Institution: Newcastle University

Unit of Assessment: UoA14 Civil and Construction Engineering

a. Overview:

The School of Civil Engineering and Geosciences (CEG) comprises one of the largest civil engineering groupings in the UK and returns in excess of 40 academics to UoA14 who currently manage 49 Research Associates. Strategic development has resulted in Newcastle academics now leading the largest EPSRC civil engineering research funding portfolio in the UK (£20M as of 25 October 2013). UoA14 researchers are primarily organised in five disciplinary groups: ***Environmental Engineering*** (EE) lead *Curtis; Davenport, Dolfing, Graham, Jarvis, Neumann†, Sallis, Werner*, ***Geotechnical and Structural Engineering*** (GSE) lead *Wilkinson; Bridgens, Davie, Elia†, Fang†, Galasso†, Glendinning, Gosling, Hughes†, Masoero†, Rouainia, Vinogradov†*, ***Geomatics*** (***Geodesy and Geospatial Engineering***, GGE) lead *Moore; Barr, Berry, Clarke, Gaulton†, Grant†, King, Miller†, Mills, Palamartchouk†, Penna*, ***Transport Engineering*** (TE) lead *Blythe; Bell, Namdeo,* and ***Water Resources Engineering*** (WRE) lead *Kilsby; Bárdossy, Bathurst, Burton†, Dawson, Fowler, Liang, O'Connell, Parkin,* where † denotes an Early Career Researcher (ECR). This structure is maintained from the successful 2008 RAE submission, and has been strengthened by injection of new talent through 11 external appointments, most notably in GSE. Recognising strong inter-disciplinary initiatives across these groups, the Centre for Earth Systems Engineering Research (CESER; www.ncl.ac.uk/ceser) was established in 2009 underpinned by funding from an EPSRC Platform Grant. CESER is a University Research Centre led by the UoA and constitutes our main vehicle for *Earth Systems Engineering* (ESE) research. Local, national and international collaborations are further facilitated through the Newcastle Institute for Research on Sustainability (NIReS) and the Digital Institute.

b. Research strategy:

Vision: As one of the largest and most wide-ranging civil engineering research groupings, we have been able to establish and pursue an ambitious and synergistic programme to place civil engineering at the centre of the analysis, design and management of human-technological-natural systems. This agenda is uniquely embodied at Newcastle as ***Earth Systems Engineering*** (ESE), which combines scientific understanding with engineering analysis and design in order to provide adaptation and mitigation solutions to global change. Such a programme requires traction and integration at a wide range of scales, and the Newcastle team possesses the full spectrum of expertise to address issues at all scales from the microbial, through infrastructure assets, cities and river catchments up to global issues. ESE integrates the five research groups in this submission, in collaboration with other disciplines at Newcastle and leading research institutions internationally. Our strategic plan is to sustain our distinct and integrated research programme tailored to address the four cross-cutting ***ESE challenges*** (below). These grand challenges were originally established a decade ago, and are re-stated here with specific objectives updated to reflect our own progress in shaping and advancing research in these areas as well as changing national and international priorities.

Challenge 1: Engineering the transition to a low-carbon economy

- Design the next generation of affordable and efficient water, transport and energy systems, using technical, financial and broader sustainability metrics to determine success.

Challenge 2: Adapting physical infrastructure systems

- Improve the understanding of environmental and other risks to our infrastructure systems;
- Determine robustness and inter-dependencies, and the nature of interactions between hazards and system resilience (including technical, economic and social resilience); *e.g.* the effect of repeated or synergistic shocks.

Challenge 3: Managing and monitoring coupled human and natural systems

- Assess environmental hazards, threats and global change (*e.g.* flood, drought, sea level rise, global water cycle, tsunami, urban heat, wind, polar ice sheets), their spatio-temporal patterns, likely impacts and possible mitigation;
- Innovate new approaches to understand, simulate and effect sustainable transitions in these systems across a variety of settings - national and international - built and managed - natural and technological - physical and digital.

Challenge 4: Towards 'Ecopolis' - engineering sustainable cities of the future

- Utilise the city as a laboratory: measuring, monitoring and simulating the 'Smart City';
- Develop a fundamental understanding of the interactions within and between urban areas to

explore inefficiencies and opportunities;
- Promote and manage changed behaviour of social, governance and engineered systems to improve the sustainable use of materials and environmental justice.

To meet these challenges we have established a vibrant and ambitious research culture. This is sustained by a national and international funding portfolio combining standard, programme and platform grants with a cohort PhD programme and a global network of excellent partners in leading research institutions as well as industry and government.

Evaluation relative to RAE 2008: Our strategy proposed in 2008 was bold and, at the time, largely aspirational in putting forward specific objectives related to the ESE Challenges described above. The objectives set in 2008 are summarised below with an assessment of progress against each. Overall, we assert that we have comprehensively exceeded the ambitious targets we set ourselves, as evidenced by our research outputs - in-line examples below referenced by [*staff name* and *output number*]. This has been facilitated by major RCUK grant support, including a Platform Grant in ESE, a Frontier Engineering Award, the Infrastructure Transitions Research Consortium (ITRC) Programme Grant, a Dream Fellowship and four research council Fellowships, allowing us to put in place sustainable research programmes with development of staff, methods and data resources that have engendered new initiatives not envisaged in 2008. This strong funding position has ensured opportunities for home grown talent to flourish as well as new blood and experienced, internationally leading research appointments to be made (*e.g. Bárdossy, Berry*).

