Sellafield Ltd

The Sellafield Contaminated Land and Groundwater Management Project: Characterisation of a Complex Nuclear Facility

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Abstract

The Sellafield site in North West England is one of the oldest and largest nuclear sites in the world, with a 70 year industrial history of processing and power generation. At certain points in time this industrial activity has affected the quality of land on parts of the site and one of the main tasks for Sellafield Ltd is to understand and control the legacy of ground contamination to ensure protection of the workforce, the public and the environment.

Sellafield Ltd has recently completed a multi-million Pound investigation of the most complex part of the site in order to understand the impact of the various known and potential sources of contamination. The constraints of working in a challenging operational environment required both the use of tried and tested approaches and experimentation with innovative techniques. As experience was gained during implementation of the project, the characterisation plan was evolved and adapted to ensure a successful outcome.

This paper outlines the role and importance of characterising land and groundwater at Sellafield, explains how the site investigation strategy and techniques were designed to meet the challenge and describes the performance of the investigation in practice. It concludes with a summary of how the results will be used to better support ongoing safety and environmental management and to aid the development of strategy and planning for the future.

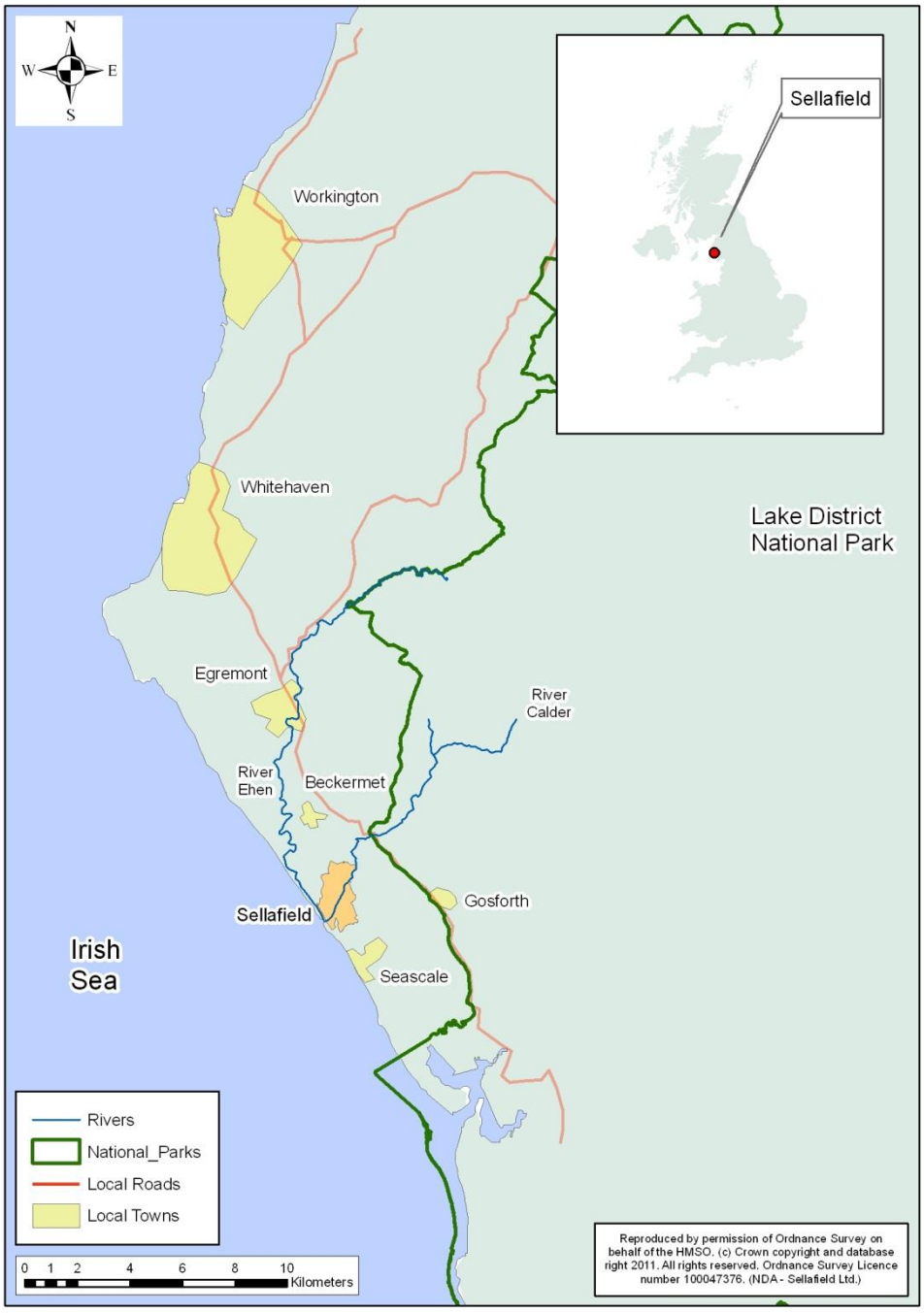
Introduction

The Sellafield site is located on the north-west coast of England on the margins of the Lake District National Park (*Figure 1*). The surrounding land use is predominantly agricultural with a number of farms and villages. There are two major surface water features present within and adjacent to the site, the Rivers Calder and Ehen which join to the south-west of the site where they discharge into the Irish Sea.

