Institution: University of Manchester

Unit of Assessment: UoA 7 Earth Systems and Environmental Sciences

a. Context: UoA7 activities at the University of Manchester (**UoM**) are concentrated in the School of Earth, Atmospheric & Environmental Sciences (**SEAES**) with embedded collaboration with staff and use of infrastructure across the University. We have a very large and strong research base, illustrated by receipt of the largest NERC income of any UK Department in 2011-12 (£4.8m). Our activities play a major role in cross-Faculty interdisciplinary themes including the Dalton Nuclear Institute, through our leadership of the Research Centre for Radwaste and Decommissioning (RCRD), Manchester Energy, in which we lead the Hydrocarbon Exploration and Development capability, and our lead in the Atmospheric Science and Gas phase measurement theme.

Beneficiaries of UoA7 research: Our research bridges fundamental physical and biological processes through to applied multidisciplinary environmental investigation. We interface with our non-academic users in a variety of ways and at various levels of delivery. Beneficiaries and users can be divided according to the "readiness for use" level of the research area and by extension the general public. Whilst more fundamental investigations sometimes provide direct impact to ultimate beneficiaries, they largely feed intermediate users. More applied studies are closer to the end-user. Without comprehensively listing our broad user base, examples of each category include:

- **End-user or beneficiary taking direct delivery from UoA7**: agencies and utility distribution companies using environmental monitoring products developed and marketed by a UoA7 spin-out company (see Boult Case Study); agencies and / or Central Government directly receiving policy recommendation or policy-relevant advice (e.g. Volcano and Nuclear Case Studies).
- **Intermediate user taking delivery for ultimate indirect provision to beneficiary**: agencies such as the Met Office taking our numerical process descriptions for inclusion in large-scale models; oil companies directly provided with model developed on the basis of our research.

In both categories the value of the Impact is realised by the ultimate societal beneficiary.

Types of UoA7 impact and mechanisms can be broadly categorised:

- **Economic**: through creation of spinout businesses to create products that directly market the research; or creation of tangible economic benefit to end-user or recipient (such as in hydrocarbon exploration, atmospheric emergency response or influencing atmospheric forecasting) and finally UK plc. Other tangible economic impacts result from partnerships with instrument development companies as "trusted partners".
- **Health**: through advice and policy recommendations directly to the Department of Health (DoH) and Government and through Air Quality predictions in Met Office models, both leading to improved UK health and hence potential NHS economic benefits.
- **Policy & Government advice**: directly advising policy (such as energy, nuclear safety & atmospheric emergency response), or through industrial advisory panels (e.g. nuclear industry)
- **Industrial Practice** and hence safety improvements, in, for example, the nuclear and water supply industries

Opportunities for exploiting results are followed up in ways that reflect the priorities, contacts and experience of the researchers. UoA7 supports diverse impact mechanisms, described below.

b. Approach to impact: The UoA's current approach to impact is based around 4 main areas: (i) major strategic interactions with business; (ii) technology development and knowledge transfer; (iii) contribution to public policy; (iv) public engagement. The following describes these mechanisms, their scale and specific cases that have resulted in substantial benefits:

i) **Major strategic relationships with end-users**: The most substantial Impact-generating partnerships in UoA7 have been developed in our broad cross-disciplinary activities, notably in petroleum research, nuclear geodisposal and atmospheric science. It is a success of our strategy that end-user involvement has been embedded in each area of our research activities to mutual benefit, ensuring optimal impact delivery to the users and directly informing our research direction.

