UCD Earth Sciences Institute

Earth & Natural Sciences PhD Programme 2011

Strand 5:

Transport & Water Engineering

Project Descriptions (v5)

Please Note:

While every effort has been made to ensure that the information contained within this document is accurate, it is possible for errors and omissions to have occurred. It is strongly recommended that potential students make contact with the Principal Investigators directly, should they have any questions about the projects.

Introduction

The ENS PhD Programme

The global change in climate and energy supplies will have a major impact on the island of Ireland, on how our economy evolves and the need for measures to protect our environment.

UCD is harnessing its considerable resources to address the challenges by developing an Earth Sciences Institute (ESI). The proposed ENS PhD programme building on the concept that energy and environment are co-dependent, draws on the unique range of disciplines and technologies of UCD, ESI and its partners to create new programmes in Earth and Natural Sciences education. The proposed ESI PhD programme will create a cohort of graduates with a strong background in Energy and Environmental studies, imbued with the innovation and entrepreneurial skills to develop an emerging green technology sector. In addition to a core of postgraduate students specialised in key elements of earth sciences, the programme will impact across a wide range of undergraduate and graduate programmes. It is only by influencing the collective skills of future graduates emanating from a range of disciplines that we will as a society adapt to the national and global challenges and opportunities in agriculture, energy, food, forestry, green technology, land resources, nanoscience and water.

This Strand – *Transport & Water Engineering* – aims to equip graduates with the training and skills needed to overcome the challenges arising from Climate Change (flooding/extreme events) and develop a greener transport sector.

Strand Keywords: civil engineering, transport, infrastructure, water treatment

Information

The Application Process

Please read the following section very carefully. It is of the utmost importance that all the relevant documents are submitted as part of a single email application. Incomplete applications will not be reviewed.

If you have any specific questions about the project or the application, please contact the Principal Investigator directly (details are available in this booklet).

Applications should be emailed to both the Principal Investigator for the specific project and to ens_phd@ucd.ie. The subject line should contain the word "Application" followed by the project number followed by the applicant's name (e.g. Application TWE 4 Joe Bloggs).

Mislabeled applications may not be processed.

All applications must include the following documents:

1. A completed Application Cover Form (download)
2. A complete Curriculum Vitae
3. A Letter of Motivation outlining your interest in the specific project
4. Certified copies of academic transcripts

and, where appropriate,

5. Evidence of proficiency in English

All documents should be typeset or scanned, as appropriate. Please provide PDF format documents where possible.

Please note that all elements of the application must be included in one email. It will not be possible to process incomplete applications and we will not be in a position to collate applications sent in separate emails.

Failure to include all of the documentation listed above will result in your application being rejected.

Applications received before **13 May 2011** will receive full consideration, and the positions will remain open until filled.

Project TWE 1

Reliable Assessment Techniques for Civil Engineering Infrastructure (RATE INFRASTRUCTURE): Slope Stability

Principal Investigator: **Dr Kenneth Gavin** (UCD) – kenneth.gavin@ucd.ie
Collaborators: **Dr Alan O Connor (**TCD**); Dr John O Sullivan (**UCD**)**

Climate change effects are increasing the burden on ageing transport networks with the incidence of infrastructure failure increasing. A large number of slope failures have occurred along the Irish railway network in recent years for example (See Figure 1) whilst scour problems (exacerbated by flooding) caused the collapse of the Malahide viaduct. This project aims to bring together expertise from three of the disciplines within Civil Engineering, namely; Structures, Geotechnics and Hydraulics to tackle three of the fundamental problems caused by climate change effects: 1. Slope Failures, 2. Flood Risk Assessment and 3. Scour of Foundations. These problems can only be tackled through this inter-disciplinary approach. The Earth and Natural Sciences Doctoral Studies programme offers the potential to cement collaboration between staff members with expertise in these areas. Outputs will include:

- New holistic design methods for assessing structural integrity
- Publications in leading international journals
- Ongoing development of further inter-disciplinary and institutional collaborations

The aims will be achieved through three research projects described briefly below. The PhD students will be jointly supervised by two of the staff members involved in the RATE project.

