Institution: University of the West of Scotland

Unit of Assessment: 7: Earth Systems and Environmental Science

1. Unit context and structure, research and impact strategy

1.1 Structure of research

UOA7 represents 13 staff headcount (12.4 FTE) working across disciplines and schools with a focus on impactful research that addresses 11 of the 15 UN Sustainable Development Goals (SDGs). Key areas of our research include sustainable consumption and production through the reduction of chemical waste and the emergence of antimicrobial resistance (AMR) in the environment and the sustainability of aquatic environments by improving aquaculture practice and reducing pollution. Our research in environment and human health links with the UWS UOA3 submission and our work in environmental and process engineering directly links to UOA12. Staff in UOA7 are located within the academic schools of Health and Life Sciences (HLS) (Division of Biological Sciences & Health) and Computing, Engineering & Physics (CEPS) (Division of Physical Sciences), brought together under the umbrella *Institute of Biomedical & Environmental Health Research (IBEHR)*. Most staff in UOA7 were historically in an earlier School prior to the creation of HLS and CEPS in 2018. This rearrangement facilitated expansion of laboratory facilities and infrastructure while encouraging cross-disciplinary research to continue through *IBEHR*. *IBEHR* consists of four research groups; staff from UOA7 are associated with two of these, the *Centre for Environmental Research (CER)* and the *Infection & Microbiology Group (IM)*.

1.2 Research Objectives

1.2.1 Review of REF 2014 and Current REF Period

In REF 2014, research in *Earth & Environmental Sciences* underpinned a strong institutional submission to UOA3, contributing academic staff (**Hursthouse**), external funding, highly rated research outputs and two impact case studies (ICS) ("*Risk Assessment in Public Health*" **Gagnon, Hursthouse** and "*Improved Eye Care Solutions and Medicines for the Prevention and Cure of Acanthamoeba keratitis*" **Henriquez**), acknowledged to incorporate "*considerable/very considerable reach and significance in environmental policy and management research and engagement*". Our activities focused on three key strategic themes: Health, Society and Sustainability and across these, our research drew on interdisciplinary collaborations. Since 2014, we have consolidated our distinctive research and developed strong internal collaborations to support wider societal engagement. In REF2014 (UOA3), we identified the *CER and IM* groups, with a focus on environment and human health and organism-environment interactions as part of the overarching *IBEHR*. We committed to grow staff numbers and further develop a vibrant interdisciplinary community.

During the review period, staff have built and sustained collaboration between physical and life sciences with substantial externally funded work programmes, e.g. AMR in the real world, aquaculture, and waste and environmental management. We make significant contributions to UWS interdisciplinary initiatives such as membership of the flagship Protracted Crisis Research Centre, contributing to British Academy GCRF projects on waste in informal communities (**Hursthouse**, **Ewins**) and have made substantial contributions to several Knowledge Transfer Partnership (KTP) projects, supporting growth across UWS and contributing to outputs and impact.

The growth of research in environmental sciences has extended to present for REF2021 a collaborative team (5 x Prof, 4 x SL/Reader, 4 x Lecturer) from across physical and life sciences with a focus on earth, waste and environmental ecological science and engineering. In the review period, our team along with 8 PDRAs/technicians/RAs and 26 Postgraduate Research (PGR) students have addressed research focused on multiple stressors, human biotic interactions and resource exploitation, mitigation and management. Activity has produced **246** peer review articles since 2014, gaining **3,459** citations. These include results from collaboration with international partners in **Europe**, **Africa**, **North America** and **Asia**, with industrial partners, government regulators and policy-focused NGOs. Staff and PGR students are active in the Scottish Funding Council (SFC) research pools (**SAGES**, **MASTS**, **SULSA**) including serving on executive and management groups.

Funding has included **GBP1,744,891** of awards from **Innovate UK**, **BBSRC**, **NERC**, **GRCF**, **SAIC**, **DEFRA**, **Marine Scotland Science (MSS)**, **Scottish Government**, **Scottish Enterprise** and major international industrial sponsors including **Skretting**, **STEMCOR/Tata/Arcelor Mittal**, **Scotia Mining & Exploration**, **Mowi**, **Scottish Salmon Company**, **Scottish Sea Farms**, **Kames Fish Farming Ltd**, **Mars Inc**, **Aquasense** and the **Fish Vet Group** (Benchmark Animal Health), **Baxters Food Group**, **Hydroklear Services Ltd**, **ODS Ltd** and several charitable organisations and learned societies.

1.2.2 Strategy: Next Five Years

UWS' research vision is to deliver transformational change through ground-breaking research that has tangible, early and positive global impacts on society and the environment. We fully support and are committed to on-going development of our researchers through an inclusive approach, in particular focussing on early career researchers (ECRs), and academics seeking to further develop their research goals. We continue to deliver doctoral research opportunities across all disciplines under the umbrella of applied, transformative, and ethical research. Staff within UOA7 have a significant international outlook and continue to grow academic capability to meet societal challenges aligned with UWS' strategic commitment to the UN SDGs.

Our strategy focuses on developing collaborative solutions to societal problems with internal and international partnerships and between academic disciplines, business, and policy areas. In line with the UWS Corporate Strategy 2025, our research maps onto 11 UN SDGs and includes: managing waste and toxin emission to air, water, and land in urban and rural systems and both terrestrial and aquatic environments [SDGs 2; 3; 6; 14; 15]; developing more sustainable innovative industrial processes and resilient economic growth [SDGs 9; 11; 12] and supporting effective partnerships to address policy and institutional buy in, sharing best practice globally [SDGs 13; 17]. Areas of research where signature research will continue to be developed include:

- Aquaculture – fish health and welfare, disease mitigation
- Ecology and pollution – contaminated land, environmental stressors in aquatic systems, emergence of antimicrobial resistance
- Land, waste, air – pollutant transport, regulation and mitigation
- Industry and business – environmental sustainability, industrial ecology, resource efficiency
- Strategic partnerships, collaboration and external engagement e.g., for environmental policy (with Environmental Protection Scotland), training (Ph.D. partnership with Hamburg University of Applied Sciences), professional development, regional environmental strategy (research programme at a Regional Key Lab in Hunan University of Science & Technology, China).