Petroleum research: our Hydrocarbon Exploration activities within our Planetary and Earth Sciences (PES) group incorporate all aspects of the sedimentary basin system, from source to sink and from micro- to macro-scales and have established strategic relationships with leading energy companies on all continents. We lead the Hydrocarbon Exploration and Development capability in the Manchester Energy institute as well as a number of focussed well-funded international

industrial consortia. Members of PES (Flint, Gawthorpe, Hollis, Mitchell, Redfern and Taylor) have secured almost £6.5M from the oil industry with worldwide sponsorship from Anadarko, Aramco, BP, Conoco, ExxonMobil, GDF, Maersk, Petrobras, Shell, Statoil, Total, Tullow and VNG. Furthermore BP, Schlumberger, Shell, Statoil, Total, Petroleum Development Oman, Chevron and Maersk provide direct PhD sponsorship further ensuring industry relevance of our research. Impact on the petroleum exploration industry is exemplified by the Basins case study.

Nuclear research: our Molecular Environmental Sciences group is directly involved in developing the UK's nuclear agenda in the area of geodisposal and environmental remediation. A BNFL Endowment funds the Chair for Morris, whilst joint BNFL-University funding supported the development of the **RCRD** laboratory in 2010. A NERC consortium grant in the area of nuclear biogeochemistry (Biogeochemical Gradients and RADionuclide transport) is led from Manchester with substantial industrial involvement, and the group were heavily influential in the development of the NERC Radioactivity in the Environment research programme. Lloyd, Morris and Polya have secured additional industry KTP and research funding from Areva, NNL and Sellafield worth around £550k. National Nuclear Laboratory and BNFL have each sponsored PhD studentships. Our research has had direct industrial, as well as policy, impacts as exemplified by the Nuclear impact case.

Atmospheric research: our Atmospheric Science group directly engages its end users throughout its research activities. The Met Office is a project partner in a substantial fraction of our wide-ranging RCUK-funded Responsive Mode and Research Programme consortia. In addition to direct delivery of model code and parameterisations to their forecast models, we provide measurements for model comparison and constraint. They additionally fund CASE studentships in this group. Impact based on our research in this area is exemplified by the Met Office case study. Further end-user involvement is secured through a "Framework" contract with Defra that establishes terms and conditions for collaboration in open calls to tender to provide evidence for air quality policy. Such groundwork ensures a state of readiness, allowing rapid response to opportunities as they arise. So far two tenders have been successful within the framework, one providing a policy-related review (see below), the other comparing air quality models. Finally, based on our measurement expertise developed through our research activities, the group provides Atmospheric Incident Emergency Response standby for the Environment Agency.

ii) **Technology development and knowledge transfer**: The Boult case study outlining the Salamander spin-out has been selected by HEFCE as an exemplar in the UoA7 REF Pilot. This is a classic example of identification of opportunity based on our research followed by exploitation through establishment of a company to market and license production of technology developed on the back of the research. The case highlights how we are ready to support an Impact delivery mechanism not widely accessible to UoA7. UoA7 research has further been exploited in 5 successful proof-of-concept projects (Gallagher, McFiggans, Percival, Ricketts, Topping), worth £676k in the recent NERC Technology programme, moving new instrumentation through Technology Readiness Levels ready for future exploitation. We have additionally developed strong working relationships with instrument manufacturers (e.g. Aerodyne Inc., DMT) providing control and analysis software that has been licensed or otherwise commercialised. Opportunities provided by the EPSRC KTA (administered by the University) have been widely taken up by UoA7, with more than £190k staff secondments to, for example Siemens and Sellafield. This has additionally funded CPD activities in radiochemistry worth £160k and a Knowledge Transfer Partnership with ARVIA on organic contamination of water was valued at more than £330k. Around £100k worth of KT "Challenge" awards have been made to conduct feasibility studies and incubator activities.