Objective 1: *To develop a diverse range of engineering technologies for climate change mitigation, focusing on urban transport, geothermal energy, carbon sequestration and carbon-neutral / carbon-negative wastewater treatment.*

In the EE group, research on engineered biological processes, anaerobic-aerobic sequence reactors and fuel cells for carbon-neutral wastewater treatment led to the first successful pilot scale demonstration of hydrogen generation from wastewater with a microbial electrochemical system with Northumbrian Water Ltd. (NWL) and the construction of a full-scale industrial waste treatment plant by L'Oreal (see Impact Case Study, ICS 2). Our unique capability at the leading edge of microbial ecology underpinned this work, allowing theory [*Curtis 1; Dolfing 1*] developed from laboratory and field studies [*Dolfing 4; Graham 1-3*] to inform and improve industrial practice [*Sallis 1, 4*], and led to an EPSRC £5.6M Frontier Engineering Award and the Water Stewardship Innovation Award for our industrial partner (L'Oreal) at the 2013 Global Water Summit in Seville.

The TE group, in collaboration with local authorities and electric vehicle companies, has pioneered the evaluation of new technology and its role in delivery of UK policy on air quality and climate change. Highlights from a series of EPSRC projects include: Futures [*Bell 2, 4*] which showed that new vehicle standards have failed to improve air quality; 4M [*Bell 4*] qualified the role of vehicle technology, including electric vehicles (eV) [*Blythe 1, 4; Namdeo 4*] to deliver reduced emissions and pollution; Footlite developed technology to encourage eco-driving behaviour; MESSAGE and Lamppost [*Bell 1*] developed a data integration platform (with the GGE group) for pervasive environment sensor systems. Switch-EV [*Blythe 1, 4*] developed and used energy monitoring system in-vehicle and charging posts to evaluate driver and charging behaviour and attitudes to the uptake of eV, helping place Newcastle top of Forum for the Future's *Sustainable Cities Index* in their most recent assessment (2010).

Objective 2: *To predict and manage the reliability of physical infrastructure in the face of intensifying environmental stresses, embracing novel and traditional materials, and advanced methods for system reliability analysis, in applications including fabric structures, slope stability and decontamination of soils and sediments.*

At site and building scale, advances in measurement and analysis have been made by the GSE group in structural fabrics, soils and slope stability. In geotechnics, the full-scale embankment Earth Systems Laboratory funded by EPSRC BIONICS 1 and ISMART projects has been used for investigation of the effects of weather events and vegetation on stability under a changing climate and to help develop integrated remote surveying techniques for slope stability hazards in the EPSRC "Transport Corridors" project [*Barr 2*]. Electrokinetic geosynthetics (EKG) have been developed and used in commercial innovations for large volume waste reduction, soft soil consolidation and slope stabilisation [*Glendinning 1-4;* ICS 3]. Other work has addressed the use in hostile environments of fabric structures [*Bridgens 1, 3*] with the new EPSRC project "Providing Confidence in Durable Composites" [*Gosling 4*], concrete [*Davie 2-4; Masoero 1; Wilkinson 3*] in EPSRC/NDA project SAFE Barriers and EPSRC "Prediction and Analysis of Spalling in Concrete Structures", as well as steel [*Fang 1*].

At the system scale, pioneering integrated assessment models [*Dawson 1*] have enabled quantification of multiple interdependent climate risks to facilitate long term planning of coastal settlements and infrastructure, whilst comprehensive EPSRC funding (ITRC, RESNET, SHOCK, i-BUILD *etc*.) has enabled development of data resources and systems models for the analysis and adaptation of inter-dependent infrastructure systems aligned with ESE Objective 4. The 2013 appointment of *Galasso* from the seismic catastrophe modelling industry enables a new cross-disciplinary strand of *Catastrophe Engineering* covering flood, wind, tsunami (*Liang's* code used in operational forecasting) and resilient design [*Wilkinson 1, 2, 4*]. This area has driven further development of future climate hazard technology, *e.g.* extreme rainfall models [*Burton 1; Kilsby 3*] developed *via* the UKCP09 Weather Generator (ICS 5) informed by analysis of probabilistic climate model outputs [*Fowler 1, 3, 4*]. Further developments include spatial models of flood, drought and wind used for assessing reliability of electricity transmission networks and other critical infrastructure [*Kilsby 1, 4*] and methods to attribute risks.

Objective 3: *To pioneer new inter-disciplinary approaches to the simulation and management of the water cycle, including geodetic assessment of the global water and polar ice balance, and a coupled human-technological-natural systems approach to land and water resources management, diffuse pollution control, treatment technologies and flood risk*.

Within the GGE group, a new global GPS-derived surface velocity field has been applied to the problem of 20th and 21st C sea-level. 12 GGE papers, including *Nature* and *Science* outputs, are cited in the 5th IPCC Assessment Report (AR5) and contributed to the American Geophysical Union (AGU) Geodesy Section Prize for *King* and his invitation to present the 2012 Bullerwell Lecture at the European Geosciences Union (EGU). Polar work is a particular focus *e.g.* the development of remote sensing techniques for modelling change in glacier systems [*Barr 3; Mills 1*], ice loadings in the West Antarctic Peninsula [*Clarke 2*] and Antarctic ice mass change [*King 4; Moore 1, 4*]. This work links to research on ocean loading and tides [*Clarke 3; Penna 2, 3*].

GGE collaboration with the WRE group, funded by the European Space Agency (ESA), resulted in the development of river discharge measurement from space [*Berry 3, 4; Moore 2*] and the appointment in 2013 of *Berry* as Professor of Altimetric Engineering. ***Berry's*** research contracts with ESA and the EU on Cryosat-2 with application to the launch of ESA's Sentinel-3 have moved with her. Research on integrated river basin management using hydrological models has been pursued globally, including Latin America [*Bathurst 4; Parkin 1*], the Upper Indus, and the Nile.

Flood Risk Management research has addressed land use change funded by EPSRC/Defra [*O'Connell 1*] and moved onto hydrodynamic modelling [*Liang 1-4*], coupled hydrodynamics agent-based models to simulate human agency [*Dawson 3*] and been applied to urban flooding in the new EPSRC projects FloodMEMORY and Blue Green Cities. Methods for uncertainty analysis [*Dawson 4*] have been applied by the Environment Agency to understand the implications of uncertainties on long term flood risks in the Thames Estuary 2100 programme. Furthermore, Newcastle joined the prestigious Willis Research Network (WRN) in 2010, ensuring relevance to the insurance industry and international collaborative opportunities with top global institutes such as Princeton and ETH Zürich. The simulation approach has been reinforced with evidence-gathering field programmes for the Environment Agency (EA) as presented to the Parliamentary Office for Science and Technology (ICS 1) and for Defra's Eden Demonstration Test Catchment. The coupled systems approach is exemplified by future flood risk and water resource studies [*e.g. Fowler 3*] which build stakeholder knowledge and involvement into the risk assessment process.

