Roinn Cumarsáide, Gníomhaithe ar son na hAeráide & Comhshaoil
Department of Communications, Climate Action & Environment

Geological Survey
Suirbhéireacht Gheolaíochta
Ireland | Éireann

**Research Programme**
**- Short Calls, Final Report -**

| | |
|---|---|
| Lead Applicant Name | Dr. Jean O'Dwyer |
| Email | Jean.ODwyer@ucc.ie |
| Host Organisation name | University of Limerick |
| Project Title | Groundwater Risk Application for Local Evaluations (GRAppLE) |
| Contract Number | 2017-sc-045 |

Date: 15/11/2018

**This report covers the period November 1st 2017 to October 31st 2018**

**2. (a) Project information**:

Final project report (*max **2500**words, excluding figures and headings*):

- *Progress* of objectives and scientific/engineering targets beyond the state of the art & *methods* used

The overall goal of the GRAppLE project was to assess the feasibility of developing a groundwater risk assessment application using pre-existing Irish data and to assess the accuracy of said application in situ. This goal has been achieved through the following four objectives:

**Objectives 1 & 2:** Completed

- Homogenise and amalgamate existing private well assessment and microbial groundwater contamination information from the Republic of Ireland to create a holistic database for analysis.
- Calibrate and validate a simplified stochastic (regression-based) Risk Model that can be extrapolated to provide hydrogeological representivity at the national scale. Simplified model will be developed to necessitate minimum levels of user-data input, thus increasing overall ease of use and accuracy.

**Progress/Method:** A dataset containing the geo-referenced microbiological sampling results of private water supplies sampled in the Republic of Ireland between 2009-2012 was statistically modelled using binary logistic regression to quantify associated risk factors as per O'Dwyer et al. (2018) and Hynds et al. (2011). An holistic and simplified risk model was created for use in the GRAppLE prototype which included the following variables:

- Subsoil permeability
- Aquifer type
- Groundwater Vulnerability
- Cattle Density
- Septic Tank Distance
- Well head cover
- Liner Clearance
- Meteorology (temperature and rainfall)

**Objective 3:** Completed

- Develop an entirely novel mobile device application that combines scientific data, live geo-referencing, and (minimised) user inputs for utilisation by private well owners.

**Progress/Method:** Due to the significance, novelty and duration of work package undertaken to complete this objective it was delineated into four distinct sub-packages, namely, Endpoint Development (WP3-1), Model Implementation (WP3-2), User Interface Design (WP3-3), and Developer Testing (WP3-4). These were implemented as follows:

## WP3-1: Endpoint Development-

Due to issues pertaining to digital storage and device hardware, the majority of GRAppLE data processing and computation takes place on an external server (i.e. the endpoint), whereby the mobile device directs geographical coordinates (upon user confirmation) via the global positioning system tracker to the external server, as shown in Figure 1. Fetch and entry" functions use the GPS coordinates to extract data from the server hosted spatiotemporal database, and populate the "device inputs" portion of the risk model.