iii) **Contribution to public policy**: Over the REF period, we have continued to nurture relationships with the relevant policy-making agencies in UoA7 research areas. Department of Health contracts have been won (Webb) to develop the evidence for UV exposure recommendations for vitamin D provision. The work has provided direct input to the Scientific Advisory Committee on Nutrition) in their review of guidance on vitamin D nutrient intake, and methods of acquiring vitamin D. It has also influenced the UK's sun protection campaign (Sunsmart). The overall result has been to reduce the confusion generated by two seemingly opposing aspects of health policy, and to provide clear guidance on the issue of sun exposure. This clarity includes skin type and culture specific advice and should lead to improvement in population health and a reduced burden on the NHS. Water quality research within the Molecular Environmental Science group has resulted in better-informed public policy-making and improved public services with respect to arsenic in groundwaters in south and southeast Asia. It has attracted considerable media attention, influencing policy-making through meetings with

government agencies in various parts of Europe, southeast Asia and India. We lead an international programme in the area of groundwater quality and public health (Polya) supported through major British Council/UKIERI and EU funding and supported by a Marie-Curie training network. Leadership in this area has been established via the major AquaTRAIN, CALIBRE and PRAMA programmes, with water remediation tackled via the EPSRC KTP funding with ARVIA. PhD graduates have been involved with NGOs (UNICEF in India and RDI in Cambodia 2009) educating villagers on risks related to groundwater arsenic. Further examples of direct engagement with policymakers include Defra funding to participate in an Air Quality modelling comparison and to conduct a policy review of secondary particulate material in the atmosphere.

iv) **Public engagement and outreach**: Many elements of our research are of major societal relevance and interest and have been used to raise the profile of fundamental science with the public. We therefore consider it important that these elements are widely promoted. UoA7 research attracts substantial media attention that is optimally nurtured and exploited to significant effect. Of the highest profile are our palaeontology research activities, with media exposure including a series for National Geographic ('Jurassic CSI' six 1 hour episodes in Spring 2011) that was transmitted in over 50 countries. This series showcased the application of new technologies and methods to vertebrate palaeontology. The group also contributed to all episodes of a recent BBC series on palaeontology ('Fossil Detectives' eight 30 minute episodes in 2009). Further broad outreach and media contributions have been made across UoA7 with, for example, high profile exposure for Atmospheric Science research in Severe Weather and Cloud formation and for lunar research within our Planetary and Earth Science group on popular science TV programmes.

Agility in approach to opportunities: Our state of preparedness to respond to opportunities to deliver impact from our research is demonstrated by rapid response to two recent environmental emergencies. Our airborne measurements of fugitive CH_4 emissions from the Total Elgin gasfield leak ensured rapid resolution of the emergency by well-capping, without resorting to a more drastic relief well solution. Similarly, measurements of atmospheric ash from Eyjafjallajökull enabled the opening of UK and North European air corridors earlier than otherwise possible (see Volcano case study). Both responses were only possible because of the measurement capabilities developed by the National Centre for Atmospheric Science staff hosted in the Atmospheric Sciences group.

UoA7 Support for Impact: The University promotion criteria include impact and knowledge exchange in addition to teaching, research and administration, dedicated to. Staff who are active in this area are very much encouraged to promote their cases through this route with appropriate work load allocation. The appointment of Bowman was directly targeted towards industry, building links between our Hydrocarbon Exploration research group and BP. The appointment of Flint has led to building of wider relationships across the group through interactions with a number of oil companies and our stratigraphy research group. Most recently, industrially related fellowships have been used as an important element of promotion cases.

c. Strategy and plans: UoA7 has a broad range of research activities and our impact strategy has developed over the period around four key areas:

(i) Developing strong, industrial and government agency partnerships in key areas of applied research notably in nuclear geodisposal, atmospheric science and petroleum exploration;
(ii) Enabling and maintain an environment within the UoA that fosters and supports our wide ranging impact activities;
(iii) Growing our role as public policy advisors. Much Environmental Science informs and develops public policy. Members of UoA7 have been encouraged to develop their fundamental research into policy areas.
(iv) Promotion of public outreach and dissemination. Our research both has major societal relevance and raises the profile of fundamental science with the public and it is important these activities are promoted.

