions and governance; Ramadan - everyday geopolitics; Tranos – economic geography, 'big data'). Although 5 of these new colleagues (Arribas-Bel, Hadfield-Hill, Leszczynski, Noxolo, Oldfield) will not be in post until 2014, their appointments evidence our forward momentum and long-term strategy.

CURS staff (Andres, Lee) joined from the Business School during this REF cycle to deepen our urban focus on regeneration and local economic development. Fregonese's appointment (under the Birmingham Fellowship scheme: to attract internationally-prominent, early-career staff) has strengthened research synergies across the University (Politics, International Studies), and within the School (consolidating links between urban, regional and political geography). Departures, often for overseas posts (e.g. Baker – UNSW; Bassin - Södertörn; Coaffee – NYU/Warwick; Kidd – NASA; Pinay - Rennes), have always resulted in reinvestment in staff.

GEES has a thriving and dynamic research culture. This positive, supportive environment is evidenced by the School hosting >35 Visiting Scholars, including Marie Curie Fellows, in this REF cycle. Visitors have developed links with international-leading universities (e.g. Freiburg, Oregon). All staff are encouraged to undertake research fellowships overseas, to enable world-leading research and for personal development (e.g. funded fellowships for Moran in Helsinki and Round in Hokkiado).

Our demographic profile is strong in early- and mid-career, with decentralisation of decision-making through our themes to encourage active participation in developing research strategy. Investment in early-career staff is important because we aim to create pathways for the next generation of academics. New lecturers are encouraged to advance research (e.g. start-up package, light teaching/ administration loads, allocation of mentor and early PhD supervision).

All staff (including contract researchers) are involved in staff development review (SDR) to achieve their personal best. The University was awarded the HR Excellence in Research accreditation in 2011 and is working towards full implementation of its Concordat action plan by end of 2013. Organisational-level process, policies and activities include an integrated leadership development programme for researchers/ academics at all levels and recurrent central funding to maintain development provision for researchers. College-level activities include a College PDRA & Early-career Development & Training Committee, mentoring schemes and specific local induction for research staff. Research staff members take full advantage of professional development provided by the People & Organisational Development unit.

To further the career prospects of women in academia, the University reached Bronze on the Athena SWAN programme, in 2012. GEES will apply for a Bronze award in November 2013, with aspirations to move through higher levels. To ensure transparent treatment of staff across the School, a workload model has been implemented (2013). GEES management structures ensure equality of opportunity for input (e.g. early-career academics sit on the School Executive and the School Research Committees). Staff members are trained to be aware of, and take account of, all diversity and equality issues *via* the University's compulsory Diversity in the Workplace online training course. The biennial Have Your Say staff survey yields action plans at local to University-level, as a result of staff feedback changes to SDR occurred in 2011. Prior to accepting any research grant awards or beginning a PhD, projects are subject to ethical scrutiny using an online (Intranet) system.

ii. Research students

Postgraduate researchers (PGRs) are at the heart of our community. In this REF period, PGR intake has increased consistently year-on-year (from 12 in 2008 to 29 in 2012); and 46 PhDs have been awarded. GEES has recent success in expanding PGR numbers from overseas (particularly across Human Geography and Water Sciences), which was deemed exemplary by the University. Overseas intake has risen from 33% (2008) to 58% (2012) of the total PGR cohort. As numbers grow, our breadth of PGR funders has also widened to encompass: AHRC, ESRC, NERC, EPSRC, Environment Agency, Big Lottery, Ford Foundation, EU-FP, EU Marie Curie Initial Training Network and various international government scholarships. CASE awards account for >33% of studentships with partners from private (e.g. Campbell Scientific) and public (e.g. Scottish Government, Environmental Agency, BTO) sector, and overseas organisations (e.g. NIWA-New Zealand). This range of topics, funders and nationalities enriches the diversifying our postgraduate community.