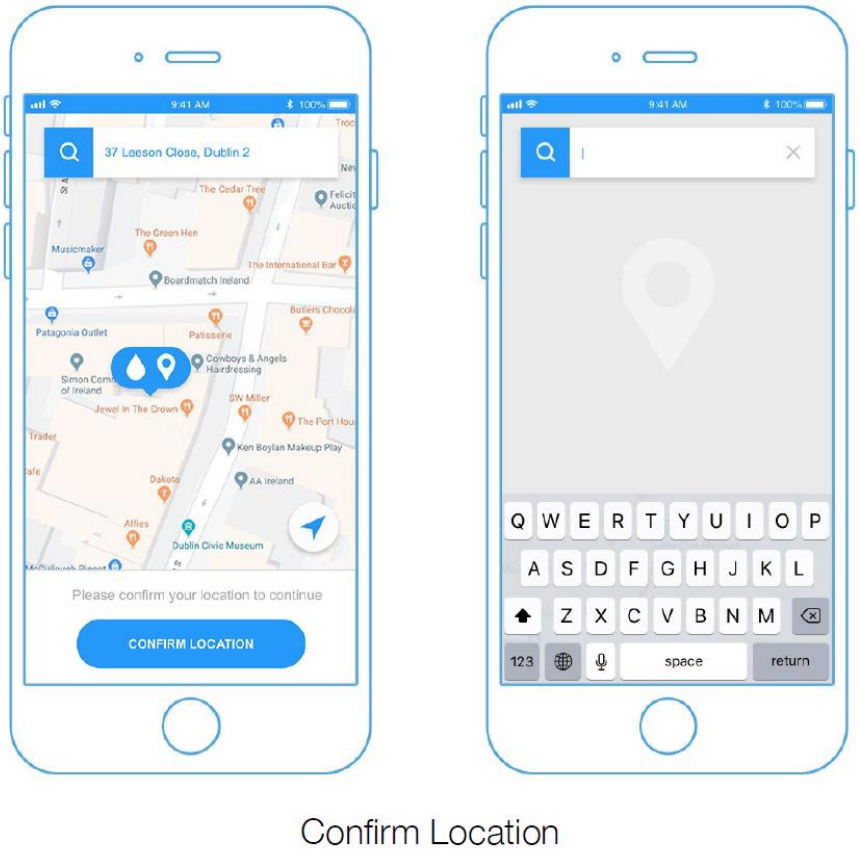


***Figure 1: Geographical coordinate identification using GPS and 'Confirm Location' interface on the GRAppLE Prototype.***

Once the geographical coordinates are established and confirmed, this information is used to search, identify, and retrieve locally-specific data from the developed live dataset (Objective 1) (also hosted on the external server) for risk model input population, thus ensuring that an accurate contamination risk estimate can be delivered to the application user with a minimum of effort on their behalf.

## WP3-2: Model Implementation and Development (Backend)

For model implementation, a spatial database was developed using existing data (shapefiles and datasets) from the Environmental Protection Agency, the Geological Survey of Ireland, and Met Eireann etc. Upon opening the application, GPS coordinates and user-defined inputs are 'sent' to

the external server initiating a "live call" (data query), subsequently using a "fetch and entry" function (data query) to retrieve necessary shapefile data for the specific geographical location and populate the risk estimation equation. To achieve this, application coding was undertaken using the JavaScript programming language, with Appcelerator Titanium employed for application development. The Appcelerator platform was selected as it permits native, hybrid, and mobile web apps across all platforms/devices (i.e. Android, IOS, Blackberry) from a single JavaScript code base. Additionally, a series of 'user-derived' variables have been included which directly populate the user-defined inputs portion of the risk model. Specifically, the user is prompted to enter four "source-specific" (user-defined) inputs pertaining to their private well, which are (1) Wellhead cover, (2) Septic Tank Distance, (3) Road on Gradient and (4) Liner Clearance.

### WP3-3: User Interface (UI) Design (Frontend)

As stated in the original proposal, it was considered critical that the GRAppLE prototype be simple, understandable, and highly functional with respect to non-expert users (private well owners/utilisers). As such, the four "source-specific" (user-defined) inputs were developed using a graphical interface (GUI) via a raster graphics editor (e.g. Adobe PhotoShop CC). This was done for all four user defined variables and shown in Figures 2-4. To guide users, 'Help' windows were also installed to explain why the variable was of importance and how to assess it (Figure 2). For instance, if users are asked if their private well is finished (located) inside or outside, a pictorial (icon) example of both options is provided and utilises touchscreen controls i.e. users can press the icon most similar to their own source.