We are committed to pursuing the development of these contributions, engaging staff and PGR students in income generation and impact development. External partnerships will be supported by experienced staff and internal collaborative contributions, to ensure current capacity is maintained and growth facilitated through shared experience. We will maintain a focus on funding opportunities, international partnerships, and academic-industry collaboration.

1.3 Achievement of impact

Enhance business/industry links

We have collaborative partnerships with business and industry, responding to opportunities highlighted through a variety of sources including Interface Partnership enquiries, and local industrial networks in innovation centres and we support the strategic drive by UWS to develop world-leading impactful research. During the REF2021 review period, UWS has risen to a position as #1 in Scotland (2020) for KTP awards and among top 3 in the UK. UOA7 leads collaborations on awards looking at waste reduction in the food and drink sector (ICS2) (copper removal from distillery waste: Hydroclear Services Ltd – **Hursthouse**), (innovation in food waste management: Baxters Food Group - **McLellan**, **Hursthouse**, **Kelly**; new product development from waste soft fruit: Colbeggie Fruits Ltd & Abertay, and waste recovery from fish nets – WJKnox Ltd & Abertay – **Schaschke**) and we collaborate across Schools in more recently introduced management KTP (mKTP) projects, addressing resource efficiency in clothing supply (ACS Clothing – **Hursthouse**)

and developing innovative environmental services (Albion Environmental – **Hursthouse**). These provide opportunity to develop experience of research leadership for ECRs and facilitate increased research engagement and performance. UWS is now #1 mKTP University in the UK, representing 25% of all mKTP projects.

Our industrial focus in aquaculture, supported by 100% of Scottish salmon producers (and multinational partners), has developed and is commercialising innovative, rapid, non-lethal blood-based methods to assess fish health, replacing lethal histopathology (ICS1). Alongside this we have an aquaculture based KTP (Kames Fish Farming Ltd – **Quinn, Sloman, Henriquez**) integrating the use of routine blood-based monitoring for continuous fish health assessment and provided welfare expertise to a KTP looking at fish vaccination (Aqualife – **Sloman**). Collaborating with groups in Computing/AI and the School of Business & Creative Industries we work with a not-for-profit company to establish a sustainable model for aquaponics in Rwanda, funded by Innovate UK. Development of natural plant-based pest controls looking at weevils on Skye Highlands and Islands Council and NEEMCo Ltd. (**Thacker**) led to our involvement in Scotland's first African AgriFood KTP with Mount Kenya University (**Thacker, Hursthouse**) addressing novel pest management products for high value fruit crops.

Collaboration and networks
We maintain a productive membership with SFC research pools (SAGES, MASTS, SULSA), supporting the growth of our PGR student cohort and in developing new staff who have benefited from the MASTS SUPER-DTP (NERC) studentships either currently in progress or with funding secured (**Orton, Alexander, Henriquez**). Research pools have facilitated opportunities for Ph.D. students to develop international industrial connections (SULSA; SAGES) along with networking and CPD opportunities. Our UWS-German Partner joint Ph.D. programme continues to run after a decade of collaborations with a number of staff from *CER* (see 2.6).

Staff led on major initiatives addressing emerging societal issues. Tackling AMR is a cross-council initiative, responding to the UK Government's 2013-2018 strategy; our activity has focused on theme 3: *Understanding real world interactions* (NERC; **Henriquez**, **Hursthouse**, **Williams**). This is continuing with local and international collaborations focused on specific industrial and policy challenges in an interdisciplinary project funded under the India-UK AMR initiative in collaboration with the DBT India (NERC UK-India **Henriquez**, **Hursthouse**). This acts as a nucleus for further national and international collaboration. We continue to maintain strong links with Dr Silva-Pereira (ITQB, Lisbon) with research linking microbiological interactions in disturbed soil systems (carried forward from UOA3 REF2014), in a multi-partner FCT (Portugal) funded initiative FATE (**Hursthouse**). We are partners in a NERC Citizen Science study (PI Entwistle, Northumbria) addressing the chemical-microbiological link to AMR in the HomeBiome (**Hursthouse**), and in a recent award from the Royal Society of Edinburgh SAPHIRE (Ward, Strathclyde) which establishes a Scotland-wide network of research teams tackling AMR in the environment. Linking our expertise in AMR with our expertise in fish welfare, a recently awarded project will work with Mars Petcare on effectiveness of antimicrobials within the ornamental fish trade (**Sloman, Henriquez, Alexander**).

Cross-UWS initiatives include contributions to the **Centre for Protracted Displacement**, securing BA-GCRF Grant (UWB190022) Waste Water & Wellbeing in Dharavi (Jeffery PI, **Ewins, Hursthouse**) to address the link between society, economy, and waste in informal recycling. Collaboration with the BREATH (Border & Regions Airway Training Hub) project (**McLellan**) links UOA3 and UOA7 in addressing the role of environmental factors (air quality) in respiratory disease. It works towards a preventative approach to an incurable lung disease prevalent within regions of Scotland where UWS has campuses. This EU LIFE programme project crosses Scotland-Ireland geographies, fully integrating biomedical and environmental health research.

Hursthouse has been appointed to successive fellowships at HNUST, China (2014 Hunan Government, 2015 Chinese Government, 2016-2020 as 100 Talent Expert by Hunan Government) to develop academic research impact associated with a Key Lab in Shale Gas Exploitation – specifically in resource exploitation and mitigation. This has resulted in significant stakeholder

engagement – policy and regulatory support in water and environmental management in Chinese local government and UK wide in the development and construction sector (ICS2).

We are also involved in conservation-orientated projects within the aquatic environment. **Sloman** and **Alexander** are part of an international collaboration researching the return of fish communities to restored reefs in Indonesia, working with academics from Hasanuddin University (Indonesia), Florida International University and with industrial support from Mars Sustainable Solutions. Work on the conservation of UK amphibians is led by **Orton** in collaboration with Scottish Natural Heritage and academics from the University of Exeter.