Objective 4: *To deliver new whole-system approaches to simulating and managing entire cities, through the synergistic integration of our core disciplines and building upon our Tyndall Centre research under the Cities Programme.*

The recognition of the necessity to represent inter-dependent systems and a focus on the city as a laboratory for our research has borne fruit in understanding emergent city-scale phenomena such as the urban heat island [*Barr 1*] as well as understanding the interactions between social processes (*e.g.* long term land use change) and major engineering challenges such as managing flood risk [*Dawson 2*] and many more outputs published, in press or forthcoming. This evolved from the Tyndall Centre Cities Programme into further EPSRC projects: ARCADIA, ITRC, *Dawson's* Fellowship *etc*. Work on detailed surface flood modelling incorporating explicit building information (EPSRC/JISC Flood Modelling for Cities using Cloud Computing) has proved timely and invaluable in analysing city-wide flooding impacts on cities such as Newcastle for resilient transport and other infrastructure planning. The EPSRC ESE Platform Grant has been particularly valuable for strategic funding for ECRs to develop underpinning technologies, data resources and simulation models. Developments include a real-time capability to create a decision support system for traffic

operation and modelling scenarios with real-world implementation in Medway, Kent [*Barr 4*].

Sustainable transport scenarios for transitions through to 2050 have been created by EPSRC projects SOLUTIONS [*Namdeo 1*] which investigated the effect of different urban forms on sustainability, REVISIONS which extended impacts to include water, waste and energy, 4M which quantified carbon footprint from household to city, and SECURE [*Namdeo 1*] which studied inefficiencies in the provision of transport, food, water and waste. A key finding using *Platform Integrated Traffic, Health Emissions Modelling* [*Namdeo 2, 3*] is that fundamental understanding of human behaviour and attitudes (*e.g.* accident risk due to driver boredom, age related functional decline [*Blythe 3*], tailpipe emissions, use of energy [*Blythe 1*] and water cannot be ignored, confirming that the ESE integrated human-technological-natural systems approach is essential.

Future strategy: Mindful of the effectiveness of the ESE paradigm in providing focus and synergy across the UoA and more widely (*cf.* Special Issue on ESE of *Proc. Inst. Civ. Eng.-Eng. Sustain.*, 2013), we will invest further to meet the updated objectives for the ESE Challenges detailed at the start of this section. Specifically we will:

(a) Continue to execute our ESE mission: observe, analyse, simulate and design coupled human-natural-technological systems, seeking priority renewal of our EPSRC Platform Grant in 2014 and training a new cadre of Earth Systems Engineers through our PhD programmes;
(b) Capitalise on our unique data sets and bespoke modelling systems to demonstrate their utility in providing the evidence to make radical changes to designs for future cities and infrastructure systems necessary to deliver truly sustainable solutions;
(c) Pursue a global perspective on the impacts of geohazards and climate change on infrastructure, *e.g. via* geodetic monitoring of the cryosphere, global water cycle, solid Earth and built structures, through a newly awarded ERC Consolidator Grant on changing hydrological extremes and through Earth Systems Observation and Modelling within the newly awarded IAPETUS NERC Doctoral Training Partnership;
(d) Develop our most ambitious Earth Systems Laboratory that directly observes and monitors human, environmental and infrastructure behaviour, performance and crucially their interactions over the long term. This will make full use of the University's new *Science Central SURE* programme (see below) which operates on neighbourhood, urban and regional scales;
(e) Create new specialisms within ESE by building on recent appointments such as *Galasso* and *Masoero* in structural and catastrophe engineering, *Berry, Gaulton, Grant* in remote sensing, and *Bárdossy* to bring new directions to Earth Systems Modelling;
(f) Pursue further inter-disciplinary opportunities through our new i-BUILD centre, CESER and NIRES using a portfolio of traditional and innovative methods, *e.g.* agent-based modelling as well as statistical and physically-based methods, building on research underway in FloodMEMORY and proposed in two other EPSRC projects.

c. People

c1. *Staffing strategy and staff development*

Appointment strategy has been on the basis of research excellence recognising the need to maintain disciplinary strengths as pillars on which to build inter-disciplinary work. We have maintained strength across groups whilst the core GSE group has doubled its FTE relative to the RAE 2008 submission. Further specialist expertise has been added by the appointments of *Gaulton* in remote sensing, *Masoero* in materials, *Neumann* in environmental chemistry. Equally, we recognise that ESE demands skills bridging disciplines, so the dual appointments of *Dawson* (previously School Research Fellow and ECR in RAE 2008) as *Professor of ESE* and *Bárdossy* as *Professor of Earth Systems Modelling* add wide-ranging subject expertise (flood hydrology, climate, risk, groundwater) and methods (geo-statistics, copula, agent based modelling). Balance has also been sought between internal academic appointments (five in period: *Dawson, Fowler, Hughes, King, Penna*) to capitalise on developed expertise, and external recruitment (11 in period: *Bárdossy, Berry, Elia, Fang, Galasso, Gaulton, Grant, Masoero, Namdeo, Neumann, Vinogradov*).

International recruitment to established academic level has been strong in the last two years, with *Bárdossy* (Germany), *Elia* (Italy), *Galasso, Grant, Masoero, Neumann* (all USA) appointed on the back of global recruitment campaigns. Visiting scholar arrangements are encouraged and CEG's academic staff sabbatical policy enables research visits overseas of at least three months, including *Bathurst* (Chile), *Fowler* (USA), *Liang* (China, Japan), *Penna* (USA), *Rouainia* (Barcelona), *Sallis* (Malaysia) since 2008. CEG has six visiting professor appointments and has welcomed 227 visiting staff members during the assessment period.