The industrial history of the Sellafield site began in 1941 when it was developed as a Royal Ordnance Factory for the production of trinitrotoluene (TNT). TNT production ceased at the end of the Second World War and the site was cleared in 1946. In 1947, the site was acquired by the Government as the location for Britain's plutonium production plant. The area developed for this purpose is now called Separation Area and incorporates an area of approximately 31 hectares. In the early 1950s, the world's first civil nuclear power generation reactors (Calder Hall) were constructed and expansion has continued since that time. With the exception of a prototype reactor built in the 1960s, this later expansion has largely been for the purpose of reprocessing spent nuclear fuel and the temporary storage of solid and liquid reprocessing wastes prior to vitrification, encapsulation and storage.

During the lifetime of the site there have been a number of leaks and spills that have resulted in contamination of the ground and studies of soil and groundwater quality have been carried out intermittently since the 1970s. To understand the nature and extent of the contamination and the pattern of groundwater movement a programme of characterisation work called the Sellafield Contaminated Land Study (SCLS) was started in 2002. Phase 1 of the project investigated the Sellafield site outside of the Separation Area, together with adjacent offsite areas, primarily to the west. The work consisted of a drilling programme of over 70 boreholes with associated sampling and analysis of soils and groundwater, followed by the installation of permanent groundwater monitoring wells. The drilling work was supported by an evaluation of the existing groundwater monitoring wells. The results did not identify any major source areas of contamination but indicated the presence of some radioactive contaminants in groundwater that were interpreted to have originated from inside of Separation Area.

Figure 1 – Location of Sellafield (UK Context)



Phase 2 of the project to investigate the Separation Area was taken forward as the Sellafield Contaminated Land and Groundwater Management Project (SCL&GMP) which started in April 2007 and ran until August 2010. The drilling programme included the drilling of 132 boreholes to investigate ground conditions, acquire soil and groundwater samples for analysis and to allow long term groundwater monitoring in selected locations. The Phase 2 work also included the development of numerical models for groundwater flow, contaminant transport and risk assessment to aid in the development of strategy and planning for the future.

Objectives and Implementation of the Project

The objectives of the Phase 2 Sellafield Contaminated Land and Groundwater Management Project were:

- to identify the radioactive and non-radioactive contaminants in the leak source areas
- to map the distribution of the contaminants in the groundwater
- to improve the understanding of how the contaminants can move and interact with the environment
- to assess the current and potential future impacts of the contaminants

The investigation started with a review of available information in order to prioritise known or potential radioactive contamination source areas for study. Areas of potential concern were targeted for investigation based on known contamination events, on the potential for facilities to have caused ground contamination and on environmental monitoring data. Priority was given to investigating potential source terms with large estimated radioactive inventories and where boreholes could be drilled relatively closely to a feature of particular interest. In addition, general coverage of Separation Area with new borehole information / groundwater monitoring wells was aimed for on approximately a 50 m spacing and some key pathways outside of Separation Area were also characterised further.

Due to the congested operational nature of the site with many restrictions on where drilling is possible, less intrusive geophysics methods such as EM31 ground conductivity, EM61 metal detector, Ground Penetrating Radar and Electrical Resistivity Imaging were trialled but had only limited success. Cone Penetrometer Testing (CPT) using resistance/friction cones to log the nature of the ground was used in former burial sites to avoid generating contaminated waste but again the use of specialist cones (video, gamma, conductivity, water sampler) to provide information on contamination gave generally disappointing results. Overall there were

too many interferences in the complex industrial environment for surface geophysics, ground conditions were generally too tough for probe instrumentation and generic down-hole radiometric equipment would need development to be effective on this particular nuclear site.

Sonic drilling was trialled for the first time on the Sellafield site and proved so reliable and rapid that it was used for virtually all the investigation holes. It drilled through clays, running sands, granite boulders and bedrock sandstone with no refusals in any boreholes and the rapid progress had benefits for dose considerations and the overall programme. Sonic drilling minimised waste generation, with the ability to drill dry to moderate depth, and high quality core was recovered with fewer fines requiring to be cleaned out of the groundwater monitoring installations.