Current UoA7 Impact Structures: The UoA is committed to the development of the impact agenda. The SEAES Research Committee has the remit for developing the UoA7 Impact Strategy, and, in addition, we have implemented industrial liaison panels to inform the development of research and its impact within the nuclear geodisposal and petroleum geosciences areas comprising representatives from our main sponsors, and identify knowledge exchange opportunities across these broader cross-Faculty UoA7 activities. The panels' reports are provided to the Research Committee. The wide range of impact activities conducted by the UoA are monitored by an External Affairs Officer whose current role is one of identification, collation and dissemination of opportunities, but will be broadened to incorporate a more strategic impact-

development function as our impact activities widen and diversify.

Impact Communication: Dissemination is achieved within UoA7 through our Research Committee, across the faculty through Faculty Research Committee, and to our industrial partners through our newly developed research newsletter. We have developed strong links with the faculty media relations team, and have recently revised our website to reflect our pro-active approach to impact and public outreach, including using Facebook and Twitter, as well as a web based news feed to relay our impact activities to our current collaborators and to foster future links.

Support for Staff: We promote impact activities through dissemination of funding opportunities for: developing impact and fostering knowledge exchange through RCUK and other agencies; industrially linked fellowships (Lloyd, Royal Society Industrial Fellowship, 2010-2014; £1589k); and communications fellowships (Manning, STFC Fellowship, 2013-2015; £79k). Such activities are recognised within staff workloads and contribute to the annually assessed load balance. In several cases, temporary staff have been used to cover such activities where academic impact roles are particularly demanding. The University recognises and rewards knowledge and technology transfer and public engagement activities of its staff through a separately defined element of the promotions criteria up to and including professorial level, and including at least 85% of net income from licensing going to the investigators.

Sustainability of UoA7 Impact: The national impact agenda has developed rapidly over the period since RAE2008 and to date the UoA7 strategy has been to nurture, develop and promote our ongoing activities. The University has put in place an integrated and enhanced governance structure, the Knowledge Exchange Advisory Board, chaired by the Vice-President for Research, which has a strategic overview of knowledge exchange activities across the University. We have won £170k through the new NERC Impact Accelerator Award to develop our KE across UoA7 activities. The Faculty restructured its research support in 2012, this included a new research support manager, dedicated to SEAES, who as part of her role seeks to foster industrial collaborations and identify areas of impact development. We are developing a more proactive approach to identify new impact opportunities. Each of our research groups: Atmospheric; Planetary and Earth Science and Molecular Environmental Science will be expected to develop annual impact plans, identifying key industrial partners and other organisations where our research quality matches business or policy priorities and developing a management plan to grow and strengthen key relationships. Individual staff members will be asked to develop impact plans that will be discussed in their annual Performance Development Review meetings and will use this to assist staff in developing promotions cases with strong impact activity. We will continue to strengthen the monitoring of our impact through incorporation of our External Affairs database into the information maintained within our Research Support Management administration. UMI^3 (the University's innovation company) and the School will continue to develop academic awareness of IP protection and commercialisation opportunities.

Social Responsibility forms the third Goal of the Manchester 2020 Vision and the University and Faculty of Engineering and Physical Sciences are developing strategic plans to meet this vision. The School will contribute to this through a new Social Responsibility Champion who will work with our External Affairs Officer and our Research Support Manager to establish an Impact Group within the School. The Social Responsibility Champion will identify and highlight research that addresses grand societal challenges and assist in the develop future cases studies and coordinate and support key public and community engagement in the School, including outreach activities, particularly those which engage with less advantaged groups.

d. Relationship to case studies: Our case studies have followed from our approach and the relationships are detailed in section b) above. Case 1: *Salamande*r spinout case details the development and marketing of sensors for water quality and fugitive gas emissions and is an example of opportunistic knowledge transfer. Case 2*: Nuclear Decommissioning* case outlines the impact our research has had on biological remediation and radioactive waste disposal operations in the UK and overseas. Case 3: *Rift Basins* case details our impact on the petrochemical exploration industry. Cases 4 and 5: *Weather and Climate* demonstrates the impact of our atmospheric emergency response case on the Eyjafjallajökull ash crisis, and the influence of our research on improving weather forecasting and climate projection capability.