The University supports training of PGRs with increasing disciplinary specificity from the Graduate School, College, within GEES, down to the level of individual research themes. UoA17 staff deliver courses as part of the Graduate School training portfolio (e.g. Andres, Moran - Postgraduate Certificate in Advanced Research Methods & Skills). All PGRs undertake a Development Needs Analysis, to assess immediate and long-term training requirements with respect to personal effectiveness, research governance, ethics, the impact agenda, as well as discipline-specific knowledge using the Vitae's Researcher Development Framework. PGR progress is monitored through monthly supervisory meetings and at progression committees at 6, 12, 18, 24 and 30 months. The reports are filed for both meeting types, as part of the student's portfolio of achievement (archived online since 2012). We hold an annual School-wide PGR symposium to develop conference skills and to share research perspectives across our range of disciplines. Looking ahead, the restructuring of RCUK doctoral training into Doctoral Training

Centres/ Partnerships puts a clear focus on the training element of doctoral research. All PGRs entering from 2013/14 will undertake at least 60 days of skills training, tailored to their needs. Every PGR has at least 2 supervisors and 1 academic advisor, ensuring stability and broadening intellectual engagement. Continuing professional development (CPD) in doctoral supervision is provided at College-level; and, from 2013-14, reflective practice-based CPD will be a requirement.

All PGRs are involved actively in the research themes, organising workshops and conferences, presenting their work-in-progress as part of theme meetings, and participating in School academic seminars. PGRs publish academic papers routinely in high-impact international journals (e.g. *Area*, *Children's Geographies*, *Ecosystems*, *Economic Geography*, *Freshwater Biology*, *Frontiers in Ecology & Evolution*, *Geografiska Annaler*, *Geography Compass*, *Global Ecology & Biogeography, GRL*, *HESS*, *Hydrological Processes*, *Jl. Climate*, *Jl. Environmental Management*, *Jl.Hydrology*, *Local Economy*, *Nature CC*, *PLoSOne*, *PNAS*, *Water Resources Research*, *Weather, Climate & Society*). Our PGRs have won external academic awards for their publications and conference papers (e.g. British Ecological Society Conference 2012), and authored policy reports for government and NGOs (e.g. Environment Agency).

Effective PGR research is facilitated by a well-developed infrastructural (Section d) and financial support from the School, College and University. As part of RCUK studentships, funds (supplemented by regularly successful applications to external sponsors; e.g. British Ecological Society, British Hydrological Society, RGS-IGB) are available to attend domestic and international conferences, enabling candidates to disseminate work at AAG, AGU, EGU and RGS-IBG. College funding is provided for PGRs to design and deliver conferences that bring internationally-leading researchers to campus. PGRs won funds to aid hosting of major events – e.g. the British Hydrological Society's Peter Wolf Early Career Hydrologist's Conference (2012) and RGS-IBG Mid-Term Postgraduate Conference (2013) – evidencing further the vitality of our research culture plus excellent conference and research facilities.

PGRs are involved actively in Universitas-21 (e.g. U21 Graduate Conference on Energy in Dublin 2013; research visits to Melbourne) to internationalise their work and build global networks.
As a result of their skills, research training, publication track-record and enthusiasm for the discipline, UoA17 PGRs have taken-up academic posts in the UK (e.g. Leeds, Oxford) and overseas (e.g. Canadian Rivers Institute, Çanakkale Onsekiz Mart University, Otago, Iowa), as well as senior research and policy positions in government bodies (e.g. CEH, EA, UK Met Office) and consultancies (e.g. Atkins).

d. Income, infrastructure and facilities

i. Income

Sustaining a balanced, diverse portfolio of research funding is critical for continued growth and development of UoA17 activities. Following RAE2008, we recognised that the funding landscape had become even more competitive and responded by implementing a rigorous internal review system to increase grant application success rates. In addition, early career researchers now attend subject specific grant writing workshops run by proven winners of funding. To boost capture of EU funding, the University was the first UK HEI to establish a Brussels Office (in 2010) with space for 120 people to facilitate networking and proposal development meetings, which has been used extensively by UoA17 staff.

These strategies have led to sustained and growing income throughout this REF cycle with annual totals of £0.90M in 2008-09 rising to £1.29M in 2012-13. So far, total grant spend since 2008 is £5.92M with £0.21M of in-kind support. RCUK funding (AHRC, EPSRC, ESRC, NERC) is our primarily research revenue source (57% of total income). EU funding represents 16% of our funding, excluding the recently awarded 3.8M€ Marie Curie ITN (above). We gain significant funding from UK government and charities (24%), which shows the policy relevance and real-world applicability of our research. Further evidence of potential for our research impact is the growing amount (now 3%) of funds secured from industry. We have also been able to generate income from spin-out of commercial activities. Notable is the route-based road weather forecasting product spun-out as Entice Technology Ltd, which forms a UoA17 impact case study (Chapman, REF3b). Projecting forward, recent grant awards in this REF cycle (since Oct 2012) exceed £4.1M, guaranteeing a further rise in research income in the next REF period and providing a strong platform for the research plans outlined above (Section b).