Project Findings

The project was successfully completed in August 2010. Main findings of the investigation were:

- beneath Separation Area (where most of the contamination sources are located) much of the ground above the groundwater table contains only low activities of man-made radionuclides or is uncontaminated
- the highest observed levels of radioactivity are in and around the two facilities associated with 99% of the radioactivity lost to ground
- observations of radioactivity were also made in and around some areas previously known to be associated with historical leaks or identified to have had the potential for a leak
- highly elevated radioactive soil contamination was only found in one previously unknown area, which was adjacent to a historical disposal site
- lateral spreading of radioactive contaminants above the groundwater table is typically restricted to a few tens of metres
- in all contamination source areas containing tritium the contamination has reached the groundwater table and an extensive area of tritium contaminated groundwater extends from the Separation Area of the site towards the coast
- technetium-99 has a similar distribution to tritium in groundwater
- strontium-90, carbon-14 and uranium isotopes have reached the groundwater table in some contamination source areas but are less mobile, being largely or wholly contained within the boundary of the Sellafield site

- caesium-137 and plutonium isotopes have not generally reached the groundwater
- only localised elevated concentrations of chemo-toxic substances have been detected in soil and groundwater

As an innovation, the project used dose rate data as an alternative approach to estimating the source inventory from the largest radionuclide leak on site which had previously been estimated from the tank contents and the estimated leak rate/duration. Sellafield Ltd undertakes routine monitoring of arrays of 'blind tubes' installed at the facility. Each 'blind tube' consists of a metal tube sealed at the base to prevent water ingress. The distribution of radioactivity in the soil at the facility indicates that most unsaturated zone contamination detected in the blind tubes (i.e. caesium-137) is located within 10m horizontally from the leak. The inventory of radioactivity calculated using the blind tube data is 3.8E+15 Bq compared with the decay-corrected leak inventory of 3.4E+16 Bq derived previously. The agreement is to within an order of magnitude, and increases confidence in the inventory estimate for this source.

The investigation has lead to a considerable improvement in the interpretation of the geology, hydrogeology and land quality of the Sellafield site which confirms much of the previous understanding and gives confidence in the current management arrangements for the historical contamination. Lessons from experience of implementing the investigation include:

- characterisation on nuclear sites can be difficult, requiring commitment and a realistic approach
- maximising the use of existing knowledge is key
- the use of less intrusive investigation techniques would be preferred but to date results at Sellafield have been generally disappointing
- innovative techniques e.g. directional drilling will be needed to investigate below structures where most contamination sources are located but these will have to meet stringent safety standards

A recognised formal and structured methodology has been used to develop a risk assessment (the Sellafield Risk Assessment) for the ten highest activity source areas. The overall conclusion of the Sellafield Risk Assessment is that most of the radioactive contaminants remain on site and that risks to off-site exposed groups are small and within levels considered to be broadly acceptable from the operation of a nuclear facility.

Future Programme

The project has given the Land Quality team a wealth of data and tools with which to improve understanding and future management of the land contamination at Sellafield. The installation of a network of groundwater monitoring wells across Separation Area was a considerable achievement in the constrained environment of an operating nuclear processing plant and will improve confidence in the condition of the site. Inevitably some uncertainties remain which will be addressed by the Land Quality forward programme but enough information is now available to allow the next steps to be taken in the development of site strategy and the assessment of options for the future management of land contamination.

The forward Land Quality programme aims to build on the new understanding and confidence given by the project to improve management of land contamination by:

- developing the Land Quality Strategy to provide the framework in which the options for the management of the contaminated land can be assessed
- reviewing and updating the Contaminated Land Safety Case to increase the efficiency of the ongoing control of the radioactive material in the ground to ensure safety and environmental protection
- carrying out a Best Available Techniques (BAT) assessment of the management options for the Solid Active Waste Disposal Area and for the management of the groundwater contamination in the period before site restoration
- supporting the Solid Waste Storage Facility and Magnox Storage Pond 2 waste retrieval projects in developing their leak detection and mitigation strategies
- producing new approaches to estimating the volume of contaminated land at Sellafield to provide realistic estimates of potential future waste management needs
- improving the quality of the groundwater monitoring data by using the new network of groundwater monitoring wells to cover key sources and pathways, prioritising the rehabilitation of key existing wells and decommissioning “failed” wells
- commissioning new data management and record keeping systems to enable preservation and best use of both historical and new information

This forward programme is a structured approach based on good information and will involve engagement with stakeholders on the way in which the land contamination at Sellafield will be managed. Further information on the work of the Land Quality team will be made public on the Sellafield Ltd website as it becomes available.