Career development is a priority and is addressed *via* PDR (Performance Development Review)

and within research groups as follows:

- ***Mentoring*** is provided to all new staff within their research group to advise, integrate and build networks. A new faculty system assigns experienced mentors from other Schools to new academic appointments (optional for existing staff). ECRs are initially assigned low teaching duties so that they can cultivate their research. New academics are required to complete the Certificate in Advanced Studies in Academic Practice, which provides training in teaching and knowledge transfer skills. All external research proposals are subject to internal peer review by senior colleagues. The success of this strategy is evidenced by the high quality outputs of our ECRs.
- ***PDR*** is annual, with a six month interim review. All academic staff maintain a Personal Research Plan that is reviewed in PDR and sets and reviews research objectives in grant applications, paper writing, PGR supervisions, networking, workloads and professional training requirements which are met by the Staff Development Unit, for example the successful programme for new and aspiring Principal Investigators, or targeted external provision where appropriate.
- Academic staff ***workload*** is managed by allocating credits for research project management, proposal writing, scholarship, conference attendance, publications and external examiner duties. ECRs are given additional ring-fenced research time on a sliding scale from 400 hours in the first year to 100 hours in the fourth year of appointment.
- ***Research Training Development*** (RTD) funds of £1200 p.a. are allocated to all academics (and Fellows) for travel, networking, proposal development and scholarship alongside Group RTD funds for activities such as seminar series support, workshops and annual "away days". Depending on requirements, start-up accounts of two-year duration (up to £12k p.a.) are provided to all new academic appointments to supplement their RTD resource and stimulate immediate research activity. We also invest strategically in equipment and facilities to attract the best new talent to Newcastle (*e.g.* HPC - *Masoero*; Mössbauer spectrometer - *Neumann*).

Career progression and Research Concordat: Our 49 current Research Associates are provided with mentoring, PDR and travel funds. In September 2010, the University secured the HR Excellence in Research Award for reviewing policies against the principles of the Concordat in 2009, followed by institution-wide implementation of improved policies and PDR processes. Following a recent review, the University has retained the award for a further two years until 2014. A ***Career Pathways Framework for Research Staff*** is provided, which identifies five principal career pathways for researchers. The ***Fellowship*** pathway has been facilitated by the competitive award of Research Fellowships to PDRAs with excellent track records, firstly *via* School Fellowships (since 2007) and since 2012 *via* Faculty Fellowships. *Miller* (GGE) currently holds a School Fellowship whist *Dolfing* (EE) was awarded a three-year Faculty Fellowship in 2012. Support for career continuity is augmented by £4k p.a. to be used to fund activities in support of external fellowship applications and broader development, *e.g.* to assist with funding visiting researchers, visits to international labs and hosting a workshop to explore new lines of research.

Early Career Researchers: in 2008 we submitted 14 ECRs of whom nine are submitted again: *Dawson*, *Fowler* and *King* (now Chairs); *Jarvis* (Reader); *Davenport*, *Liang*, *Penna* and *Werner* (Senior Lecturers); *Davie* (Lecturer). We include 12 ECRs in this submission: *Burton, Elia, Fang, Galasso, Gaulton, Grant, Hughes, Masoero, Miller, Neumann, Palamartchouk, Vinogradov*.

Competitive external fellowships include: *Curtis* EPSRC Dream Fellow (2011-13); *Davenport* RCUK Academic Fellow (2007-12), EPSRC Challenge Engineering Fellow (2011-16); *Dawson* EPSRC Career Acceleration Fellowship (2010-2015); *Fowler* NERC Postdoctoral Fellow (2006-10), ERC Consolidator Grant (2014-19); *King* NERC Postdoctoral Fellow (2006-09), RCUK Academic Fellow (2009-2012); *Werner* Humboldt Fellowship for Experienced Scientists (2012-14).

Equality and diversity commitments are managed by the University, reinforced by its "Single Equality Scheme and Action Plan" launched in 2010. In a 2013 staff opinion survey conducted by Capita, 99% of CEG staff felt safe and secure in their working environment (*cf.* 93% national HEI median). In gender equality, the University became an Athena Swan institutional Bronze Award holder in 2009 with the ambition of Silver status by 2015. CEG has appointed *Gaulton* School Champion with the initial objective of departmental Bronze Award status by 2014. Maternity and paternity leave are managed by temporary appointments to maintain momentum in research proposals and publications. A successful example is *Fowler* who has published uninterrupted and achieved promotion to Chair with two periods of maternity since 2008. We benefit from academic and research staff drawn from 20 different nationalities (including 10 non-EU).

c2. Research students

An outstanding cadre of more than 100 current doctoral researchers is central to the promotion and

dissemination of our research vision and culture. Since 2008 we have succeeded in a policy of recruiting higher quality students through rigorous competitive interview and applying higher academic and English Language standards. A cohort approach has been followed for the majority of PhD appointments, strongly aligned with funded projects and pooling our EPSRC and NERC Doctoral Training Account funds. Students are co-located in a custom designed centre in CEG. We plan further consolidation in this direction with the recently-announced NERC 'IAPETUS' Doctoral Training Partnership (Newcastle, Durham, Glasgow, Stirling and St Andrews) where UoA staff, notably in GGE and WRE, contribute to the themes of "Global Environmental Change", "Geodynamics and Earth Resources", and "Hazard, Risk and Resilience". As well as advertising opportunities nationally and internationally, we operate a policy of nurturing strong undergraduates and taught postgraduate students, taking advantage of our provision of an integrated portfolio of 18 MSc programmes. As well as alignment of studentships with successfully funded areas, some seeding of innovative areas and funding for new staff is ensured (all new academic appointees are guaranteed a PhD studentship to commence within two years of their start date).