The Geotechnical Research Group at UCD has developed numerical techniques to predict the rate of infiltration of rainfall into slopes and simple probabilistic design tools to measure the reliability (in terms of slope stability) of these structures. There is a need to develop these probabilistic design tools through:

- Using more sophisticated (and appropriate) statistical modelling methodologies – this will be achieved through interaction with Dr. Alan O'Connor
- Collecting data using low-cost embedded sensors which are available to measure critical parameters such as in-situ moisture content and through the use of on-site weather stations (the costs of which are already provided in the ESI budget). The demonstration project will be carried out on a live railway.

The is one studentship associated with this project and will be based at UCD

Project TWE 2

Reliable Assessment Techniques for Civil Engineering Infrastructure (RATE INFRASTRUCTURE): Flood Risk Assessment

Principal Investigator: **Dr John O Sullivan** (UCD) – jj.osullivan@ucd.ie
Collaborators: **Dr Kenneth Gavin (**UCD**); Dr Alan O Connor (**TCD**)**

Climate change effects are increasing the burden on ageing transport networks with the incidence of infrastructure failure increasing. A large number of slope failures have occurred along the Irish railway network in recent years for example (See Figure 1) whilst scour problems (exacerbated by flooding) caused the collapse of the Malahide viaduct. This project aims to bring together expertise from three of the disciplines within Civil Engineering, namely; Structures, Geotechnics and Hydraulics to tackle three of the fundamental problems caused by climate change effects: 1. Slope Failures, 2. Flood Risk Assessment and 3. Scour of Foundations. These problems can only be tackled through this inter-disciplinary approach. The Earth and Natural Sciences Doctoral Studies programme offers the potential to cement collaboration between staff members with expertise in these areas. Outputs will include:

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If one wishes to apply a risk analysis methodology to determine optimal flood protection strategies, one must consider the relationship between design storms with different occurrence probabilities (modified and updated to incorporate the effects of climate change) to (i) characterize existing and future flood potential, (ii) assess the vulnerability of floodplain occupants to flood damage impacts, and (iii) to formulate and evaluate the costs and benefits of a range of potential solutions. This multi-variate problem is best handled in a probabilistic approach which (i) considers the interaction of different contributing variables (using for example joint probability distributions), (ii) can consistently incorporate uncertainties in models and available data and (iii) can facilitate statistical updating (e.g. Bayesian Updating) on the basis of measured information. Considering the above, the aim of the proposed project is to develop a probability based optimisation methodology for the provision of flood defences in Ireland.

The is one studentship associated with this project and will be based at UCD

Project TWE 3

Reliable Assessment Techniques for Civil Engineering Infrastructure (RATE INFRASTRUCTURE): Scour Effects

Principal Investigator: **Dr Kenneth Gavin** (UCD) – kenneth.gavin@ucd.ie
Collaborators: **Dr John O Sullivan (**UCD**); Dr Alan O Connor (**TCD**)**

Climate change effects are increasing the burden on ageing transport networks with the incidence of infrastructure failure increasing. A large number of slope failures have occurred along the Irish railway network in recent years for example (See Figure 1) whilst scour problems (exacerbated by flooding) caused the collapse of the Malahide viaduct. This project aims to bring together expertise from three of the disciplines within Civil Engineering, namely; Structures, Geotechnics and Hydraulics to tackle three of the fundamental problems caused by climate change effects: 1. Slope Failures, 2. Flood Risk Assessment and 3. Scour of Foundations. These problems can only be tackled through this inter-disciplinary approach. The Earth and Natural Sciences Doctoral Studies programme offers the potential to cement collaboration between staff members with expertise in these areas. Outputs will include:

- New holistic design methods for assessing structural integrity
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The aims will be achieved through three research projects described briefly below. The PhD students will be jointly supervised by two of the staff members involved in the RATE project.

Scour is the removal of material from complex 3-Dimensional flow fields that develop around structures resting on mobile beds within rivers and estuaries. Scour is accelerated during flooding events. Although advances in computational models have facilitated an improved representation of the 3-D flow field around bridge piers and abutments, physical models are still required to fully understand the interactions between hydraulic structures, flow and the geotechnical properties of the river bed. This project includes a laboratory investigation of these interactions and their impact on local scour for a range of bridge geometries and bed materials. The work will be undertaken in a 20m long flume with a $1m^2$ measuring section and a discharge capacity of 0.07m3/s. The flume (the base of which will be filled with soil) is equipped with digital equipment for measuring water surface profiles and channel bed deformation. A 2-D/ 3-D Nortek ultrasonic velocity probe measures the cross-sectional flow field.