ii. Infrastructure and facilities

The broad portfolio of research evidenced by our research outputs has been supported by continuing investment in laboratory, field, computational, archival and desk-based resources. Research infrastructure and services are maintained and refreshed continuously through grant awards (above), the University's Research Investment Fund (RIF, totalling £1.4M across the School since 2008), and innovative equipment sharing. Our facilities are well-supported by specialist technical staff. The School belongs to a College IT consortium (5 computer officers) supporting PCs and networking, with a full-time PC technician in-house and 0.5 FTE Unix support. Technical staff (13.5 FTE across GEES) provide support for water sciences and palaeo-environments laboratories, chemical processing and analysis, stable isotope analysis, designing and maintaining field equipment, fieldwork, map room and cartography. Several of our facilities represent the state-of-the art; and, therefore, they are leading national/ international resources. Recent, significant developments in infrastructure and facilities are highlighted below.

Laboratories. Research within Water Sciences (WS) has received a major boost, since 2008, partly through development of novel laboratory facilities (below). The ***Facility for Environmental Nanoscience Analysis and Characterisation*** (FENAC) was set-up to produce reliable data analysing nanoparticles under realistic conditions for the better understanding of biological and environmental impacts of manufactured nanoparticles. In 2009, as recognition of the quality of this work, FENAC became a NERC facility allowing consolidation and expansion of the laboratory. Analysis done within FENAC has allowed exciting new research avenues to be explored by WS staff, most notably in exploring the role of bed sediment structure and turbulence in determining the transport and fate of nanoparticles (NERC - Sambrook Smith). The School's ***Stable-Isotope Laboratory*** (SILLA) was refurbished in 2009 with an additional £160K of investment, allowing the analysis of stable isotopes to fingerprint water sources in aquatic systems (Hannah, Kettridge, Milner). One SILLA application has shown that wetlands are vulnerable to changes in groundwater levels and may represent potentially a significant source of riverine carbon if groundwater levels fall (Bradley); while another has provided new understanding of trophic interactions and prey selection of riparian beetles (Sadler). ***Other laboratories*** include new ICP-MS and GC-MS; organic carbon instrumentation, chemical analysis, flow-systems, palaeoecology preparation, magnetic susceptibility equipment, microbiology, and an optical and fluorescence microscopy suite.

Field observation/experimentation. Building upon the Lord Stafford award-winning BUCANNEER Knowledge Transfer Partnership with TSB-NERC-Birmingham City Council (REF3b), the £0.7M NERC-funded ***Birmingham Urban Climate Laboratory*** (BUCL) was established. BUCL comprises >250 WiFi-enabled air temperature sensors together with 30 automatic weather stations. BUCL data will be used (as part of the £0.6M NERC-funded HiTEMP project, Chapman) to identify, model and inform adaptation to the impacts of urban heat stress and climate change on people and infrastructure of the cities. A new ***Environmental Change Outdoor Laboratory*** (ECOLAB) will be opened in 2014, funded by the University's RIF and alumni donations, supplemented by new NERC grants (Section b). ECOLAB is an innovative, on-campus field laboratory focused around mesocosm river channels and ponds, providing an experimental facility to examine the effect of multiple environmental stressors (e.g. water temperature, flow variability) on aquatic ecosystems. This facility builds on existing NERC funded research on ecological impacts of drought and biofilms (Section b; Ledger, Milner, Sambrook Smith). Also located on-campus, two logging ***borehole arrays***, the (near-real time display) Bourn Brook ***river flow and quality monitoring site***, and a ***UK Met Office weather station*** are used for groundwater, urban hydrological and climatological studies, respectively. A very wide range of field equipment is maintained and renewed to underpin our water, ecological and atmospheric research (e.g. automatic weather stations, infrared cameras, water quantity and quality sensors, new fibre-optic distributed temperature sensing, biological and biogeochemical sampling equipment).

Computing. The University continues to invest heavily in cutting-edge computer facilities, which are essential for our numerical modelling efforts. The Birmingham Environment for Academic Research (BlueBEAR) was upgraded in December 2012 to provide an IBM iDataplex HPC cluster with 800 Sandy Bridge based computer cores complete with large memory servers and a GPU-assisted compute node. This computational power allowed us to develop new methods for validating General Circulation Models (Widmann) and modelling of extreme weather (Leckebusch).