Funding: DTA allocations averaging six per year are augmented by STREAM EngD studentships (six in progress), internationally-funded students and one-off funds, such as a Vice Chancellor's scheme aligned with the University's Sustainability Societal Challenge theme (two studentships).

Monitoring and support: CEG and Faculty Graduate School have invested in training, induction and the *e-portfolio* system which provides a record of the student's personal development. Monitoring and support is provided by CEG and Graduate School with the new *e-progression* system. Annual progression is reviewed by a panel of two academics who are independent of the supervisory team of at least two. An annual Postgraduate Conference is held and all students have budget to attend two national and one international conference during their studies.

Development: Employment of PhD graduates as researchers is strong, with at least nine in the last five years: Christgen, Forsythe, Heidrich, Manning (PDRAs at Newcastle); Jones - NCAR (USA); Geris - University of Aberdeen; Speight - Scottish Environment Protection Agency; Hardy - Lecturer at University of Aberystwyth; Clement - researcher in policy analysis at IWMI Nepal.

EPSRC Doctoral Prize Fellowship: We facilitate applications for this prestigious Prize for recent students: Dunn (PhD student in GSE) was successful in 2013 and will use the funding to continue her research with new member of staff *Galasso* on "Increasing the resilience of our communities in a changing climate through adaptation of infrastructure systems".

d. Income, infrastructure and facilities

Income summary: Our current research spend of £23M in the assessment period equates to £112k per FTE per annum, increased from £65k in RAE 2008. Funding is primarily drawn from RCUK (£14M), with £2.2M from industry and £6M from other sources, of which £2.7M is from the EU. Our strategy of targeting national and international funding (RCUK, EU) and international organisations (L'Oreal, Willis, Google, *etc*.) is proving increasingly successful in overcoming the relative scarcity of potential major industrial partners in the North East region (Nissan, NWL).

Research Portfolio: *UK funding*

EPSRC funding constitutes the majority of our research income, with the largest current portfolio of any civil engineering department in the country (as of 25 October 2013) comprising 14 grants worth £20M awarded to UoA14 PIs. Key EPSRC projects led, or with a major component from UoA14 researchers, awarded during the assessment period include:

- ***Large grants:*** Social Inclusion in the Digital Economy (SIDE), Self Conserving Urban Environments (SECURE), two Platform Grants (one across the School in ESE, one in EE group), Programme Grant (ITRC);
- ***Frontier Engineering Award:*** "Simulation of open engineered biological systems";
- ***National Infrastructure Plan 2011:*** Infrastructure BUsiness models, valuation and Innovation for Local Delivery (i-BUILD) Centre (jointly funded by ESRC);
- ***Standard grants:*** include RESNET, ARCADIA, CREW, SCORCHIO, FloodMEMORY, Blue-Green Cities (all under *Adaptation and Resilience in a Changing Climate Coordination Network*).

NERC funding is also substantial, with 25 grants awarded since 2008 and a total value of £4.6M. Active projects in the period, classified under the following thematic areas, include:

- ***Living With Environmental Change (LWEC) programme:*** SINATRA (*Flooding from Intense Rainfall* theme), CONVEX (Convective rainfall - under *Changing Water Cycle*), *Flood Risk from Extreme Events* programme (FRACAS and "Land Use Management Effects in Extreme Floods");
- ***Greenhouse gas mitigation studies:*** Examples include "Role of methanobactin and copper in

methane oxidation rates in the environment" and "Impact of methanotrophs, methanogens and geochemical conditions on net methane flux to the atmosphere from Arctic soils";
- ***Geodesy and Geospatial Engineering:*** "Reducing the uncertainty in estimates of the sea level contribution from the westernmost part of the East Antarctic Ice Sheet", "The spatial and temporal distribution of 20th Century Antarctic Peninsula glacier mass change and its drivers", "GNSS Wave Glider: a new tool for sea level and sea state measurement", "Dual-wavelength laser scanning for forest health monitoring", "Regional gravity fields from GOCE and GRACE".

Research Portfolio: *overseas funding*

EU Framework 7: UoA staff have been partners in 14 projects since 2008, with a Newcastle spend of £2.7M, in transport engineering (SAVE ME, Balance@Home, VERITAS, OASIS, SMARTCEM, COMPASS-4D, TEN-T), sustainable cities (RAMSES, DESAFIO), climate risks (ECLISE), environmental engineering (CORAGEM), altimetric engineering (LOTUS) and industrial waste treatment (ENERMIN, MERMAID International Training Network for microbial ecology in water engineering).

ESA has funded projects in altimetric engineering; CRUCIAL and "River and Lakes", GOCE User Toolbox (GUT), and REGINA.

EU COST Actions led by Newcastle with major international networks include: TU1202 Impact of climate change on engineered slopes for infrastructure; TU0902 Integrated assessment technologies for sustainable development of urban areas; ES1103 Microbial ecology and the earth system; ES0701 Improved constraints on models of glacial isostatic adjustment.

Provision and operation of specialist infrastructure and facilities

Our research demands, and benefits from, outstanding facilities which are sustained and expanded through pro-active review and continuous investment in both technical and human resources. These facilities include a suite of 30 on-site specialist and collaborative laboratories, a unique set of full scale Earth Systems Laboratories and extensive ICT capabilities, all supported by qualified, dedicated technical staff. On-site specialist group facilities include:

- EE researchers benefit from molecular microbiology capacity that is unique in the UK (*e.g.* Ion Torrent DNA sequencing system with dedicated bioinformatics clusters, pipelines and support, qPCR instrumentation, DNA purification and liquid-handling robots, flow cytometer and epifluorescence microscopy), analytical chemistry (*e.g.* Liquid Chromatography MS- ion trap and triple-quad; ICP-OES and ICP-MS for metals analysis; Mössbauer spectrometer) and pilot plant facilities (multi-instrumented data-logged replicate lab-scale reactors);
- GSE labs include heavy reaction frames and strong floors for large scale structural testing, climate-controlled bi-axial and tri-axial testing rigs, dynamic tri-axial testing rigs and seismic simulation table. We also possess state-of-the-art strain field measurement capabilities, *e.g.* Digital Image Correlation for 2d and 3d analysis, Hall Effect transducers and bender elements. Such facilities give us specialised, and in the case of the bi-axial test rig, unique capabilities;
- GGE field equipment and processing facilities, housed in a dedicated laboratory, include an Unpiloted Aerial Vehicle (UAV), two terrestrial laser scanners, visible, near- and thermal-IR cameras, 10 geodetic GNSS receivers (plus 14 base stations deployed in Antarctica and two in the UK, as well as a GNSS Network of Sensors for deployment in polar geodesy), field spectroradiometer, meteorological sensors;
- TE labs including a rapid prototyping facility to test ICT systems and services using immersive video in virtual reality cave, driving simulator with eye-tracking system and bio-harness;
- Our extensive WRE hydraulic labs include a range of tilting re-circulating flumes up to 18 m long, a 19 m sand bed for hydromorphology, fluid-structure interaction and floating debris modelling, a rainfall-runoff simulator, and a high-pressure valve testing rig.

Earth Systems Laboratories are a unique platform for inter-disciplinary systems scale research, fusing theory with large scale experimentation and demonstration, comprising:

- The BIONICS national facility is a densely instrumented full-scale section of infrastructure embankment with climate control capability; used to assess vulnerability to climate change and test innovative new monitoring systems in collaboration with major infrastructure asset owners, UK-wide universities and the British Geological Survey (BGS);
- An experimental groundwater borehole array at Cockle Park Research Farm comprises nine single and multi-piezometer boreholes up to 150 m deep, developed with the UK water industry, and used for testing new geophysical equipment and borehole management techniques;
- The Eden CHASM / Demonstration Test Catchment (DTC) contains ~ £1M worth of

instrumentation and is a UNESCO designated HELP basin. The site is a Defra flagship site addressing sustainable farming and mitigating sediment and nutrient pollution. The DTC site hosts the NERC Environmental Virtual Observatory Pilot where telemetry and web-based maps and models are available to a wide range of local stakeholders and national policy makers;
- Unparalleled research access to the only full-scale passive metal mine water treatment system in the UK (designed by Newcastle University; see ICS 4), dedicated pilot- and laboratory-scale mine water treatment facilities, complemented with national water quality data sets on mine water pollution through unique collaborations with the EA and Coal Authority;
- EE lab-scale laboratories are complemented by a new unique large-scale replicate pilot-plant facility under design with NWL at one of their full-scale works, anaerobic digestion (Nafferton Farm), temperate (microbial fuel cells), tropical and industrial wastewater treatment (see ICS 2);
- The Belford Catchment Flood Solution Project was one of the first full-scale natural flood management projects to be created in the UK (see ICS 1). The site was fully instrumented and thus the key evidence gathered determined both the causes of flooding in the village and proof that the soft engineered methods could address flash flooding at this scale.
- TE host the Tyne and Wear 'Urban Traffic Management Control' (UTMC) System funded by DfT and Local Authorities. Live data capture simultaneously from 150 traffic loop detectors from Medway towns, pervasive monitoring (CO, NO, NO_2, O_3, noise) arrays in Medway (108), Newcastle (24), Gosforth (14) and met stations in Medway (3) Newcastle (1). A fixed site with precision monitoring (NO, O_3, NO_2) for sensor validation and portable exposure monitoring equipment for noise (10), CO (5) and particulates (2).
- The GGE group contribute to national and global geodetic infrastructure through their Morpeth geodetic GNSS facility, including the 'MORP' IGS station (part of the NERC BIGF, EUREF and IGS networks), the 'MORG' Leica SmartNet reference station and the 'MORO' Ordnance Survey fundamental GeoNet station. GGE also operate the 'NSLG' GNSS receiver at North Shields in the UK Tide Gauge and IGS 'TIGA' networks, and host a Topcon NRTK reference station 'NCLV' and the Ordnance Survey national GPS network 'NCAS' station. Operation of the IGS Global Network Associate Analysis Centre (GNAAC) and Associate Analysis Centre of the International Laser Ranging Service contribute to international state of the art geodetic analyses underpinning the development and evolution of the International Terrestrial Reference Frame.

CEG specific ICT resources are administered by three dedicated ICT specialists, and include:

- *Hardware:* 30 Blade servers; 236 node dedicated geodesy Linux condor cluster with some 100 Tb storage; two GPU arrays; 300 node Condor cluster administered by the Digital Institute;
- *Software:* a full range of state-of-practice industry software (*e.g.* FEM software including Plaxis and Flac for geotechnics, Abaqus and Ansys for structural applications; Terrasolid laser scanning suite; MODFLOW-based Groundwater Modelling System), as well as specialist scientific processing (*e.g.* GIPSY-OASIS, Bernese and GAMIT geodetic quality GNSS processing suites; BGS's GSI3D geological modelling software), and in-house research code (*e.g.* SHETRAN catchment modelling system; FAUST precise orbit determination).

Research Portfolio: Consultancies and professional services

Our philosophy is to only pursue consultancy (as distinct from collaborative research) where we have a unique skill set which is unavailable through normal commercial channels, with the primary aim being knowledge transfer. An example is in the GGE group where specialist GNSS processing expertise is applied to the monitoring of oil platform subsidence for Shell, BP and others. Two contracts from The Survey Association (TSA) have assessed Network RTK GNSS system performance in Britain, and developed best practice Network RTK positioning guidelines for the survey profession. Such projects help support the critical mass of researchers in GGE.

In a similar fashion, composite materials expertise in the GSE group has led to a combined testing, characterisation and analysis service for technical textiles in a variety of sectors including the construction, aerospace and automotive industries. Income raised from this unique professional service has been re-invested into the development of a state-of-the-art biaxial and shear test rig and also part-financed GSE research staff. Clients include Arup and Serge Ferrari, with a growing portfolio of high-profile projects, including the London 2012 Olympic Stadium.

