**Institution:** Queen's University Belfast

**Unit of Assessment:** 17 – Geography, Environmental Studies and Archaeology

**Title of case study:** Investigating Crime: Geoforensics at Work

**1. Summary of the impact** (indicative maximum 100 words)

Geoforensics in the School of Geography, Archaeology & Palaeoecology (GAP) has developed three principal avenues of inquiry for improving the application of Earth Science research in criminal investigations: (a) development of strategies for the search and recovery of buried/submerged items; (b) advancing the use of spatial sampling systems at crime scenes; and (c) furthering the non-destructive testing of trace evidence. The impact of our research is advising law enforcement organisations worldwide on improved procedures for collecting evidence at crime scenes and directly working with such bodies in gathering, analysing and testing evidence during criminal investigations. Evidence has been presented as expert witnesses in court cases for defence and prosecution (e.g. environment agencies, police forces, law firms), and training has been provided to professional forensic scientists employed by various law enforcement bodies including the UK and Irish police, Colombian Forensic Laboratory, Australian Federal Police and US Army/FBI.

**2. Underpinning research** (indicative maximum 500 words)

GAP research on Geoforensics has developed from the late 1990s (first published in 2002, Reference 1) and is mainly undertaken by Ruffell (1990- Lecturer, 2009- Reader; search, geophysics, trace evidence) and McKinley (2004- Lecturer, 2010- Senior Lecturer; Geographic Information Systems, geostatistics). Experiments have been undertaken in (a) new ways of searching the ground and water; (b) best practice for soil sampling and (c) novel trace evidence testing, all through grant-funded research, in order to better inform law enforcement. The research uses field and laboratory experiments (Reference 2: Northern Ireland Department of Education and Learning [DEL] funded PhD student Antoinette Keaney) as well as consultancy-driven work at crime scenes to develop better and more efficient methods of searching, sampling and statistical testing to assist in forensics (Reference 3). This approach of using both experimental and 'real' crime sites has enabled development of the research towards the interests of wider societal agencies (Section 4). At the macro scale, research on improved methods of searching for buried objects has included, for example, experiments and casework on using geophysics to detect both water-submerged objects and illegally-buried toxic waste (References 4 & 5). Searching narrow bodies of freshwater can prove difficult for dive teams, but use of our 'ground penetrating radar in a boat' method has proven effective in three cases worked on by us (one recorded in Reference 4, the others in Reference 6). This method is now used by geophysical contractors in the UK and the police in Australia and Brazil. We have demonstrated that the volume of illegally-buried toxic waste can be established with geophysics, rather than intrusive digging, and this is used to determine the amount of fine and/or prison sentence imposed by the courts (six cases of the 21 we have worked on are summarised in Reference 5). At the medium scale we have used spatially-referenced sampling to better inform the collection of evidence at crime scenes (Reference 3). Prior to our work, aerial photography, ground-based digital topography and spatial sampling were rarely integrated by investigating police forces: our work (Reference 3) demonstrates the better understanding and visualisation (e.g. by a jury) of such a scene of crime. At the micro-scale we have developed new methods of non-destructive analysis (Reference 2), developed both in response to increased criminal knowledge of how to 'clean-up' following an offence, as well as increasing the number and speed of analyses. Prior to the start of our work in 1998, the Northern Ireland justice system rarely used soil or sediment analyses in cases. Over 120 cases have now now concluded, providing more robust evidence in a timely manner for consideration by the criminal justice system. Similar non-destructive work is being adopted in the USA as a result of our advice (Ruffell is the external adviser on the US Army-funded Scientific Working Group on Geological Forensic Materials). Improved sampling and statistical knowledge underpin all three scales of our research, which has now been published in a range of peer-reviewed scientific and

