**APPENDIX 1: TRAINING PROPOSAL FROM THE BID DOCUMENT**

2. Training Excellence

FRESH will train students who can blend theory and practice to address the pressing issues that academics and stakeholders have identified as the four priority research areas:

1. Quantify and manage emerging risks to freshwaters that stem from changing patterns in behaviours, demography, governance or climate;
2. Develop and test next generation tools for assessing and monitoring ecosystems and ecosystem services;
3. Tackle extinction and impairment in freshwater ecosystems;
4. Create integrated solutions to manage ecosystem service sustainability for people and ecosystems.

To achieve these goals, FRESH training principles have been set that form a blueprint to ensure the development of independent researchers and world-leading scientists:

* A supportive learning environment to encourage self-reflection, in-built choice to allow students to self-direct their training and development, collaborative working (section 2.1)
* Timely access to an unparalleled range of world-class facilities and unique resources from leading research institutions and major stakeholders (section 2.2)
* Cutting-edge interactive training to address national and international development needs within a resource limited and rapidly changing world (section 2.3)
* Challenging research projects that tackle real-world problems (section 2.4)
* Active engagement with the end-user community that supports external partnerships and outreach to allow maximal impact of the students’ research (section 2.5)

2.1. A supportive learning environment: cohort and wider community

FRESH will prioritise high quality student environment and experiences, which will be achieved through a supportive learning environment. The three complementary groups involved with the CDT learning environment are:

**The Supervisory team:** The FRESH cohort in freshwater bioscience and sustainability will be formed from graduates with life and environmental science backgrounds, but also graduates in a range of relevant disciplines such as engineering, earth sciences, mathematics, computing or geography. After an initial Skills Need Analysis, each candidate will develop a Personalised Development Plan under the advice of their supervisory team that will be delivered by a balanced portfolio of learning activities (section 2.4). This is an important step since each student will have a different background. The supervisory team will consist of: the hosting institution supervisor, a co-supervisor from a different FRESH institution, and a partner supervisor consisting either of a stakeholder or an overseas partner. This will help to foster cross-fertilisation of ideas between the two institutions involved, and between the institutions and the partner organisation. In aggregate over the FRESH CDT, this will increase the collaborations within the WSA and help to trigger novel research initiatives across the Water Security Alliance that would not happen without the FRESH CDT.

**The cohort:** While the training programme of each student will be individually tailored to specific requirements of the student and research project, cohort level activities will be designed to promote frequent peer to peer interactions. We have designed the cohort activities (section 2.4) for the FRESH students to develop peer support and networks that will help doctoral students navigate the methodological, organisational and psychological challenges of a PhD. Cohort structure also naturally enables peer learning through teaching and discussion between doctoral scholars. FRESH cohorts will also have the opportunity to engage with many other peer groups (Fig. 3).

**The wider community:** Despite the fact that we have 176 current freshwater science PhD students studying across the WSA, there is yet no coherent centre to this activity. To ensure that the FRESH CDT delivers a transformative generation of freshwater scientists, it must also move away from more traditional and/or disciplinary approaches to freshwaters, and build a novel community of scientists that understands the complexity of freshwater challenges and has the theoretical and practical tools to address these in an integrated way. FRESH cohort-based activities (section 2.4) will include collective presentations, challenge-oriented problem solving as a group, peer-to-peer teaching, and research event organisation, will equip the doctoral students with the skills to deliver that vision. This environment will also help the FRESH team to improve the quality and flexibility of the training, foster greater interdisciplinarity and altogether help to build a strong sense of a national cohort of highly-skilled and motivated researchers. We expect the FRESH cohorts will provide a platform (Fig. 3) to bring together the diverse group of water researchers, including other doctoral students, to create capacity and leadership in the emerging and fundamentally interdisciplinary field of freshwater biosciences and sustainability.