Regular *pro bono* work is performed by EE staff, including disaster relief with Red Cross, Red Crescent and Médecins Sans Frontières and the design of a water treatment system for reducing risk of cholera in Haiti. Consultancy is often aimed at developing guidance for environmental protection, including Port of Tyne, Environment Agency, City of Newcastle and the Centre for Process Innovation. *Curtis, Graham, Dawson and Kilsby* are advisors to international companies

such as Keppel Corporation (Singapore), Calysta Bioenergy (San Francisco), and EDF Energy.

Continuing Professional Development (CPD) provision to the global profession is achieved by a dedicated Professional Development Unit in CEG, transferring our knowledge through a portfolio of short and bespoke courses, with delegates from 37 countries since 2008 turning over some £200k *p.a*. in course fee income (see http://www.ncl.ac.uk/cegs.cpd/download/cegcpd.pdf). We work closely with all relevant professional institutions, for example we host both the ICE North East regional office and their weekly evening lecture series, and contribute to best practice guidelines and specifications, *e.g. Mills* sits on the RICS Mapping And Positioning Practice Panel (MAPPP).

Investments (current and planned)

A key planned investment is the NIReS-led Science Central faculty initiative which will house our new Sustainable Urban Research and Engagement (SURE) research centre on an integrated city-centre site where research will sit alongside business, enterprise and the community. The SURE Long Term Urban Research Facility is part of a £50M University investment including £650k for city-wide monitoring and some £5M for lab and ICT facilities including data visualisation and a Decision Theatre. A major investment in PhD research is our recently awarded NERC Doctoral Training Partnership, IAPETUS, where our technical strengths in Earth Observation and geodesy, in our field equipment pool and Earth Systems Laboratories are highlighted as flagship facilities of the partnership. A further planned investment is our hosting of a European Research Council Consolidator Fellowship (value €2M, with a team of four PDRAs) "Intelligent use of climate models for adaptation to non-stationary hydrological extremes" awarded to *Fowler* to run from 2014-2019.

e. Collaboration and contribution to the discipline or research base

The nature of our ESE funded research and its outputs are highly collaborative and end-user focussed. This is evidenced by our EPSRC research portfolio where of 49 grants active in the period associated with UoA14 investigators, 44 are collaborative with other institutions, with 43 different UK universities. There are 250 other unique partners (by EPSRC definition of providing a financial contribution) on these 49 grants, constituting a very active end-user community (*Source*: EPSRC Grants on the Web, accessed 25 October 2013). Our published research also shows the inter-disciplinary and collaborative nature of our ESE work, with UoA14 authors contributing to some 354 ISI cited papers in the period 2008-2013 co-authored with a total of 232 unique institutions, with 166 of these based overseas. Furthermore, 58 of the co-authors are "end-users" (*e.g.* industry or government departments) rather than from research institutions (*Source*: Web of Science, accessed 25 October 2013).

Key collaborations and interactions: A strategic approach to promoting key collaborations has been adopted, focusing on leading institutions closely aligned with our objectives. This includes:

International: Stanford University's Prof. Luthy and his centre "Re-inventing the Nation's Urban Water Infrastructure" are longstanding collaborators and work jointly on pollutants [*Werner*]. *Fowler* led workshops and co-authored papers with National Center for Atmospheric Research (USA). Prof. Allenby of Univ. of Arizona initiated ESE in 2000 and has advised CESER since its founding; *Masoero* works with MIT's Concrete Sustainability Hub and ETH Zürich's Institute for Building Materials; *Kilsby* is Senior Academic with the Willis Research Network of 30 institutions working on risk and insurance; *Liang* collaborates with the Disaster Prevention Research Institute (DPRI, Kyoto) and European Joint Research Centre who both used his model for tsunami forecasting; *Dawson* is on the steering group of the Urban Climate Change Research Network managed by Columbia Univ.; In India, IIT Delhi, Chennai and Mumbai collaborate with *Bell*, *Namdeo* on UKIERI and PMI2 projects and IIT Delhi with *Graham* on antibiotic resistance; the Institute of Research for Development (France) jointly publish on pollutants [*Dolfing*]. *UK:* Newcastle led the Cities programme [*Barr, Dawson*] within the Tyndall Centre for Climate Change Research, a multi-disciplinary consortium of eight UK universities plus Fudan (China); NERC CONVEX project [*Fowler*] funds an RA based at the Met Office/Hadley Centre who also collaborated on NERC project on ensemble flood forecasts [*Parkin*] and UKCP09 climate projections (ICS 5); Prof. Aplin at Durham Univ. collaborates with *Rouainia* on shale gas and rock properties, whilst Prof. Bentley and Dr Whitehouse collaborate with *Clarke, King, Moore* through NERC grants on polar ice sheets and loading; Prof. Hall at Oxford Univ. leads the ITRC where Newcastle provide water sector models [*Curtis, Kilsby*] as well as the underpinning spatial database and modelling [*Barr*].

Leadership and esteem: Some selected examples during the assessment period are:

Environmental Engineering. ***Fellowships, awards and prizes:*** *Curtis* - EPSRC Dream Fellowship (2011-13); *Davenport* - RCUK Academic Fellow (2007-12), EPSRC Challenging

Engineering Awardee (2011-16); *Werner* - Humboldt Fellowship for Experienced Scientists, Germany (2012-14); *Dolfing, Graham* - Runner-up Awards for Science Merit from the American Chemical Society. ***Editorial boards:*** *Curtis* - ISME J., Water Res., Environ. Microbiol.; *Dolfing* - Appl. Environ. Microbiol.; *Graham* - Front. Microbiol. (Assoc. Ed.). ***Boards and committees:*** *Graham* - Scientific Advisor to Calysta Bioenergy Corporation, USA; *Jarvis* - Int. Steering Committee of Global Acid Rock Drainage guidelines, Technical Expert Advisor to UK Coal Authority, Executive Councillor of Int. Mine Water Assoc.