1.3.1 Impact Case Studies and Impact Approach

We receive central UWS support for proactive engagement with potential stakeholders. **Hursthouse** brings a track-record of innovative industry interaction, initiated in the late 1990s, focused on SME engagement to problem-solve technology development and environmental performance. This experience supports research activities in the group to engage stakeholders from an early stage, inform direction and maximise wider societal impact. This strategy underpins our ICSs and ensures our future development continues to address UN SDGs and opens a global context to target potential impacts.

Research on the health and welfare of aquatic animals is a major impact focus within UOA7, drawing on expertise from a range of academic staff. All projects within this area involve industrial partners, ensuring our science is beneficial to industry with economic and societal impact. Our ICS '**Improving Health and Welfare of Animals in Aquaculture**' (ICS1) brings together three areas of impact, focusing on salmonid aquaculture, shrimp aquaculture and the ornamental trade. Funded projects involve collaborations between staff (salmonid aquaculture: **Quinn**, **Alexander**, **Henriquez**, **Sloman**; shrimp aquaculture: **Alexander**, **Sloman**; ornamental trade: **Sloman**, **Henriquez**, **Alexander**, **McLellan**) and schools. Looking forward we are committed to expanding these areas and involve additional members of the group; e.g., **Cowie** will join the shrimp aquaculture project providing expertise in shrimp physiology. Outputs include industrial partners as authors. Several studentships have received joint funding from UWS, as a mechanism for driving impact in this area forward. All studentships within this area have included ECRs (noting that career trajectories have moved forward in the REF period), providing a supportive and inclusive research environment.

The challenge of pollution control and preservation of environmental quality in the aquatic environment is a major burden on industry and environmental regulators. Underpinning treatment trials for our ICS **Making industrial waste work and safeguarding global environments** (ICS2) focus on geochemical principles governing contaminant behaviour in complex media. In identifying and evaluating the mechanisms of interaction and performance of new materials, the validation of treatment approaches gave confidence in the strategies applied in industrial processes for waste capture and reduction of effluent discharges. This led to new approaches to resource recovery in Waste Electrical and Electronic Equipment management, supported by international networks translating into advanced training and upskilling programmes for end users in the UK and overseas.

1.4 Interdisciplinary Research

Most of our outputs are co-authored with individuals from different schools, disciplines, and external organisations. These demonstrate the inherently interdisciplinary approach of our research. Collaboration is fundamental to many of our external partnerships and thematic development. We highlight a number of interdisciplinary partnerships (see 1.3) and major societal challenges being addressed in international projects are built on interdisciplinary working. For example, our studies of AMR in the real world include underpinning collaboration between Physical and Biological Sciences to aid in the identification and assessment of significance but also include engineering and technology development for remedial strategies. Overlying this is a policy and societal context, which crosses cultural as well as organisational boundaries and brings opportunity to influence and direct positive change. UOA7 staff lead an interdisciplinary, cross-school project in Human-Animal Interaction, investigating benefits of fish aquaria to human health

and well-being (involving staff from UOAs 3, 20, 24). Our interdisciplinary work monitoring shrimp behaviour in aquaculture involves colleagues from UOA11 in developing systems for recording shrimp in turbid conditions. From April 2020, staff engaged in interdisciplinary COVID-related research, including assessment of antimicrobial/antiviral surfaces (with UOA3) and development of effective reusable face-coverings (with UOA24).

1.5 Open Research Environment

The University has in place resources and support for compliance with REF open access policies, via centralised Research Services and the University Library. Where practicable, open access (OA) routes to publication are favoured and supported by the school [including funding publication processing charges, and recommending publishers who facilitate reduced or no-cost OA arrangements (green route)]. Our research is available through the University's research portal, PURE, and working with the library we are committed to ensuring all outputs are publicly available. We aspire to openness of research data, and aim to meet the requirements of funders (e.g., NERC) even when not instructed, of ensuring research projects have data management plans in place, whilst acknowledging commercial sensitivities of industrial work.

1.6 Research Integrity

UWS publishes a code of ethics, embodied operationally in a University Ethics Committee (UEC), reporting to Senate. School-level ethics committees are responsible for the development and embedding of an ethics culture for research activities. It is mandated that all research be scrutinised for ethical dimensions and where required subjected to ethical approval. UOA7 work is overseen by its relevant school committee and is guided by the UEC to ensure practice at the school level is consistent across the university. Working within the oversight of various institutes of Professional practice, we are held to high standards of professional conduct and integrity. This is borne out through the professional accreditation of our taught programmes that incorporate significant elements of research-informed teaching, and student dissertation work. UWS supports adherence to the Concordat on Research Integrity and Open Data and is a signatory of the Declaration on Research Assessment (DORA).

2. People

2.1 Staff Development Strategy

Commitment to staff development is evidenced through a collaborative annual process that highlights where staff would like to enhance their skills. UWS is fully committed to the ***UK Concordat to support the Career Development of Researchers*** which sets out clear standards that research staff can expect from the University. UWS has a staff development programme in which UOA7 staff (including RAs) have participated both as participants and as co-creators and/or trainers. All programmes are designed according to the Athena Swan charter and support family-friendly policies.

2.2 Staffing and Recruitment

Recruitment strategy across the two schools recognises the need to balance resources with portfolio development and expertise to support accredited programmes. We have recruited staff from a wide range of backgrounds and experiences, including an UWS alumnus moving from public policy sector to an academic role. Since 2014, there have been several appointments/promotions, which have greatly expanded the remit of *CER* and strengthened links with *IM*. These include new lectureship positions (**Alexander**, **Cowie**, **McLellan**, **Orton**), alongside promotions to SL (**Alexander**, **McLellan**) and Professor (**Quinn**, **Henriquez**, **Sloman**). Three staff have departed in the review period and we have had eight PDRA/RA contracts supporting the work of externally funded research projects. We have developed and retained PDRA staff (two returning PDRA on separate contracts).