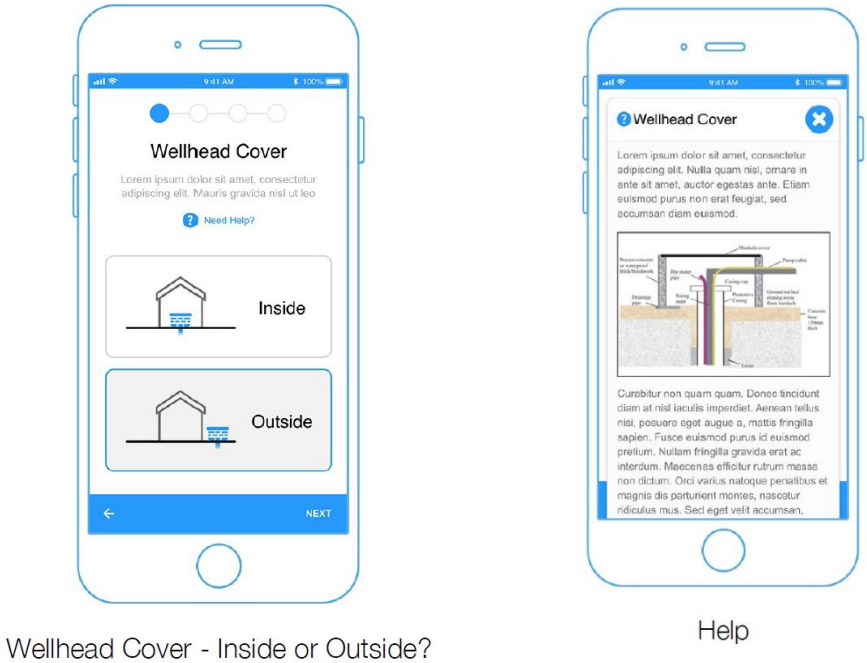


***Figure 2: Example of GRAppLE Prototype user defined inputs and Help function.***

Furthermore, in order to reduce uncertainty and increase engagement with the application, where units of measurement were specified, the user is given the option to use multiple units. For example, for septic tank distance, both metres and steps are included (Figure 3).