2.2. Unique support and facilities

**Timely access to world class facilities:** The quality of the training will stem from the level of expertise of the FRESH team. It is also made possible through the exceptional level of shared facilities uniquely available to FRESH staff and students:

* Large state-of-the-art infrastructure investments including Advanced Computing Research facilities at all six core Institutions, some of the UKs most advanced genomics and imaging facilities, and high resolution analytical facilities covering all aspects of cutting-edge biogeochemistry research including the new Bristol Radiocarbon Accelerator Mass Spectrometer at Bristol, and the cutting-edge Chemical Characterisation and Analysis Facility for emerging and priority pollutants in Bath;
* Unique experimental facilities such as the Cardiff Stream Llyn Brianne Observatory mesocosms in Central Wales and freshwater mesocosm facility in Tobago; Bristol’s Biogeochemistry Research Platform; the CEH Aquatic Mesocosm Facility and Plynlimon Experiment; and Exeter’s state-of-the-art aquarium systems;
* Specialized models and associated training such as Exeter’s TIM model for Water economics; 3D visualization suite at BGS; Bristol’s global flood model (Lisflood-FP), national catchment modelling systems (i.e. Dynamic TOPMODEL), state-of-the-art modelling tools like SAFE for global sensitivity analysis, the BGS suite of multi-scale groundwater models (ZOOM) and CLiDE 3-D geomorphological simulator, and CEH modelling capabilities;
* Unique data provisioning for catchment science through field monitoring platforms, including: Bristol’s High Resolution Catchment Monitoring Platforms in the Hampshire Avon, Conwy and Tamar catchments, CEH’s Automatic Lake Monitoring Buoys and associated lab, boat and field facilities in Cumbria; Cardiff’s Llyn Brianne 35+ year Stream Observatory and experimental streams; BGS’ groundwater-surface water interaction and flooding research observatories, Big data from our Defra programmes, and key partners such as long-term BGS, Environment Agency, Water Industry and CEH data holdings on freshwaters.

**FRESH students will be given free access to all these facilities with relevant training when required.** FRESH researchers will be available to provide direct hands on demonstrations of these cutting edge techniques, either on a one-to-one basis or through inclusion in existing taught modules (e.g. ‘Training for sample preparation and instrumental analysis at the NERC Life Sciences Mass Spectrometry Facility’ provided by Bristol). Staff will also be available to advise on the latest methodologies, and best sources of data relevant for their PhD.

**Dedicated Training Infrastructure at the research organisations:** Further to these major investments in cutting-edge research infrastructure, the FRESH partner institutions have made investments in bespoke Doctoral Colleges (Bath, Bristol, Exeter) and Academies (Cardiff). Each provides coordinating foci for central PhD support and training. All four offer supervisor training programmes and development programmes for PhD students that address all elements of the Research Development Framework (RDF). Through the GW4 agreements, researchers enrolled at one institution are able to access training from the other 3, increasing their choice. Such initiatives, taken together are very timely for the FRESH CDT, as they draw on recent experiences of the partner institutions in building and managing successful CDTs and DTPs. [….]

2.3. Cutting edge interactive training and research

The FRESH academic team have proven excellence in postgraduate research training. This is evidenced by the key roles that the FRESH team plays in delivering a number of successful CDT, DTP, MSc and IDC training programmes that will inform and support this CDT. For example, the NERC GW4+ DTP in Earth and Environmental Sciences (led by Bristol, with Exeter, Cardiff, Bath, CEH, BGS), the ESRC SWDTP MRes in Sustainable Futures (Bath, Bristol, Exeter), the EPSRC GW4 CDT in Water Informatics Science and Engineering (WISE CDT, led by Exeter with Bath, Bristol and Cardiff), the EPSRC STREAM IDC (Exeter), as well as Marie Curie Innovative Training Networks, such as SEWPROF at Bath in urban water and public health, and SANITAS at Exeter in sustainable and integrated urban water system management. In aggregate, these will provide FRESH students with a unique opportunity to interact with the research of their peers broadening their knowledge in other areas of water and environment sciences (Fig. 1).