2.3 Support for Early Career Researchers (ECR)

UOA7 has a balance of senior and less experienced staff. We prioritise junior colleagues for internal support for doctoral studentships and mentoring from experienced colleagues through formal mechanisms. Wider support includes a Staff Forum for Research launched in June 2018

to bring together new researchers at UWS, foster cross-school partnerships and build networks to encourage multi-disciplinary projects and funding bids. Junior staff benefit from further training opportunities; the UWS Crucible and Grant Accelerator Programmes target specific aspects of career development. Staff in UOA7 have engaged in development of grant writing skills (Grant Accelerator- 2018 **Williams**, **McLellan;** Mentors **Hursthouse**, **Quinn**), academia-industry links (PROPEL 2018 **Williams**), interdisciplinary skills (UWS Crucible 2017 **McLellan**, Mentors **Henriquez, Hursthouse, Quinn**) and Leadership skills (Future Research Leaders, **Henriquez, Quinn, Sloman**). Staff have competitively won places in external development programmes. **Quinn** and **Alexander** on the Scottish Crucible (in 2015, 2019, respectively) and **Henriquez** membership of the Royal Society of Edinburgh Young Academy of Scotland. Participation in these programmes has had a positive impact on achieving successful career trajectories and increasing our external networks. Contract based PDRA and RA staff are supported by UWS through funding to bridge time gaps between external projects and contract extensions during COVID-19 to cover time when laboratory access was not possible. PDRA staff are encouraged to lead and write grant proposals (e.g., named author on SAIC funded grant SL_2018_01).

Staff activity is managed through quantitative activity planning and the 'MyContribution' process. Research is a clearly identified activity aligned to UWS objectives and enabling plans. The minimum, default allowance is 10% of activity for research, and is in general greater across the whole staff group. Allowances bring responsibility, related to objective setting for publication, supervision, and funding applications. This approach offers flexibility, and in many cases, time-based support for varying intensities of research. More research active staff have additional time allocation for research. This acknowledgement of research activity is further leveraged by institutional facilitation, particularly for ECRs, for whom time for research is proactively protected.

2.4 Academia – Industry Exchange

The strategic focus of UWS is for useful and impacting research. The university provides centralised support for innovation and industry engagement including a dedicated KTP centre (see 1.3). All members of UOA7 are involved in delivering KTP projects, CPD and responding to innovation enquiries through Interface (SFC sponsored innovation hub for academic-industry partnership). Many of our research projects involve industrial partners and include PGR, ECR and experienced staff ensuring future development of successful partnerships. PGR students often have industrial supervisors and are actively encouraged to invest time working with their industrial sponsor.

2.5 Research and Impact Rewards

The Staff Appreciation and Reward Scheme (STARS) recognises outstanding staff contribution. This collegiate nomination scheme has to date seen eight researchers nominated from UOA7, one receiving 'Excellence Award for Research & Enterprise'. The UWS student body also recognise staff contributions and one member of staff, nominated by PhD students in UOA7, received the 2019 award for *Outstanding Achievement*. Externally, through the commercialisation of the aquaculture fish health diagnostic research, **Quinn** was the winner of the European Aquaculture Society (EAS) Innovation Forum award 2019 and was a Converge Challenge and Kickstart Finalist (2020) and recipient of the HATCH Irish Aquaculture Accelerator Programme, (2020). In 2017, **Hursthouse** was awarded the Liancheng Friendship Award "*to commend foreign experts who have made outstanding contributions to the development of Xiangtan City and foreign exchanges".* In 2018 the collaboration between UWS and HNUST was shortlisted for the Times Higher Education Award for "International Collaboration of the Year".

2.6 Research Students

Since REF2014, UOA7 staff have overseen 26 successful doctoral completions (11 submitted for REF4a) equating to approximately 2 per FTE staff. There are an additional 26 doctoral students in progress within the UOA, with an additional four starting in February 2021, representing an overall growth in numbers. Successful doctoral completions are 50:50 male:female, with a similar ratio for current students. The majority of our students are fully or part-funded by external sources including industry (e.g. STEMCOR, Mars Inc., Skretting, Aquasense, Fish Vet Group, Marine Scotland Science, DEFRA), with UWS providing part or match-funding as part of the UWS

studentship scheme. Students co-funded in this way benefit from links to the real-world application of their research and engage with industrial partners as part of their supervisory team. Other studentship funding includes the MASTS-DTP (NERC), Marine Scotland Science, The Carnegie Trust and international students who are self-funded. Recent (2019/20) changes in SAAS funding have encouraged a small and growing number of students from our undergraduate cohort to pursue M.Res. Degrees.

We have a strong relationship with Hamburg University of Applied Sciences and a number of other German institutions, collaborating on jointly supervised Ph.D. projects (**Hursthouse**, **Kelly** & **McLellan**) hosted in partner institutions. The collaboration, established in 2009 has seen seven successful completions and contributed collaborative peer review outputs. Research includes ecotoxicology of persistent and emerging pollutants, to biomass, waste and biotechnology for energy recovery. Currently six students are progressing under this model, including two funded as part of the PANORAMA MCSF-ITN on rare earth element behaviour in the environment. PANORAMA is a programme of 15 fellowships in which HAW and UWS are members of a pool of European centres of excellence (UWS supervision: **Hursthouse**, **McLellan**).

PGR students have access to UWS training courses (e.g., academic writing, the Researcher Development Framework, research dissemination and impact, research ethics), and additional training opportunities are available dependent on studentship funding. For example, MASTS DTP and SAGES Grad School member students attend writing retreats to support progress in thesis and publication output. EU COST networks have provided thematic collaboration and opportunities for PGR and ECR staff to network and undertake short-term scientific missions to partner institutes including COST Action TU1201 (2013-2016) on urban allotment gardens, and ES1407 (2015-2019) European network for innovative recovery strategies of rare earth and other critical metals from electric and electronic waste. PGR students are encouraged to participate in undergraduate teaching and are provided with training in support of this activity.

Confirmation of successful transfer from M.Phil. to Ph.D. occurs *via* a transfer event at 12-18 months, comprising a written report, discussion with an internal assessor and oral presentation. To maximise success of our PGR students, progress is monitored through a PGR platform allowing students, supervisors, assessors and the Doctoral College to track progress. All students are required to submit a research proposal within 12 weeks of starting followed by progress reports and meetings at 6 months, 1 year, and then on an annual basis. The lead supervisor and internal assessor provide independent comment on progress at these time points, and students are given the opportunity to discuss problems confidentially in the absence of their supervisor. PGR Division Coordinators within HLS and CEPS, also support students and have oversight of progress from enrolment through to degree conferment.