Geotechnical and Structural Engineering. ***Fellowships, awards and prizes:*** *Glendinning* - Royal Acad. Eng. Industrial Secondment. ***Editorial boards:*** *Glendinning* - Proc. Inst. Civ. Eng.- Eng. Sustain. (Chair); *Gosling* - Appl. Math. Model.; *Glendinning, Rouainia* - Geotechnique. ***Boards and committees:*** *Davie* - RILEM Technical Committee 227-HPB Physical Properties of High-Performance Concrete at High Temperatures; *Glendinning* - US Transportation Research Board on Cementitious Stabilisation, ISSMGE Committee on Transportation Geotechnics; *Gosling* - UK representative on CEN248 WG4 Coated Fabrics, CEN250 WG5 Membrane Structures, BSI TCI/69 Coated Fabrics, Int. member of AIAA Technical Committee. ***Peer review colleges:*** *Glendinning, Gosling, Wilkinson* - EPSRC. ***Learned societies:*** *Wilkinson* - Soc. of Earthquake and Civil Eng. Dynamics (SECED). ***Conference keynotes:*** *Gosling* - TENSINet 2010 and 2013.

Geodesy and Geospatial Engineering. ***Fellowships, awards and prizes:*** *King* - NERC Postdoctoral Fellow (2006-09), RCUK Academic Fellow (2009-12), Philip Leverhulme Prize 2009, AGU Geodesy Section Prize 2012. ***Boards and committees:*** *Clarke* - Chair of NERC Geophysical Equipment Facility Committee, IAG National Correspondent, UK IUGG panel; *King* - Chair of NERC Space Geodesy Facilities Committee, Chair of Int. Assoc. of Geodesy Sub-commission 3.4; *Mills* - ISPRS Council (2012-16), President of ISPRS Tech. Commission V (2008-12), Chair ISPRS Working Group I/4 (2004-08), RICS Mapping and Positioning Practice Panel; *Miller* - RSPSoc Council; *Moore* - EU Galileo Geodetic Reference Interface Working Group, IAG GGOS Working Group on Vertical Datum Standardization; *Penna* - Chartered ICES Geospatial Engineering Practices Committee, IGS Tropospheric Product Working Group. ***Peer review colleges:*** *Clarke, King - NERC.* ***Editorial boards:*** *Barr* - Comput. Environ. Urb. Syst.; *Clarke* - J. Geodesy; *Mills* - Geo-spatial Info. Sci., Photogramm. Rec. (Edit. Board, Guest Ed.). ***Conference keynotes:*** *King* - British Geophysical Assoc.'s Bullerwell Lecture, EGU, 2012; *Mills* - 35th ISRSE, Beijing 2013.

Transport Engineering. ***Fellowships, awards and prizes:*** *Bell* - Elected Fellow of the Institution of Civil Engineers (ICE); *Blythe* - ITS(UK) Reece-Hills Award, 2012. ***Boards and committees:*** *Bell* - ITS(UK) Chair of Smart Environment Interest Group; *Blythe* - Danish EU presidencies plan for EU Horizon 2020 Research Programme, DfT Future Road Strategy Expert Group, Advisor to DfT, Foresight Science and Technology ambassador for UK, Royal Acad. Eng. Climate Change and Energy expert round table, Royal Acad. Eng. Steering Committee on Electric Vehicles, Chair IET Transport Policy Panel, ITS(UK) Chair of Electric Vehicles Interest Group; *Namdeo* - Transport Research Board USA ADC20: Transportation and Air Quality Committee; *Blythe, Bell* - oral and written evidence to Transport Select Committee. ***Peer review colleges:*** *Bell* - EPSRC, ESRC, NERC; *Namdeo* - MRC, NERC. ***Editorial boards:*** *Bell* - IET Intell. Transp. Syst.; *Blythe* - IET Intell. Transp. Syst., Eur. Transp. Res. Rev.; *Namdeo* - Int. J. Environ. Waste Man. (Guest Ed.).

Water Resources Engineering. ***Fellowships, awards and prizes:*** *Dawson* - EPSRC Career Acceleration Fellowship (2010-15), Lloyds Risk Prize for best paper (2012); *Fowler* - NERC Postdoctoral Fellow (2006-10), Philip Leverhulme Prize 2011; *Liang* - New Century Excellent Talents, 2010 (Ministry of Education of China); *O'Connell* - Fellow, Royal Acad. Eng.; *Dawson, Kilsby* - ICE Robert Stephenson Award (2009). ***Boards and committees:*** *Burton* - British Hydrological Soc.; *Dawson* - Urban Climate Change Research Network; *Kilsby* - UK Climate Projections Steering Group (for Defra); *O'Connell* - Advisor to Nile Basin Initiative; *Dawson, Kilsby* - British Energy Climate Change Working Group. ***Peer review colleges:*** *Dawson* - EPSRC; *Fowler* - NERC. ***Conference programme chairs:*** *Dawson* - Earth Systems Engineering 2012; *Liang* - 20th Int. Offshore (Ocean) and Polar Eng. Conf. Beijing, 1st Eur. IAHR Congress Edinburgh, 4th Int. Conf. on Fluid Mechanics, Dalian. ***Editorial boards:*** *Bárdossy* - J. Hydrol. (Editor-in-Chief); *Dawson* - Climatic Change, Proc. ICE J. Infrastructure Asset Management (founding board member), Proc. ICE Civil Engineering (2008-2012); *Liang* - J. Hydrodynam.; *O'Connell* - ASCE J. Hydrol. Eng., Hydrol. Earth Syst. Sci., J. Riv. Basin Man., J. Wat. Res. Man.; *Parkin* - Groundwater. ***Visiting positions:*** *Dawson* - Arizona State University, *Fowler* - IMAGE Lab, NCAR; *Liang* - DPRI, Kyoto (Japan), School of Water Resources and Hydropower Engineering (Wuhan, China); *O'Connell* - Hon. Prof., Inst. Water Resources and Hydropower Research (Beijing, China).