Archives. As well as investing in new technology, the School understands the value of preserving capability in more traditional geographical resources. We host: (1) an extensive ***Map***

Room collection of >250,000 sheet maps, >600 atlases, a local history reference collection, archive of map memoirs, travel guides and gazetteers; and (2) ***historical climate data for Birmingham*** (back to 1793). Our urban research within the SEE-CURS is enhanced by the ***Conzen Collection.*** This archive, from the Anglo-German school of urban morphology, includes >50,000 maps and >25,000 town plans along with other related material. Some of the Conzen material is held by partners in Chicago, cementing a longstanding and prestigious international collaboration. The SRIF-funded (£250K) ***Shotton Room*** acts as an interface between the School's substantial paper-based map and archive collections and digital mapping/ GIS facilities. This has been further enhanced by a SRIF3-funded (£110K) specialist visualisation suite.

PGR space and facilities. In 2010, Roberts' funding was allocated by the University to refurbish of a dedicated suite of rooms in the Geography Building for use by postgraduate researchers (PGRs; Section c ii) with individual office space, new computers and a social area.

e. Collaboration or contribution to the discipline or research base

Collaboration within and beyond the University (nationally and internationally) is fundamental for the vitality and sustainability of our research, and postgraduate training. All staff are active in major international research networks; and most lead in providing academic citizenship to advance geographical thinking and also Geography as a discipline (e.g. journal editorial boards, research council and other peer-review work; conference session conveners; services to professional associations and learned societies). Given their geographical perspective on multifaceted research questions, our staff engage frequently in inter- and trans-disciplinary collaborations. Indeed, all the largest grants held by UoA17 involve some element of interdisciplinary working. It is beyond the scope of this document to include every interdisciplinary and international collaboration, contribution to the discipline, or collaboration with non-academic end-users. Therefore, we present selected examples to convey the strength and dynamism of UoA17 collaborative activities undertaken during the REF census period.

i. Interdisciplinary research and collaborations

Capitalising on our interdisciplinarity, and extending and reinforcing international collaborations, are strategic aims for 2008-2015 (Section b). ***Interdisciplinary*** lies at the heart of a substantive proportion of UoA17 activity; and we make major disciplinary contributions by linking theoretical aspects of science and social science to place, policy, practice and governance. To illustrate this examples are drawn here from our recognised areas of excellence in urban geography, water sciences, and environmental sustainability and energy (Section b).

In ***urban geography***, the EPSRC- SUE2 Urban Futures project (£3.2M; Sadler; REF3b) engaged engineers, biogeographers, sociologists, designers, landscape architects focused on city design and futures, with the findings embedded into stakeholder communities through a series of workshops at city councils (e.g. Lancaster, Milan) and at professional bodies such as the Royal Institute of Architects (RIBA) and the Chartered Institute of Civil Engineers (CICE). Two projects spanning geography, engineering and planning have explored the influence of the urban heat island and temperature extremes on environmental risk (BUCCANEER; REF3b) and UK transport infrastructure (£ 1.4M EPSRC-ESRC funded FUTURENET project, Chapman). Within ***water sciences***, Birmingham is internationally well-known for its distinctive interdisciplinary 'brand' in hydroecology/ ecohydrology (Bradley, Hannah, Kettridge, Krause, Ledger, Milner, Sadler); and we continue to lead the way in developing this emerging field (e.g. Hannah, Krause on editorial board of *Ecohydrology* with Sadler publishing a key special issue on 'interfaces' in 2011). The EU-FP7 ACQWA (Assessing Climatic change and impacts on the Quantity and quality of Water) consortium is worth >6.5M€ and aims to assess the impact of climate change on the quantity and quality of water in mountain regions (Hannah, Milner). This project is highly interdisciplinary and links a range of natural and social scientists with legal scholars, local stakeholders and EU policy makers. ***Energy equality and sustainability*** are central to 2 EPSRC projects (Day) in which civil engineers, software (gaming) engineers, sociologists and (transport) planners collaborate. The £1.1M Build-TEDDI project aims to create smart systems for household energy use; and £4.9M DEMAND Centre project seeks to model and understand the complexities of energy use.