PGR students and their supervisory teams are further supported by the Doctoral College, established in 2018 (formerly the Graduate School) to provide a collegiate, interdisciplinary research environment underpinned by the three pillars of “Behaviours, Interactions and Wellbeing”. The multidisciplinary doctoral training programme is aligned to the Vitae Researcher Development Framework. ECRs are supported and actively encouraged to take on PGR supervision, mentored by experienced academics and are provided with initial training. Given the impact of COVID-19 on PGR research, UWS has facilitated funding extensions and supported a return to COVID-safe research environments where possible.

PGR students attend seminars provided within their School and/or Division, which are advertised across schools to facilitate cross-discipline participation. PGR students are involved in the annual UWS Learning, Teaching and Research conference, submitting lay summaries in year 1, posters in year 2 and 3-minute thesis presentations in year 3. Entries are assessed competitively with the winner of the 3-minute thesis presentation proceeding to the national-level competition. Combining student presentations within the UWS conference provides integration of PGR students within the UWS academic community. Final year PGR students are also expected to present their work at least one international conference with funds to support this provided by industrial sponsors or the School.

2.7 Equality and Diversity

The UWS strategy highlights an institutional focus on wellbeing and commitment to equality, diversity and inclusion. UWS holds a Bronze Athena Swan award and the HR Excellence in Research Award, which recognises commitment to achieving the UK Concordat's principles, setting clear standards that research staff can expect from the University. In 2016 UWS became Stonewall Diversity Champions and continue to embed equality, diversity and inclusion through all aspects of the institution. In addition UWS is a Disability Confident employer.

In terms of gender balance within UOA7, four of the 13 academic staff are female, representing lecturing, senior lecturing and professoriate staff. In addition, gender balance within our successful doctoral students who have completed within the REF period are 50% female and 50 % male.

Our institutional inclusive approach to well-being, family friendly and carer initiatives facilitates flexible working which has been of particular importance in response to COVID-19. During the REF period, staff members have taken maternity leave and shared parental leave. Staff are also supported to attend, for example adoption related panel meetings or other family related leave. Staff were supported to return part-time and also by either a small *IBEHR* fund (pre-Returner's fund) or by the UWS Returner's fund initiative.

Each school has an EDI lead and an EDI champion in each division. All staff enrol on unconscious bias training and there is support for career advancement prior to promotion calls. UOA7 staff sit on the committee of the staff LGBT+ group, Liberty. UOA7 staff and students participated in the Athena Swan Self-Assessment Team (co-chair and members) for a departmental Bronze award (previously School of Science and Sport) and institutional Bronze Award. Despite the unsuccessful departmental application, the action plan and areas of good practice have been further developed in conjunction with the UWS strategy for EDI. One female staff member served as Athena Swan panellist (2018, 2019). Resubmission of the Athena Swan departmental application was delayed due to division of the School of Science & Sport. Future applications in respective schools are planned for 2022.

At all levels UWS proactively supports and promotes equality and diversity, with a number of initiatives that support career progression, enshrining the principles of EDI. Staff have participated in the 2017 Future Research Leaders initiative. This led to all staff who had taken part in this programme being promoted to Professor this included both males and females (see 2.3). One Professor has undertaken an Advance HE Programme in '*Preparing for Strategic Leadership*' in support of her interim role as Assistant Dean in Education, during the School merger (2018-2019).

The university actively promotes a culture of flexible working supported across both. Before COVID-19, the University/Schools recognised the need for different working patterns to meet the variety of staff circumstances. During COVID-19 staff and PGR students have been offered support for remote working. Arrangements for research and other responsibilities were facilitated to ensure as much flexibility as possible in response to issues such as caring responsibilities, illness, and disabilities. Access to campus was actioned in a timely and consistent manner with health and safety at the forefront of decision-making.

REF preparations have been approached with equality, diversity and inclusion in mind. The UWS REF code of practice was developed with particular attention to colleagues with individual circumstances and requests for consideration were open to late January 2021 and processed through a confidential system separate from individual units. The peer-review process of REF output submissions included an equal number of male and female reviewers and fair distribution of outputs to review.

3. Income, infrastructure and facilities

3.1 Research Income and Funding Strategy

During the period of assessment UOA7 staff secured GBP1,744,891 as actual income to the university, accepting this does not include in-kind contributions or reflect contributions as Co-Is to projects led by staff outside UOA7.

Our aquaculture-based diagnostic work was first awarded funding in 2016 and by 2020 had raised >GBP2,000,000 (including industry in-kind contributions). This work involves all salmon producers in Scotland and is being commercialised through the Scottish Enterprise High Growth Spinout Programme (company spinout September 2021). Funding has included a BBSRC grant focused on high throughput immunology and haematology for assessing fish health (**Quinn**, **Henriquez**), three grants from SAIC (Scottish Aquaculture Innovation Centre) looking at diagnostic techniques to monitor fish health (**Quinn**, **Henriquez**), causes of failed fish (**Quinn**) and optimisation of thermal delousing (**Quinn**, **Alexander**, **Sloman**) and a grant from the CEFAS Seafood Innovation Fund (**Quinn**, **Alexander**) on the clinical significance of blood biochemical parameters in salmonid aquaculture. This research was complemented by an award from the Fish Vet Group supporting identification of antimicrobial targets for the effective management of amoebic gill disease in cultured fish (**Henriquez**). The strategy for taking this work forward includes a High-Growth Spinout Programme grant (**Quinn**, **Henriquez**, **Alexander**) for the development of rapid diagnostics to assess fish health. Work on shrimp aquaculture consisted of two projects part-funded by Skretting ARC (**Sloman**, **Alexander**) looking at feeding behaviour of Pacific white-leg shrimp. Work on fish welfare during live transport in the ornamental trade (**Sloman**, **Henriquez**, **Alexander**, **McLellan**) has been sponsored by Mars Inc. as a variety of projects throughout the REF period.