legal journals (over 20 articles) and distributed in training sessions in Colombia (70 attendees), Australia (25 attendees, representing the Australian federal and state police, with police investigator attendees from Netherlands and Brazil) and Russia (including CIS countries, with 50 attendees), delivered through the auspices of the UNESCO/IUGS Intitiative on Forensic Geology, of which McKinley and Ruffell are committee members. Publication topics range from describing criminal casework, exploring new methods of using Earth Science in assisting the law, to unusual applications of regular geological analysis, for instance, the use of ground-penetrating radar in fresh water for the search for submerged objects such as bodies, boats, contraband (work with DEL-funded PhD student Rachael Parker). A monograph by Ruffell and McKinley, *Geoforensics,* summarises this research and traces the diversity of Earth science techniques that are used (and will be used) in criminal, environmental and engineering forensics. Reviews of the book include a description of the work as "an essential reference source for all interested in forensic geology and geography – law enforcement and environmental agencies" (2009, Geophysical Journal International). Ruffell and McKinley work in collaboration with the GAP Centre for Archaeological Fieldwork and individual School specialists in radiocarbon dating, pollen analysis, dendrochronology and body recovery (Reimer Lecturer 2004, Professor 2009; Bennett Professor 2007; Hunt Senior Lecturer 2005, Reader 2006; Murphy Senior Lecturer 2008).

**3. References to the research** (indicative maximum of six references)

1. Ruffell, A. 2002. Remote detection and identification of organic remains. *Archaeological Prospection*, 9, 115-122.
2. Keaney, A., Ruffell, A. & McKinley, J. 2009. Geological trace evidence: forensic and legal perspectives. In: Ritz, K., Dawson, L. & Miller, D. (eds) *Criminal and Environmental Soil Forensics*, Springer. p.221-237.
3. McKinley, J., Ruffell, A., Harrison, M., Meier-Augenstein, W., Kemp. H., Graham, C. & Barry, L. 2009. Spatial thinking in search methodology: a case study of the 'no body murder enquiry', West of Ireland. In: Ritz, K., Dawson, L. & Miller, D. (eds) *Criminal and Environmental Soil Forensics*, Springer. p.285-302.
4. Ruffell, A. 2006. Under-water Scene Investigation Using Ground Penetrating Radar (GPR) in the Search for a Sunken Jet ski, Northern Ireland, Science & Justice, 46, 221-230.
5. Ruffell, A. & Kulessa, B. 2009. Application of Geophysical Techniques in Identifying Illegally buried Toxic Waste. *Environmental Forensics*, 10, 196-207.
*6.* Ruffell, A. & McKinley, J. 2008. *Geoforensics*. Wiley, London & New York. 352pp.

***Grants*** (either resulting from, or impacting on, Geoforensic research)

- 2010 – ongoing. Leachate plumes from illegal waste. Tellus Border Survey (£4.1 million in total, £65,000 to Queen's), INTERREG IVA/Special EU Programmes Body. Collaborative with QUB (Engineering) and the two geological surveys of Ireland. Developed from consultancy on buried illegal waste.
- 2009. Emerging technologies for underwater imaging (£62,925), funded by Knowledge Transfer Partnership scheme. Developed from assisting police searches.
- 2008. WASTEMON: Remote Sensing for Detection of Buried Toxic Waste (€247,384, 10% to Queen's) funded by European Space Agency, collaborator with ERA-MAPTECH, Dublin.

**4. Details of the impact** (indicative maximum 750 words)

Geoforensic evidence gathered by techniques developed in GAP has contributed at the heart of criminal court cases across a range of jurisdictions. In the absence of eyewitness testimony or other corroborating evidence, geoforensic data has been crucial to the conviction or acquittal of those accused of serious criminal activity. GAP geoforensic research has provided mechanisms for enhancing the quality of the collection, sampling, testing and statistical analysis of geomaterials and consequently has improved the veracity of such evidence. It has further developed a distinctive blend of applications at macro- (landscape) to micro- (trace evidence) scales by advising and training police personnel in several jurisdictions worldwide, where Ruffell and McKinley have been consultants in a variety of cases. Seventy serious crime cases (murder, rape, kidnap, smuggling, all funded by police consultancy) have been concluded, with 16 going to court. Thirty-

three geotechnical and military cases have also been undertaken, with 16 successfully concluded, including one concluded court case. Ruffell and McKinley have completed or are involved in 21 environmental crime cases, with 13 through the courts or ongoing. Overall GAP research expertise has been applied to over 120 cases. It has had a direct and verifiable impact on the preparation and prosecution of cases in two interrelated ways, detailed below.