Recently commenced or awarded projects will ***sustain our interdisciplinary activity***. A Birmingham-led (Jones) £1.5M AHRC consortium will examine the critical role of the creative economy in tackling issues of inequality by integrating academic perspectives from economics,

history, sociology, computer science, law and arts practice. A £6.2M EPSRC programme grant will bring together engineers, biogeographers, sociologists, energy specialists, psychologists, economists and demographers working to re-imagine cities and city liveability (Sadler). Two ESRC (£1.1M) projects will link psychology and criminology to examine the geographies of incarceration with a focus on prison design and prisoner rehabilitation (Moran). The £1.8M NERC-ESRC-DFID ESPA MOUNTAIN-EVO project will use theoretical understanding of adaptive governance of water and mobile technologies to help alleviate poverty in remote mountain regions (Hannah, Clark) and the Birmingham-led 3.8M€ Marie Curie ITN Ecohydrological Interfaces also bridge multiple traditional disciplines (Section b).

To stimulate and support interdisciplinary research, the University founded an ***Institute for Advanced Studies*** (IAS) in 2012 (Section b). The inaugural theme on *Regeneration Economies* is co-led by Andres and Bryson, in collaboration with Chicago, and involves researchers from social sciences, engineering and education.

As part of other international collaborations, 18 UoA17 staff led/ are leading work-packages on EU, ESF or ERC projects that involve multiple partners spanning Europe and disciplines, and some lead major international research networks (e.g. Hannah - UNESCO-International Hydrology Programme). Notably, Clark led 3 ESF workshops on interdisciplinary understandings of water use in agricultural landscapes (20 partners); Milner and Hannah organised in 2013 an ESF workshop on glacier-fed rivers and climate change to establish protocols for a worldwide monitoring network of Arctic and Alpine rivers (15 partners). We participate in 3 active EU-COST programme networks: co-chairing a 23 partner group validating and comparing downscaling methods for climate change applications (Widmann); leading the UK contribution to a 12 partner work-package on the ecosystem impacts of artificial light (Sadler); and collaborating on a 15 partner EU Label Priority Area 7 Flagship Project to sustainably manage the Danube Region (Bradley). Sambrook Smith is leading in developing new water science links in North America, building on NERC-funded collaborations with Chicago.

ii. Research collaborations with non-academic end-users

End-user and policy collaboration is fundamental to all our research because not only do we provide the academic evidence-base to inform practice, but also we co-create projects with stakeholders to give them direct input into the research process and so ensure research is of wider value beyond academia. Research collaborations with ***government and its agencies*** include: UK House of Lords Select Committees on the European Union (Clark) and behavioural change (Pykett), UK Ministry of Justice (Moran), Scottish Government (Hannah), Office for National Statistics and All Party UK Parliamentary Group on Poverty (Pemberton), Defra/ LWEC (Clark, Emery, Hannah), DECC (Day), Environment Agency (Bradley, Hannah, Krause), Birmingham City Council (various), French Environment Agency (Andres), POPSU Europe (Andres), Moscow City Government (Round), Highways Agency (Chapman), CEH (Hannah, Ledger) and BGS (Krause). Local and regional government links have been strengthened and expanded since CURS joined (e.g. Department of Communities & Local Government, Birmingham City and other West Midlands councils; Lee, Andres, Sadler). Notably, Ledger and Milner are contributing authors to a British Ecological Society's Special Ecological Issues Report (first for 10 years) entitled "The Impact of Extreme Events on Freshwater Ecosystems", which was presented at both the Houses of Parliament and Scottish Parliament in 2013. Clark's work on EU governance led him to being appointed Specialist Adviser during 2010-2012 on innovation in European rural areas to the House of Lords EU Select Committee. The Committee's published report was debated in the House of Lords (House of Lords EU Committee, Session 2010-12, 19th Report, HL Paper 171).

NGO collaborations are very diverse, for example: UN Economic Commission for Europe and UN-HABITAT (Golubchikov), UNESCO-IHP (Hannah), OFWAT (Hannah), UK Technical Advisory Group for the EU Water Framework Directive (Hannah), World Bank (Round), Oxfam (Round), Migrant Workers North West (Pemberton), West Midlands Futures (Lee), French Real Estate Association (Andres), Buglife (Sadler), BTO (Sadler), Trees & Design Action Group (Sadler), Age UK (Day), Centre for Sustainable Energy (Day), National Energy Action UK (Day), rivers and fisheries trusts (Hannah, Krause, Milner), and River Restoration Centre (Krause).

Collaboration with ***industry*** and ***professional associations*** is a two-way partnership: industry can often provide data and real-world insights beyond the capability of academics, while we provide the expertise to interpret that information to the benefit of industry and blue-skies research.