We are recognised as world leaders in the field of amoeba biology and in particular of the free-living amoeba *Acanthamoeba keratitis* that can cause a severe, life-altering infection in the human cornea, transmitted through environmental contamination (UOA3-ICS3). This has recently been patented and global collaborations are developing with other researchers, water industry and healthcare industries. We are expanding our research into the role of *Acanthamoeba* in harbouring potential pathogens in the environment and contributing to AMR emergence, supported by a programme integration NERC grant (Rodgers**, Henriquez**) and a GCRF project in the extreme environments of the altiplano, Argentina (**Henriquez,** Carnicelli in UOA24). The group has received a variety of awards from the Carnegie Trust including a PhD studentship (**Williams, Henriquez**) with the aim of characterising novel drug targets and support for work evaluating the essentiality and druggability of *Leishmania* hydroxylsteroid dehydrogenase (**Williams**), additionally supported by a Kuwait government-sponsored PhD (**Williams**).

A developing area within the group considers the environmental effects of contaminants with a grant from Scottish Natural Heritage on impacts of diffuse pollution on Natterjack toads (**Orton**). This has recently been expanded with a DEFRA funded PhD studentship developing and validating biomarkers of chemical contamination in UK frogs (**Orton**) and a Carnegie award on microplastic contamination of small water bodies and common toads in Scotland (**Orton**).

Increasing momentum in our AMR research is built upon a strategic interdisciplinary relationship between *CER* and *IM*, bringing together microbiologists, geochemists and environmental researchers (**Henriquez**, **Hursthouse**, **Williams**), with researchers in public health and policy in UOA20. The unit has created strong links with other universities and stakeholders (SEPA and 2030 Water Resource Group) in Scotland and internationally to address the emergence of AMR in the environment through funded projects (NERC, GCRF, local charities) and funded networks (Scottish-India AMR in the Environment, SIREN; funded by RSE). The theme is developing into aquaculture sustainability and the healthcare environment (with staff in UOA3) and is well-placed to respond to Government and UN strategic plans to tackle questions surrounding the emergence of AMR in the environment and the development of mitigation strategies.

Waste and Resource Management projects highlighted in ICS2 have identified opportunity for re-engineering treatment systems, evaluating complex chemistries in waste systems to optimise recovery or reduction in environmental burdens. The work has impacted on extensive legacy mining sites in China (**Hursthouse**, **Thacker**, **Kelly**, **McLellan**) and on exploitation opportunities through adoption in successful KTP projects including copper removal from whisky waste, odour and dust control in waste remediation and improved waste strategies across multi-production sites (**Hursthouse, McLellan, Kelly**) (see 1.3).

Staff contribute as Co-Is on substantial projects led by individuals outside UOA7. This includes GCRF Dharavi, Mumbai waste and well-being (**Hursthouse**, **Ewins**) recent mKTPs (Albion Environmental, ACS Clothing), partners in projects with other HEIs and internationally, as described in Section 1 including the design and manufacture of multifunctional material treatments for historic buildings (Hughes PI, **Hursthouse** CoI GBP205,000 7th FP HEROMAT).

Highlighted above, our research strategy focuses on developing collaborative solutions to societal problems and aligns with 11 UN SDGs. Looking forward, we will maintain a focus on funding opportunities, international partnerships and academic-industry collaboration that allow us to underpin our research with strong industrial and external partnerships ensuring we continue to address real-world problems with economic, societal and environmental benefit.

3.2 Organisational Investment

Arrangement of the Schools in 2018 into HLS and CEPS, facilitated the move of biology-orientated disciplines to a new state-of-the-art Lanarkshire Campus. New research laboratories dedicated to Biological Sciences significantly elevate our research capabilities, an investment of >GBP4,500,000. The ethos behind the new Lanarkshire campus reflects UWS' commitment to the environment and environmental research, winning the prestigious **Guardian University Award in 2019 for Sustainable Buildings that Inspire**. Looking forward, UOA7 staff will continue to utilise facilities and infrastructure at both Paisley and Lanarkshire campus allowing us to respond flexibly and in a timely fashion to arising research needs.

3.3 Support Staffing and Infrastructure

Pool technicians on both campuses and in both contributing schools support analytical facilities and cell culture/environmental facilities for experimental work. The Schools have, over the course of a number of research funded projects, employed fixed term RTs, RAs, PDRAs and administrative staff to support research. These dedicated posts are appointed to meet the specific requirements of the research. As part of the UWS rebalancing project (2018/19, 2019/20), the introduction of Grade 5 technicians and a change in job description for technicians at other grades have ensured that research is better supported, along with the appointment of research technicians. This benefit is only beginning to be realised due to COVID-19 and the requirement for 'essential only' work on campus. In the longer term, the technical team will significantly enhance research support. Additional support is provided by identified members of the Professional Support staff pool, e.g., in arranging conference attendance, ordering of consumables etc.

3.4 Specialist Research Infrastructure for Impact

On the Paisley Campus, UWS investment in an **Aquaculture Health Laboratory** (GBP25,000) houses a team of five PDRAs and a research technician externally funded (>GBP2,000,000) by BBSRC, SAIC, Innovate UK, DEFRA, Scottish Enterprise and the Scottish Government. Research developing rapid blood-based diagnostics to assess fish health is currently being commercialised under the Scottish Enterprise High Growth Spinout Programme (see 3.1). Two new high throughput clinical chemistry analysers (Monarch 240 and Monarch 400) were purchased with support from the Scottish Government through the Maritime Fisheries Fund, administered by the Scottish Aquaculture Innovation Centre (SAIC).

We have improved our underpinning environmental/chemical analytical facilities with new ICP MS and OES systems (2017) and a 500MHz NMR facility (2019), supporting core projects in environmental assessment and natural product discovery. On the Lanarkshire campus, dedicated laboratories have been built to support research including microbiology labs, an infection control room, Level II containment facilities, cell-culture rooms and a suite of controlled environment rooms, with facilities for handling soils, wastes and geological specimens.