**i) Case Work**

*Serious Crime* Since 2008 the ability of Ruffell and McKinley to conduct spatially-referenced search and sampling at a range of scales has involved them in criminal cases including theft, sex offences, drug dealing and murder. They have worked with the PSNI (Item 1) and other law enforcement agencies in sampling scenes of crime, investigation of burials, analysis of bulk (soil and rock) and trace evidence (dust), report writing, case reviews, and court appearances as expert witnesses including Belfast Crown Court and the Crown Court in Perth (Western Australia). For example, Ruffell and McKinley's work on the murder of Shirley Finlay (2009) was used in the successful prosecution case of serial sex offenders and murderers Trevor Hamilton and Henryck Gorski (Item 1). Both cases used a variety of soil/rock analytical methods (the multi-proxy approach), which became established best practice in trace evidence testing. They assisted in the search for six missing persons (Arlene Arkinson, Lisa Dorrian; two un-named drug dealers; two neonate infants [latter successful]). In a substitution case in 2008, high-value computer parts sent to the UK from the Far East were stolen from packaging and swapped with rock and soil, successfully identified by Hunt and Ruffell, and a culprit identified. Ruffell assisted the Royal Canadian Mounted Police in the search for a murder weapon in a pond (2009). As well as impacting on the outcome of specific court cases, involvement has influenced the wider legal system (Item 2) in general by highlighting the types of robust forensic evidence that can aid either prosecuting or defence lawyers. Ruffell was co-commissioned (with Dr Laurance Donnelly, global expert in search) by Surrey Police to review the evidence against Levi Belfield in the Amanda Dowler murder case.

*Environmental Crime* 21 environmental legal cases have benefitted from Ruffell's expert advice, including the use of innovative research-based technology (airborne and terrestrial geophysics) to identify and map illegal waste dumps and give evidence in prosecuting or defending the accused. Of these cases, 18 were located in NI (working with the Northern Ireland Environmental Agency [NIEA]), one in the Republic of Ireland, and two in Scotland. The monitoring of the location of waste, particularly hazardous waste, has facilitated the prosecution and conviction of those responsible for causing pollution (including two jail sentences), and this work has also had a wider impact by attracting media and public awareness of the potential environmental dangers, particularly for those living adjacent to such sites. For instance, Ruffell undertook a geophysical analysis of a site outside Belfast (2009) on behalf of NIEA against suspected illegal dumping, as part of an ongoing investigation.

*Geotechnical (Forensic Engineering)* A number of geotechnical consulting projects have been undertaken that surveyed unstable structures (all subject to legal enquiries) using geological and geophysical techniques. The impact of these has been the provision of hazard assessment and safety recommendations. For instance, the stability of Thompson's Dry Dock in Belfast's Titanic Quarter in 2010 was determined by Ruffell and he undertook a geophysical survey of the runway at Belfast City Airport (2010) in order to detect any subsurface instability (subjudice).

**ii) Training and Advice (examples)**

(a) United Kingdom Forensic Science Regulator. Ruffell (Chair, Geological Society of London, Forensic Geoscience Group) provided guidance and advice to the UK Forensic Science Regulator on the principles, protocols, and best practices for the collection of evidence at crime scenes. (Item 2). This advice is now being incorporated into a publication by the International Union for Geosciences (International Forensic Geology sub-committee).

(b) Ruffell was one of four invited contributors (lectures and training) to the First Ibero-American Meeting on Forensic Geology (2008), attended by forensic science students, laboratory workers, police officers and lawyers/judges, who now use their advice (Item 3).

(c) United States law enforcement agencies (FBI, federal police, army). Ruffell sits as the international member on GEOSWGG (forensic geology working group, funded by the US army, to develop forensic geology protocols, many of which are now in use).

(d) Australian Federal Police (AFP). Organised and funded by the IUGS (August 2012), McKinley provided training in best-practice search methods using Geographic Information Systems (Item 4).

(e) International Committee for the Location of Victims' Remains (ICLVR). Since 2008, GAP staff (McKinley, Pilcher, Reimer, Ruffell) have regularly provided advice to the commission on using geophysics, radiocarbon dating and palaeoecology in the search for The Disappeared of the Troubles in Ireland (Item 5).

**5. Sources to corroborate the impact** (indicative maximum of 10 references)

1. Letter from Major Crime Forensic Advisor, Police Service of Northern Ireland.
2. Letter of commendation from UK Forensic Science Regulator.
3. Letter from conference chair: First Ibero-American Conference on Forensic Geology. Bogota.
4. Letter from chair of the International Union of Geological Sciences (IUGS) Initiative for Forensic Geology (IFG).
5. Letter from the International Commission for the Location of Victim's Remains (ICLVR).