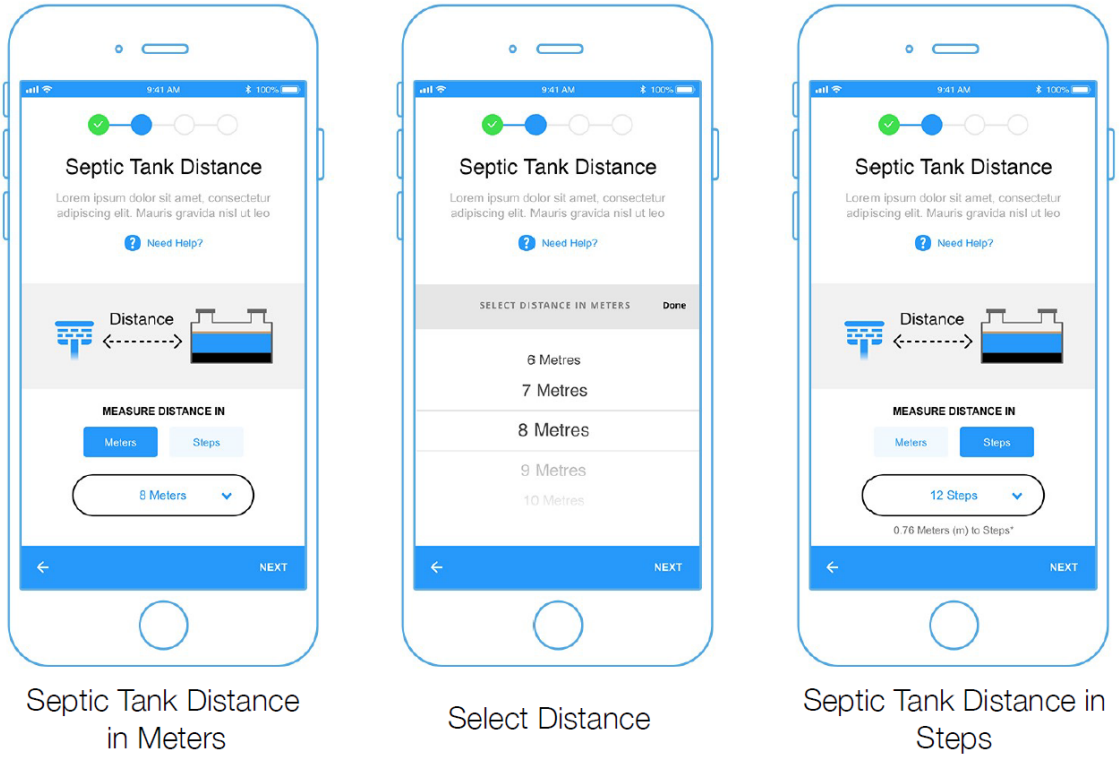


***Figure 3: Example of GRAppLE Prototype user defined inputs and multiple measurement options.***

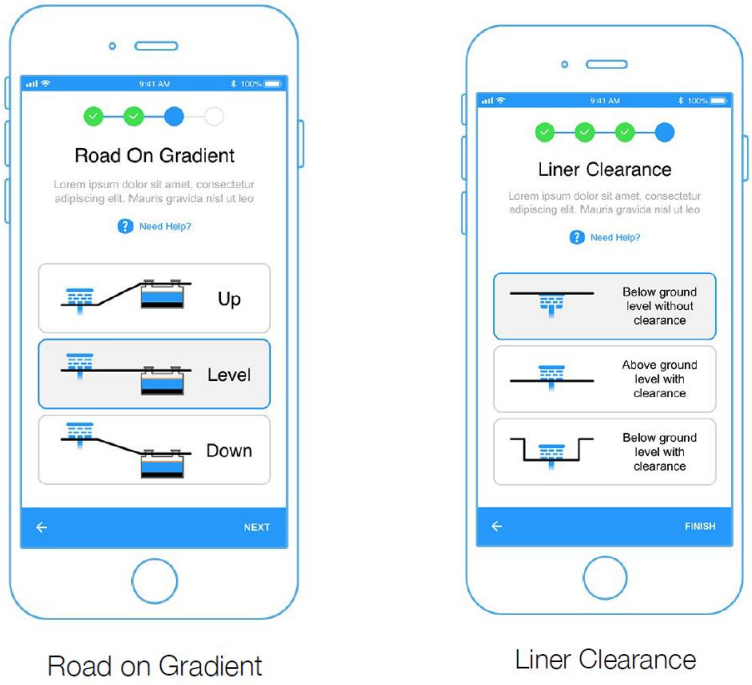


***Figure 4: Example of GRAppLE Prototype user defined inputs.***

This GUI approach ensures that user-defined inputs for risk estimation are easily understood and correctly selected by the end user.

Once the user has made their way through the application menu and inputted all 'Fetch and Entry' (GPS dependent) variables and 'user input' related variables then the final risk score is populated as shown in Figure 5.