Opportunities to interact with FRESH research are numerous. Our researchers are continually leading world-class fieldwork and experiments on a range of freshwater ecosystems from streams to lakes, rivers, and estuaries. This provides a unique opportunity for FRESH students to discover the range of approaches, methodologies and tools to tackle cutting-edge freshwater problems. FRESH students will be strongly encouraged to participate one or two days in at least one field campaign relevant to their PhD topic so that they may get hands-on experience of a range of research approaches. We feel this is particularly important for students who may have mainly lab-based projects, modelling projects, or who are working on a specific freshwater ecosystem.

2.4. The FRESH experience

The FRESH CDT will deliver a 3.5 year PhD programme - or the equivalent period part-time - starting in October. On starting the FRESH programme, the students will spend the first 6 months focussing on acquiring core skills in freshwater biosciences and sustainability identified by the call through a set of field and taught modules. The remaining 3 years will focus on the PhD project, but will include regular training opportunities as a cohort or individually. A balance will be maintained between the cohort level training needed to impart group identity and common core skills in freshwater bioscience and sustainability, and the specific training needs of each individual essential to successfully conduct their research project and learn key employability skills.

End-user engagement is core to all aspects of training, from individual projects to cohort-level specialist and transferable skills training. Additionally, stakeholder partners will provide specialist talks, attend the annual workshops to meet the students, deliver presentations, share job opportunities and host visits to their organisation (see letters of support). The involvement of our stakeholders is key to delivering our wider training in applied solutions.

Each FRESH student will benefit from a balanced portfolio of learning activities (Fig. 4) to strengthen key skills, discover new disciplines and forge networks with peers and stakeholders:

* Skills needs analysis: a Personalised Development Plan to identify and address bespoke development needs at the start of the programme (see Supervision section 2.1)
* Induction: Two-week fundamental skills fieldwork induction to secure a common baseline and build a cohesive team spirit (2.4.1)
* Core and cross skills courses in freshwater biosciences and sustainability to develop, as a cohort, the core freshwater skills and cross-cutting skills required in the call (2.4.2)
* Cohort challenges every 6 months to engage students in real-world challenges and develop key professional skills (2.4.3)
* Project specific and transferable skills training of relevance to the project or future employability (2.4.4)

2.4.1. Induction

As an important introduction and cohort building exercise, a 10-day field-based induction in Month 1 will cover freshwater science skills in a global-change context through a series of small-group and full-cohort interactive projects. Cardiff and CEH will lead through focusing on rivers and lakes localised around the Llyn Brianne Stream Observatory, the site of our internationally renowned work on global change effects on rivers since 1981. Here, 14 catchments of 70-250 ha drain contrasting land uses, and are equipped with replicate experimental mesocosms and physico-chemical monitoring. There are extensive background data on physico-chemistry and organisms (microbes, pathogens, invertebrates, fishes, birds, bats, plants), while our partners in NRW and Welsh Water provide extensive ancillary support. The adjacent Llyn Brianne, Teifi Pools and Llyn Egnant offer options for lake work. The course will blend field and lab-based teaching, survey methods and experiments to reveal the functioning of freshwater ecosystems, and threats to their sustainability.

2.4.2. Skills for freshwater biosciences and sustainability

**Core training skills for freshwater biosciences and sustainability** that align to the core skills highlighted by the call, will be acquired through 4 foundation training courses within the first 6 months (Months 1-6). Each course will be permanently based at one of the 4 partner institutions where expertise in the area is highest. These expert courses will be attended by the whole cohort, with extensive logistical support organised by the Centre Manager. The courses will combine lectures by experts in the subject, practical workshops that will take advantage of local academic or stakeholder facilities. Some of the training where appropriate will be provided by Y2 PhD students in areas relevant to their PhD project and the course. In preparing and delivering the training, these Y2 students will enhance their own learning, and benefit from cohort feedback.