The is one studentship associated with this project and will be based at UCD

Project TWE 4

Sustainable nutrient and metal removal from domestic and industrial wastewaters using Lagarosiphon major and other submerged macrophytes under temperate conditions

Principal Investigator: **Professor Nick Gray** (TCD) – nfgray@tcd.ie

Can submerged aquatic macrophytes be used under temperate conditions to provide a low-carbon sustainable treatment solution for a range of conventional and problematic wastewaters?

Native and invasive species, including Lagarosiphon major, will be screened using laboratory scale growth chambers to identify suitable species/varieties for use in the treatment of high nutrient and other specialist wastewater streams. Selected species/varieties will be characterized under growth chamber conditions in terms of growth rate, toxicity tolerance, genetic variability (where appropriate), cellular constituents (i.e. protein, lipids, carbohydrates, vitamins and trace elements) using a range of different secondary (industrial) and tertiary (domestic/industrial) wastewaters. Five species/varieties will be selected for laboratory pond trials including Elodea canadensis which has been used previously and also L. major which has the highest growth rate of this plant group. This will identify key batch and continuous culture requirements including HRT, temperature, light intensity and periodicity, reactor dimensions including euphotic depth, harvesting (biomass) rates, also treatment efficiency in terms of nutrient (N, P) and metal removal. The ability to scavenge pharmaceuticals and other trace organics will also be explored. Subsequently outdoor and indoor (controlled) treatment trials will be used to create a carbon-neutral submerged macrophyte reactor design employing passive heat and lighting for all year temperate operation. The project will be carried out in conjunction with the Botanic Gardens (Glasnevin) and Teagasc.

The proposal aims to develop a novel cost-effective treatment solution that is GHG neutral and produces a useable product in the form of a feed supplement, for metal recovery or biomass. The system is applicable to many problematic waste streams and addresses the problem of preventing eutrophication in remote sensitive areas. Natural treatment systems have a positive community response and a strong educational value. The project supports the successful implementation of the Water Framework Directive (2000/60/EC), building on current team research in this area and the training of postgraduate environmental engineers in the Centre for the Environment which has a high uptake of its graduates into the water industry. The study supports the core aims of the Government's SSTI programme in developing sustainable technologies as well as the sustainable objectives outlined in its Four Year Recovery Plan.

The is one studentship associated with this project and will be based at TCD

Project TWE 5

Design of linear wetlands for contaminant attenuation in highway runoff

Principal Investigator: **Mr Paul Johnston** (TCD) – pjhnston@tcd.ie
Collaborators: **Professor Micheál Bruen (**UCD**); Dr Laurence Gill (**TCD**)**

The runoff from highway drainage has long been established as a potentially polluting discharge, principally containing hydrocarbons, heavy metals and suspended sediment. Traditional approaches to drainage have often included simple discharges over the edge of a roadway but recent approaches have tended to collect the runoff and discharge to a point outfall, often into a nearby surface water body. The effect on the receptor/receiving water (particularly ecologically) has been increasingly questioned at the European level particularly in the light of the EU Water Framework Directive. The need to evaluate the nature of these discharges led to an extensive study of highway runoff conducted by all three PIs for the Environmental Protection Agency and the National Roads Authority. The results of extensive field work indicated that highway runoff could pose a significant threat to receiving water bodies, particularly at high traffic densities increasingly seen on Irish roads.

The need for some form of treatment prior to discharge was clearly established and was supported by results of similar research in the UK (Highways Agency). "Treatment" usually takes the form of attenuation and trapping of the relevant pollutants through the mechanisms of filter drains, swales or wetlands. A wetland was built under this EPA/NRA study and evaluation of its performance indicated an effective device for pollutant removal/storage. However, the centralization of runoff waters for treatment is not a preferred option as concentration of discharges can still pose a significant risk to receiving waters. Sustainable Urban Drainage Systems (SUDS) were developed for urban areas, specifically in response to these concerns and the basis of the philosophy is to mimic natural hydrology as much as possible. In this case, it implies the distribution of the treatment of the highway runoff as far as possible – ie alongside the highway.