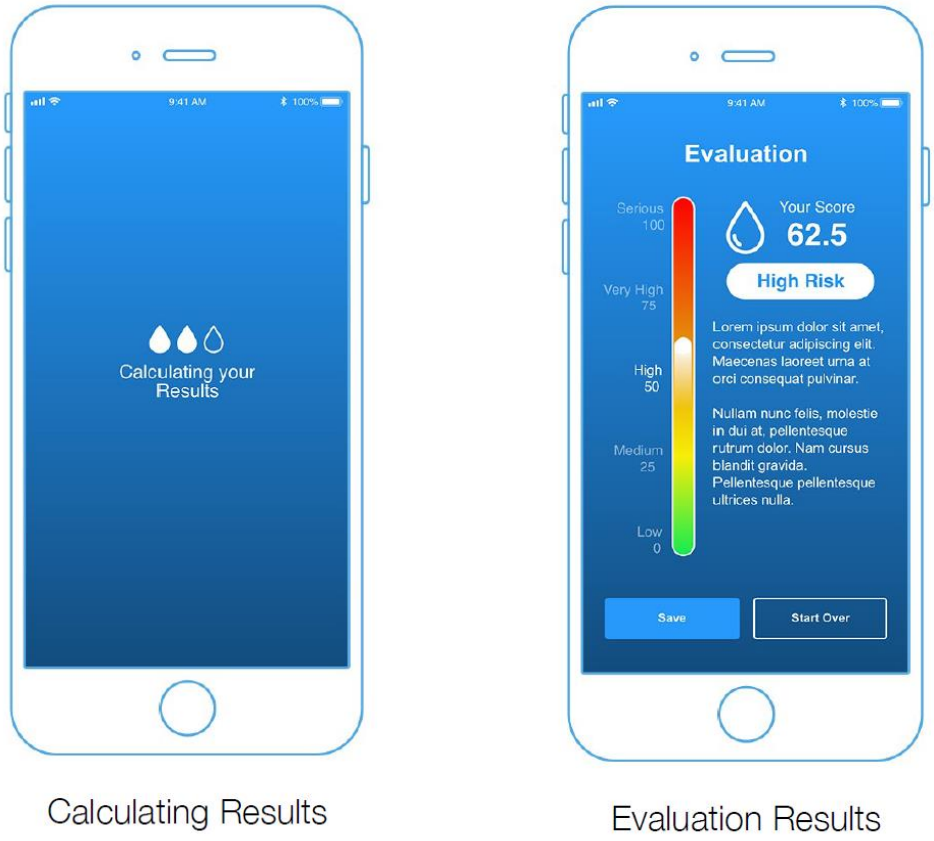


***Figure 5: Example of GRAppLE Prototype Result calculation and presentation of Risk Score.***

### WP3-4: Developer Testing (Backend/Frontend)

Prototype testing/validation was undertaken on the merged (Backend/Frontend) Appcelerator prototype with full (server) connectivity, application functionality, and first-generation raster graphics. This phase was undertaken using a desktop computer to assess issues with GPS accuracy and implementation, model parameterisation and operation, development/code de-bugging, and any other potential operational defects and/or dead ends (e.g. outlier series). Accordingly, the features and functionality of the GRAppLE prototype have been verified and streamlined for further development with the possibility of rolling out the app to a national audience.

**Objective 4:** Partially completed

- Assessment of prototype functionality and accuracy through focus groups and coordinated private water supply sampling and analysis.

To assess the accuracy and sensitivity of the application (and contained risk model), a coordinated sampling routine was undertaken. In total, 100 private water supplies were sampled between June and September 2018. Groundwater samples were taken in accordance with the standard methods and assayed for total coliforms and *E. coli* using a standard US Environmental Protection Agency (EPA) approved commercial culture kit (Colilert, IDEXX Laboratories Inc., Westbrook, ME, USA). For representivity, samples were taken from Low (n =25), Moderate (n =25), High (n =25), and Extreme (n =25), groundwater vulnerability areas. In total, 55% of the supplies tested positive for Total Coliforms (n = 55/100) and 17% tested positive for *E. coli* (n = 17/100) (Figure 6). The overall efficacy of the developed risk model in predicting contamination is 82.4%