**Core foundation course 1 (Bath):** ‘Emerging multiple risks to freshwaters’ will build on existing courses in Bath with seminal content from Cardiff, Exeter and BGS (as indicated). The syllabus includes water cycle and human health; water analytics; water quality and regulation; public health and the water environment; global change and multiple stressors (Cardiff); demographic change and water resources; groundwater and pollution (BGS); emerging contaminants, including endocrine disrupting chemicals, pharmaceuticals and plastics (Exeter).

**Core foundation course 2 (Bristol):** ‘Robust evidence for freshwater sciences’ will build on an existing course in Bristol on “Understanding Data: Experimental Design and Introduction to Statistics for Life Scientists (in R)”. We will also offer bespoke training in sample collection, handling, storage, sample preparation for analysis, and the principles of robust biogeochemical analysis of ecological materials, linking with our NERC GW4+ DTP training in Isotope Mass Spectrometry, and including an introduction to the new Bristol Radiocarbon Accelerator Mass Spectrometry facility and the opportunities these facilities offer for freshwater research.

**Core foundation course 3 (Exeter):** ‘Extinction and Impairment in freshwater ecosystems’ will draw from existing taught postgraduate programmes in Exeter, with support on freshwater conservation from Cardiff. Content will include economic pressures on freshwaters; ecosystem modelling from the current GW4DTP; bioinformatics for evolutionary ecology; approaches in evolutionary and behavioural ecology; and conservation and extinction in freshwaters (Cardiff).

**Core foundation course 4 (Cardiff):** ‘Catchments and ecosystem services’ will be hosted in Cardiff supplemented by the CEH Lake ecology taught MSc module. It will draw on material reviewed from the UKNEA as well as cutting-edge seminar contributions from the NERC Duress project on ecosystem services and EU MARS project on multiple stressors. The syllabus includes ecosystem services and natural capital concepts; biodiversity and ecosystem services; introduction to GIS for rivers and catchments; bioinformatics for ecosystem service monitoring. Components will also include tutored discussion sessions and student-led workshops.

The two-week core foundation courses will be staggered over the 6 months to allow sufficient time for the students to reflect on their learning. During this time, students will be asked to do the research planning/preparation for their PhD projects. This includes refining the project aims, methods, as well as practical details namely risk assessments, logistics, immediate training in key laboratory, field, analytical methods/skills that will be required. Students will be subsequently asked to deliver a presentation of their project at the Spring Annual WSA conference.

**Core Cross-cutting training skills for freshwater biosciences and sustainability**: Core cross-cutting skills will be acquired throughout Y1 and Y2 through 5-day courses for the whole cohort. While based on existing undergraduate or postgraduate modules, these will benefit from interventions by stakeholder partners and meet the RCUK Statement of Expectations for Postgraduate training. The first module (Month 9) will focus on ‘Fieldwork and data acquisition’ held in Exeter with the participation of the Environment Agency. This will be followed by a module in Month 15 on ‘Modelling and handling of large data sets for use in environmental system analysis’ held in Bristol, with input from BGS. A third module will follow in Month 21 on ‘Environmental legislation and water policy’ at Bath, with input from Wessex Water. The last module in Y3 will be a partner-designed unit, on ‘Stakeholder challenges in freshwater biosciences and sustainability’. This series of 6-8 seminars will be delivered in Months 24-30 by our stakeholders on the challenges businesses, NGOs and government organisations face.

2.4.3. FRESH Challenges

Every 6 months, the cohort will engage in FRESH challenges designed to provide unique opportunities to interact with key stakeholders and peers:

**The Spring WSA Annual Conference** will figure a ‘Freshwater Biosciences and Sustainability’ day with oral presentations from leading supervisors and guests, poster presentations from early career scholars, and thematic discussions. During this two-day event, in Months 6, 18, 30 & 42, FRESH CDT students will be able to network with stakeholders and with other early career scholars (see Fig. 3) from across the GW4 Water Security Alliance. The WSA early career community will organize the first event, with the CDT administration and advisory team, but subsequent events will be co-organized by FRESH cohorts. This will contribute to developing their management, networking and organizational skills. The conference will be organized in Cardiff in 2018, but will move across the consortium in subsequent years.