We have a long history of collaboration with such partners, for example: RTPI (Lee), the Commission for Architecture & the Built Environment (Andres, Lee), MunichRe (Leckebusch), National Housing Federation (Lee), New Economics Foundation (Clark), Network Rail (Chapman), Syncrude-Canada (Kettridge), RS Hydro (Bradley, Hannah), Silixa (Krause), Clean Coal Ltd. (Krause) and water companies (various). Our MSc courses in Urban & Regional Planning and Applied Meteorology & Climatology are accredited by the RTPI and UK Met Office, respectively.

iii. Prizes

2012 Lord Stafford Award for Innovation for Environmental Sustainability (Chapman; REF3b); 2013 European Archaeological Heritage Prize (Gaffney); 2013 RGS-IBG Cuthbert Peek Award (Chapman); 2011 RGS-IBG Alfred Steers prize for "best undergraduate dissertation".

iv. Seminar series and conferences

Along with the submitted REF outputs, evidence of our research power comes from high profiles within and beyond Geography. For example, UoA17 colleagues have given >90 invited papers and convened >80 sessions at international conference (e.g. RGS-IBG, BES, AGU, AAG, EGU). Three ESRC seminar series have/ will run *Exploring Everyday Practice and Resistance in Immigrant Detention* (Moran), *Behavioural Change & Psychological Government* (Pykett) and *Renegotiating Boundaries* (Clark, Round). We hold regular British Hydrological Society national meetings in Birmingham (2-3 *per* year; Bradley, Hannah, Krause, Kettridge); for example, conference on Ecohydrology/ Hydroecology attracted >100 researchers and practitioners from >40 Universities, agencies and companies. We hosted the 2011 UK-Ireland Planning Research Conference (Andres) and 2012 British Ecological Society Annual Conference (Ledger).

v. Contribution to journal editorship

UoA17 staff contribute to international journal editorships, including: *Jl. Biogeography* (Sadler - Deputy Editor-in-Chief), *BMC Ecology* (Milner), *Ecohydrology* (Hannah, Krause), *Ecology & Evolution* (Ledger), *Espaces et Sociétés* (Andres), *Europe-Asia Studies* (Moran), *Frontiers in Atmospheric Sciences* (Leckebusch), *Geography Compass* (Clark), *Hydrological Processes* (Hannah), *International Jl. Public Sector Management* (Pemberton), *International Jl. Sociology & Social Policy* (Round), *Jl. Social Policy Studies* (Clark), *Meteorological Applications* (Chapman), *Resilience* (Pykett), *River Research & Applications* (Milner), and *Sustainability of Water Quality & Ecology* (Hannah).

vi. Contribution to peer-review

We contribute to international and UK peer-review, for example: NERC Arctic Programme Advisory Group (Milner), NERC Changing Water Cycle Scientific Writing Group (Hannah), NERC Scientific Facilities & Technology Panel (Sambrook Smith), NERC Biodiversity & Ecosystem Services (Sadler), REF Panel Assessor (Sadler), AHRC (Moran), British Academy (Ramadan), British Council (Hannah), ERC (Sadler, Tranos), ESF (Clark, Milner, Sadler), ESRC (7 staff), EU (Milner, Sadler), Leverhulme (Andres), NERC Peer Review College (8 staff), RGS-IBG (5 staff), Royal Society (Hannah), Australian Research Council (Ledger), Austrian Council for R&D (Milner), ANVUR-Italy (Andres), German Research Ministry (Leckebusch), German-Israeli Foundation for R&D (Krause), Icelandic Research Council (Milner), Kazakhstan Ministry of Science (Round), NSERC-Canada (Hannah, Ledger), NSF-USA (6 staff), NWO Dutch Research Council (Hannah), National Science Foundation of Georgia (Moran), Slovak R&D Agency (Hannah), Swiss NSF (Hannah, Milner) and TÜBITAK (Hannah).

vii. Contribution to professional associations and learned societies

UoA17 staff serve many professional bodies/ learned societies, for example: UK National Representative for the International Association of Hydrological Sciences (Hannah), UK Committee for National & International Hydrology (Hannah), BES AE-SIG Treasurer (Ledger), BHS National Committee (Bradley, Hannah, Kettridge), European Geophysical Union Ecohydrology and Catchment Hydrology Committees (Hannah, Krause, Sadler), French & British Planning Study (Andres), RGS-IBG (PoIGRG Treasurer), Secretary of the Standing International Road Weather Commission (Chapman), Soc. for Freshwater Sciences International Committee (Milner), UK Panel for the International Union for Geodesy and Geophysics (Hannah) and UNESCO-IHP (Hannah).