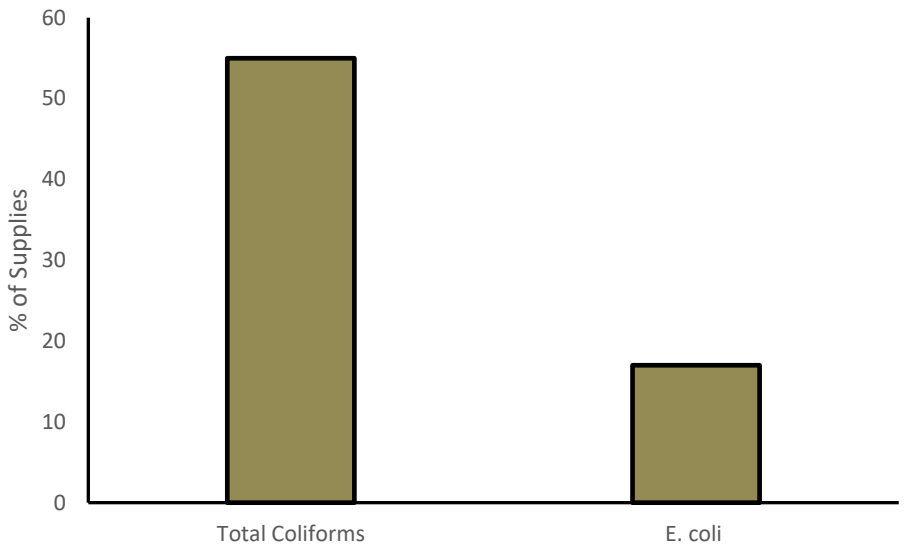


***Figure 6: Results of Ground-truthing sampling regime (June-Sept, 2018).***

Unfortunately, the ambitious nature of this project in combination with the strict 12 month timeline for completion, we did not get the opportunity to do significant beta testing as per the original proposal, i.e., focus groups were not undertaken. However, we intend to do this in the near future pro-bono in order to ensure continued development of GRAppLE.

- Implementation (please include any issues with timelines, milestones, management etc. or deviations from the original implementation plan)

- Access to data and troubleshooting of the 'fetch and entry' methodology took an enormous amount of work, and consequently time. As such, this slowed the project down resulting in an inability to undertake the usability assessment via focused groups. While this is a shortcoming of the overall project, it does not impact the overall goal which was to assess the feasibility of creating a groundwater risk application with the potential for national roll-out.
- As above, the issues of timing resulted in the sampling regime to run concurrently with the app development and thus, validation assessments are retrospective. This has no implications on the results of the project, but has altered the timeline of the milestones.

- Outputs (please provide a short description *and* complete the table below)

  ✓ A functioning prototype of GRAppLE, which can be further developed and fine-tuned into a nationally available application for groundwater users with potential to promote private well stewardship and protect health.
  ✓ It is envisioned that two Web of Science journal articles will be an output of the GRAppLE project, one detailing the development of the application and another detailing the efficacy of the application for groundwater management. These articles are not yet submitted, but we endeavour to have them submitted for peer review in a timely fashion.
  ✓ Jean O'Dwyer (PI) presented GRAppLE (Oral Presentation) at the Geoscience Union annual conference in Vienna on the 9th of April, 2018.

| Task No. | Deliverable description | Planned delivery (as per proposal) | Date of delivery |
|---|---|---|---|
| 1 | Collated Dataset<br>Final Report | Month 2 | Month 2 |
| 2 | Simplified Risk Model for national extrapolation | Month 4 | Month 4 |
| 3 | Progress Report | Month 6 | Month 6 |
| 4 | GRAppLE prototype | Month 10 | Month 12 |
| 5 | Results of functionality | Month 12 | Post-completion |
| 6 | Accuracy assessments | Month 12 | Month 12 |
| 7 | Final Report | Month 12 | Month 12 |

Publications to date: *Please use format below and provide a copy of the presentation*

Hynds, P., Regan, S., Mooney, E., O'Dwyer, J. (2018) Development of a pocket technology Groundwater Risk Application for Local Evaluation (GRAppLE) in highly groundwater reliant populations. EGU General Assembly 2018- Geophysical Research Abstracts Vol. 20, EGU2018-7685, Vienna, Austria, 09-APR-18. (Presentation Attached.)

Reference to GRAppLE was also made in an online article on the popular Science website 'Science Trends', see here: https://sciencetrends.com/what-lies-beneath-predicting-the-quality-of-groundwater-for-well-users/

**4. Data/outputs submitted with final report** *(please list the documents, presentations, datasets etc. submitted with this report)*

a. Slides presented at the European Geoscience Union General Assembly by Jean O'Dwyer in April 2018.