3.5 Cross-HEI Infrastructure Collaboration

Our membership of research pools provides opportunity to access specialist facilities in other institutions and innovation hubs support for specific programmes across institutions. A number of projects collaborate with other HEI partners and PGR students and researchers exchange for use

of specialist equipment. For example, COST action projects have supported visits to and from UWS labs and we are partners in an EU MSCF ITN where PGR students gain experience in laboratory systems of other organisations.

3.6 In-kind Benefits

During the review period, our pool of chemical analysis capability has been supported by donations of equipment from industrial partners. Donations include multiple chromatography and infrared spectroscopy systems and National Engineering Laboratory particle sizing with a total value of >GBP100,000 (BASF, Paisley). Our fish health research has attracted >GBP2,100,000 in funding, including cash from industry partners totalling GBP95,000 and GBP686,584 of in-kind contributions.

4. Collaboration and contribution to the research base, economy and society

4.1 Research Collaborations, Networks and Partnerships

Over 90% of our publications are collaborative with external national and international partners. UOA7 staff have substantial, long-term links with academic groups and industrial research teams. These underpin much of the research submitted in REF2021 and will develop future strategic significance as we move to the next review period. Cross and interdisciplinary teams feature in new initiatives such as the UWS *Protracted Crisis Research Centre*. Nationally we have sustained active membership of SFC research pools participating in community networking activities, providing strategic directions and supporting development of ECRs across the sector. We have been recognised for our international collaboration including short-listing for International Collaboration of the year THES (**Hursthouse**, 2018) and Liancheng Friendship Award of Xiangtan City, Hunan (**Hursthouse**, 2017). Our participation has secured funding for proposal development (PEER) and networking/professional development (PECRE) and collaborative PhDs.

Specific international partnerships in large collaborative networks and bilateral programmes which have been particularly important include:

- German Fachhochschulen (e.g. with HAW Hamburg), sustained for >10 years with successful Ph.D. progressions (**Hursthouse, Kelly, McLellan**) and development of new projects (see 2.6).
- COST Action networks (COST Action TU1201 (2013-2016) on urban allotment gardens, and ES1407 (2015-2019) European network for innovative recovery strategies of rare earth and other critical metals from electric and electronic waste provides a rich international partnership and led to sustained engagement with members (e.g., **Hursthouse** fellowship to IPGP, Universite de Paris 2020) and a number of Ph.D. student exchanges. These also enhanced our impact with business and industry, underpinning important components of our successful KTPs and ICS2.
- Collaboration with Silva Pereira (ITQB UNL Portugal) >15 years (**Hursthouse),** supported by grants from FCT and NATO to look at impacts of polluted soils on microbial development applied to agroforestry and contaminant remediation e.g. PTDC/AAC-CLI/119100/2010; PTDC/CTA-AMB/6587/2020.
- Development of cross-Scotland AMR interests as well as engaging with UKRI programme projects and our partners in India, where academic links to governmental and NGO groups extend beyond National boundaries to include World Bank sponsored NGOs (see 3.1).

4.2 Engagement with Users, Beneficiaries and Communities

We engage extensively with outreach activity, participating in school visits and supporting project placements for Nuffield scholarships. We have acted as hosts for International Space Station Educational Trust “Mission Discovery” events for local schools. Annual large-scale events are held at Paisley and Lanarkshire campuses (part of the Glasgow Science Festival). Co-ordinated by **Cowie**, they typically attract 300 to 400 people from local communities and involve demonstrations by research staff related to freshwater and marine pollutants, animal diversity, human health, sport and technology. We also contribute to the Biggar Science Festival (**Cowie**) delivering talks on wildlife conservation and pollution. **Ewins** manages a Royal Society of Chemistry sponsored

outreach programme "*Spectroscopy in a Suitcase*", presenting principles of chemical spectroscopy targeted at general public and secondary school chemistry. It features in all Science Festival events and in citizen science projects looking at microplastics in beach sands.

UOA7 staff sit on a variety of panels including CREW (Scotland's centre of expertise for waters) (**Quinn**; 2015-present), the Register of Experts for the Scottish Parliament Information Centre (SPICe) (**Henriquez**, **Hursthouse**; 2020), Clyde 2020 Research Advisory Group (**Quinn**; 2015-2020), Chair of the Norman Fraser Design Trust (**Schaschke**), UK representative on the European Federation of Chemical Engineering (**Schaschke**) and as a board member of Dundee Science Centre (**Schaschke**).

We are actively involved with the boards of SFC pools (SAGES – Executive Committee - **Hursthouse**, Theme lead – **Gagnon**), MASTS – Executive Committee - **Quinn**, community project chair – **Quinn**; DTP scientific review committee – **Alexander**, **Hursthouse**) and are Trustees of Environmental Protection Scotland (EPS) (Scottish policy/regulation in air, noise and land) (**McLellan**, **Hursthouse**; 2013- current), Co-Chair for Air Quality Expert Advisory Group (**McLellan**), Member of the Scottish Government's Cleaner Air for Scotland Climate Change sub-group (**McLellan**; 2016) and EU Horizon 2020 Joint Programming Initiatives (JPI) Project Steering Committee member (various projects) (**Quinn)**. **Henriquez** is elected Member of the Royal Society of Edinburgh Young Academy of Scotland (2016).

4.3 Contribution to Economy and Society

Our award-winning leadership in KTPs is a testament to this contribution. Most projects work alongside industrial partners and address efficient use of resources, productivity and the circular economy. Minimisation and re-use of wastes has a positive impact in reducing the burden of pollution on society and improving public health. Introduction of novel treatment systems both mitigates for health risk and provides opportunity for resource recovery and better use of materials with economic and social gains. We are engaged with policy and regulatory bodies. Our ICS from REF2014, supporting decision making in land contamination, has evolved to co-authorship of guidance for developers to bring vacant and derelict land into beneficial use (**McLellan**).

By assisting with the development of commercial products for industry and integrating novel fish health models in their management, we can identify health challenges earlier, reducing mortality and increasing productivity of businesses. In one industry partner (Kames Fish Farming Ltd), data-informed husbandry decisions are currently shaping fish handling and sea lice treatment events, estimated to result in cost savings and yield improvement contributing GBP280,000 per year to profit.