**Real-world challenges week**, in Months 12, 24 & 36, will focus on finding out from practitioners about challenges/opportunities in their area. The challenge will each time be co-led by one of our stakeholders. For example, Welsh Water will co-lead the first challenge on the theme ‘Abstraction within safe ecosystem limits in a changing world’. The cohort will be invited to the Welsh Water premises to understand abstraction needs and consumer behaviours. Students will work in groups to assess existing evidence on current abstraction limits, understand current and emergent pressures that might interact with abstraction, develop a range of hypothesis and experimentation protocols to determine safe abstraction limits. NRW will also be involved on regulatory and policy implications while Arup (Arup Group Ltd) has agreed to support students in writing a ‘consultant type’ report. Challenges will be discussed and designed at the Spring WSA conference each year to build experience in key employment sectors, and will be organised by the Management group.

2.4.4. Professional and transferable skills training

Students will be expected to take part in a minimum of six days (or equivalent) of professional skills development per year (Fig. 5) of relevance to future employability, and will be encouraged to take ownership and responsibility for their own learning. The training (Months 6-40) embeds ongoing self-evaluation, target setting and action planning. There will be 6 monthly updates with the supervisor to support the process. FRESH students will also take advantage of the NERC advanced skills training, for ****example the policy internships or public engagement training.

2.4.5. Challenging real life research

The central component of the FRESH programme will be a challenging and original research project focused on one of the priority areas identified by FRESH academics and stakeholders (section 2 introduction). At the Spring Annual Conference of the Water Security Alliance, academics from different FRESH institutions and stakeholder partners will start co-designing topics. Each FRESH project will be required to bring together supervisors from two different FRESH institutions, along with the involvement of an external stakeholder or international colleague. Selected projects will be advertised in October each year, and students will be able to apply for two projects. To ensure that the advertised projects are academically novel and challenging but with the proper supervisory, support and facilities infrastructure, the selection panel drawn from the FRESH Management Group (Section 4) will ensure that each advertised PhD proposal: i) defines a clear question and approach to answering it, ii) highlights its originality and/or significance, iii) explains how it adds to, develops (or challenges) existing literature in the field, iv) makes a case for the importance of the work, (v) considers the wider support infrastructure of the project and addresses any contingencies over the lifetime of the project.

2.5. Engagement and collaboration - addressing real world challenges

Engagement with our end-user community is core to the success of the FRESH CDT. Our Stakeholder Partners will advise on the Training programme through involvement in the Advisory group as they are keen to influence the building of a next generation of freshwater scientists that meet their needs (see letters of support). Our students will interact with a range of end-users throughout their PhD. Stakeholder partners will be engaged from the start during the 10-day induction (2.4.1), and will continue engaging through the cross-cutting courses (2.4.2), the FRESH challenges (2.4.3), the project itself (2.4.4) and the annual conferences (Fig. 4).

To ensure research and skills are responsive to the needs of end-users, stakeholders will have a range of opportunities to engage in the CDT. Whenever possible or relevant, students will be provided collaborative opportunities with stakeholders and end-users. This will include: i) placements with stakeholders who commit to hosting our students (see letters of support), ii) overseas studies and placements with colleagues at research organisations where we have many existing partnerships and MoUs. For example, Cardiff has a MoU with the University of Namibia, and is currently collaborating on the use of eDNA monitoring in Namibia’s ephemeral rivers, Bristol works closely with the Tanzania Fisheries Research Institute, promoting sustainable development of aquaculture and fisheries, Bath has a MoU with the University of Stellenbosch where we are working with the Stellenbosch Water Institute on water management, water for agriculture and public health, Exeter has an MoU with Tsinghua focused on the water, energy and food nexus.