For this reason, the idea has developed in Ireland to which this proposal relates, to utilize narrow wetlands integrated with the margins of the road and into which the runoff can be routed. These "linear wetlands" could act as distributed treatment devices as well as performing a role in spill containment. The significant rainfall in Ireland lends itself to the sustainability of such wetlands.

While this idea is currently being written into a design guide for road drainage undertaken by TCD for the NRA, there is a strong need to validate the design and to model potential performance of such wetlands including the nature of the required vegetation and its pollutant removal potential.

The proposal is to use as much existing data as already exists from previous studies and to develop a simple design model for the construction, operation and maintenance of such linear wetland systems. The use of HYDRUS, an unsaturated/saturated flow model (already used by the PIs) would be a preferred starting point but the output of the project would be a simple design tool for use by road engineers and catchment managers (under the WFD). Such a design tool would be innovative as the purpose designed linear wetlands are a novelty in road construction.

The is one studentship associated with this project and will be based at TCD

Project TWE 6

Small-scale hydropower – resolving the conflicts between energy and river ecology

Principal Investigator: **Dr John O Sullivan** (UCD) – jj.osullivan@ucd.ie
Collaborators: **Professor Micheál Bruen (**UCD**); Dr Ken Irvine (**TCD**)**

Approximately 6% (compared to approximately 20% elsewhere in the world) of Ireland's electricity generation is from hydropower and considerable unexploited potential exists in Ireland as Alternative Energy Requirements are increasingly being met by small, independently operated hydropower schemes. Increasing power output from alternative, more economical and environmentally acceptable sources will be a cornerstone on which the recovery of the Irish economy will depend. However, small schemes are often 'run of river' type and utilise the head behind an intake weir to drive small turbines. These schemes can alter the natural flow regimes in rivers on both spatial and temporal scales and fragment river ecosystems. The consequence is reduced biotic productivity in tailwaters that may be due to changes in flow, depth, temperature or increased scouring of channel bed and banks. Riverine fish and invertebrate species have a limited range of conditions to which they can adapt, beyond which their diversity, abundance and productivity will be significantly diminished. The effects of changed flow conditions from small scale hydropower schemes on invertebrates, marginal vegetation, and fish production is not well understood and is an area requiring research.

This problem requires a multidisciplinary approach where expertise from UCD and TCD will be combined to assess the effects of changed flow conditions (hydrology and hydraulics) from small scale hydropower schemes on invertebrates, marginal vegetation, and fish production (ecology). Both pre and post scheme field monitoring will be undertaken at two locations where hydropower schemes of different size are proposed. Flow and morphological data will be monitored to identify the change in hydrological 'signature' downstream of the scheme and this will be correlated with changes in ecological indicators. This baseline data will drive selected hydraulic and habitat simulation models to assess their suitability for investigating the changed instream conditions on aquatic life. The project will:

- produce guidance on information needs and evaluation methods for appropriate assessment of the impacts of altered instream flow conditions;
- produce journal and conference publications;
- provide a basis for further interdisciplinary and inter-institutional collaborations.

The proposal will fund one PhD student, jointly supervised by the proposers, in a Water Management research topic in Strand 5 (Transport and Water Engineering). The interdisciplinary environment will provide the PhD student with the training where, following graduation, they will be able to contribute to the national deployment of green energy generation technologies in both public and private sector enterprises.

The is one studentship associated with this project and will be based at UCD

Project TWE 7

Improving the evidence base for policy decisions affecting the sustainability of transport-land-use relationships in the Dublin Regions

Principal Investigator: **Dr Aoife Ahern** (UCD) – aoife.ahern@ucd.ie
Collaborators: **Dr Brendan Williams** (UCD)

This project will examine how transport investment (in the form of Metro North) might affect travel, planning and land use interactions in a corridor where a major piece of infrastructure is planned.

The potential interactions between travel and commuting and land use and development patterns will be explored with the following key objectives:

- To use MOLAND to investigate the impacts of land use planning policies on transport patterns, modal share and travel behaviour along the proposed Metro North corridor and to examine the impacts of new transport infrastructure on land use, modal share and traffic levels.
- To examine the interactions between transport and land use at particular, important nodes.
- To make recommendations based on the findings for land use policies along transport corridors that will result in more sustainable travel and development.
- To assess the cost implications of recommendations made.

The is one studentship associated with this project and will be based at UCD