4.4 Discipline, Interdisciplinarity and International Priorities

Our research enhances our knowledge of environmental biology, including ecology and conservation, and the behaviour and physiology of aquatic animals in aquatic environments. We address physicochemical and biological processes transferring natural and anthropogenic inputs of potentially harmful substances in soils and sediments and weathering of surface exposures at mining sites. The development of analytical techniques provides improved data from biomarkers in animal health (see ICS1) through to reliable determination of components of complex mixtures including a wide range of pollutants and wastes (see ICS2), including first demonstration of WWT contributions to environmental burdens of microplastics.

The interplay between chemistry and biology underpins studies focused on terrestrial and soil sciences; natural resources; natural hazards; pollution and environmental management. Expansion of knowledge on microbial interactions and tolerance to contaminants underpins risk assessment of environmental disruption from mining residues, development of AMR in the environment and provides opportunity to apply bioremediation strategies for quarry wastes and bioleaching of critical raw materials for resource recovery. Treatment of wastes from the food and drink industry, construction and other waste streams with resource value provides opportunities for direct business and societal impact and knowledge exchange.

Our work builds from a team approach with multiple collaborations across disciplinary boundaries. For example, work on Aquaculture in Rwanda (Innovate UK) partners expertise in fish health with computer engineers, AI data analysis with economists to develop cost effective aquaponics models for developing farmers. The impact of fish aquaria on human health is assessed by a team including fish biology, human health, sport and exercise and social work and policy. We support projects involving creative industries engaging with informal settlements in Indian recycling communities to understand drivers of action and impact on environmental health, introducing risk assessment strategies and new field measurement protocols.

We have already highlighted the contribution made to UN SDGs and our work addresses priority initiatives dealing with other high-level issues including WHO focus on AMR and the EU Circular Economy Action Plan (ICS2).

4.5 Wider Influence and Contributions

UOA7 staff are involved in a variety of academic activities ensuring wide influence and contribution within our disciplines. We act as grant reviewers and as panel members for granting agencies including NERC highlight topics moderating panel #4 2018, #6 2020 (**Hursthouse**); NERC Resource Recovery From Waste 2014 (**Hursthouse**); NERC Security of Supply of Mineral Resources 2014 (**Hursthouse**); MRC Review Panel for the China-UK AMR Partnership Hubs (**Henriquez**), NERC Centre for Doctoral Training (CDT) Panel, 2020 (**Quinn**) and Member of Research Committee Alopecia UK 2018 (**Henriquez**). As a group we evaluate grants for NERC, BBSRC, British Council Newton Fund, Royal Society, Innovate UK, UK Marine Climate Change Impacts Partnership (MCCIP), JPI Water (EU), American Association for the Advancement of Science (AAAS), Agence Nationale de la Recherche (ANR) (France), Dutch National Research Agenda (NWA), Canadian Foundation for Innovation, Mitacs (Canada), EPA (Ireland), EU Euregio Science Fund (EGTC), Israeli Ministry of Science, Technology & Space (MOST), Leverhulme Trust, EU COST actions, Austrian, Belgian, Cyprus; Slovakian, Polish, Hungarian US DoD research funding agencies.

Many of our staff are fellows of professional societies including FRSC (**Hursthouse**), FRSB (**Quinn, Sloman**) and FIChemE (**Schaschke**) and have held visiting fellowships (Universite de Paris IGPG: **Hursthouse**, 2020). We have editorial roles in scientific journals including Section Editor Heliyon (**Hursthouse**); Processes (**Schaschke**), Associate/Senior/Topic editor Environ. Monit. Assess.; Environ. Earth Sci. (**Hursthouse**); Sustainability (**McLellan**); J. Fish Biol. (**Sloman**) and editorial board members (Environ. Geochem. Health; Frontiers Environ. Sci.; Ecotox. Environ. Safety; Int. J. Environ. Res. Pub. Health; Environ. Chem. Lett.; Proc ICE Waste & Resource Man. (**Hursthouse**); Intl. J. Sanit. Eng. Res. (**Thacker**); Sci. Rep. (**Henriquez**); Int. J. Food. Sci. (**Schaschke**); Comp. Physiol. Biochem. (**Sloman**); Aquat. Invasions; Bio-invasion Records (**Alexander**).

UOA7 staff contribute to the external academic research environment as PGR external examiners (Ph.D., M.Res., M.Sc.), totalling 45 examinations over the REF period from nine different countries (UK, Italy, Australia, Spain, Ireland, Denmark, Brazil, South Africa & Canada).

Finally, UOA7 staff have given a large number of keynote, plenary and invited research talks over the REF review period including: 2014: Universitas Indonesia, Jakarta (**Hursthouse**), International Congress on the Biology of Fish, Edinburgh (**Sloman**); 2015: Society for Environmental Geochemistry & Health, Slovakia (**Hursthouse**), Universitas Brawijaya, Indonesia (**Hursthouse**), Hunan University, China (**Hursthouse**); 2016: EXIL COST Action CM1206 (**Hursthouse**); 2017: International Science Conference in Kano, Nigeria (**Schaschke**), SETAC, South America, Santos, Brazil (**Quinn**), University of Central Lancashire (**Hursthouse**), College of Civil Engineering, Hunan University (**Hursthouse**), Society for Environmental Geochemistry & Health Guangzhou (**Hursthouse**); 2018: Testate Amoebae Conference, Belfast (**Henriquez**), TOXO-UK day, London (**Henriquez**), ALAM, Santiago, Chile (**Henriquez**); SETAC South America, San Luis, Argentina (**Quinn**), Geological Society of London (**Hursthouse**); 2019: PROIMI, CONICET, Tucuman, Argentina (**Henriquez**), REHIS Annual Environmental Health Forum, (**Quinn**), MAC & NWWAC Workshop on Marine Plastics and the Seafood Supply Chain. Interpretation Directorate (SCIC),

Brussels (**Quinn**), 15th International Congress of the Geological Society of Greece, Athens (**Hursthouse**), Guangdong University of Technology, China (**Hursthouse**), Hasanuddin University, Indonesia (**Alexander**).