LONG-TERM GROUNDWATER MONITORING

Note of a SAFESPUR workshop held at CIRIA Offices, London EC1, 10 July 2013

Chair's Welcome

Peter Booth (Hylton Environmental) introduced the meeting. He said it would cover:

- the drivers for long-term monitoring
- what to consider when designing a long-term monitoring programme
- approaches to sampling and analysis
- data storage and integration.

He thought that the presentations would deal in balanced way with aspects of these topics that are relevant to the nuclear industry. He noted that long-term groundwater monitoring supports decision making and links to regulatory needs, particularly in the context of decisions on site end states. It is important to understand the objectives of such monitoring when designing and carrying out a monitoring programme.

An Overview of Long-Term Groundwater Monitoring

Presentation

The first presentation, by Sean Amos of AWE, provided a nuclear site licensee's perspective. He said that the drivers for long-term groundwater monitoring (including associated measurements of rainfall, temperature, surface water flows etc.) are: site characterisation, monitoring of processes on site, stakeholder reassurance and compliance with legal, regulatory and commercial requirements, especially in respect of eventual delicensing. The quality of monitoring data has improved greatly with time but older data can still be valuable, although they are of poorer quality. It is important to devote sufficient resources to maintaining data, that is to storing information in a way that enables it to be retrieved easily when needed.

As an example of how groundwater monitoring programmes have changed over the years, Sean briefly described the AWE programmes from the 1980s to the present. There have been several phases of land (i.e. soil and groundwater) investigation, each including a desk study, drilling boreholes, groundwater monitoring and making recommendations for the next phase. At the start there were large uncertainties about the locations of groundwater on the $3km^2$ Aldermaston site and about flow directions and rates. Since the mid 1990s there have been extensive investigations (about 2,000 boreholes, probe-holes and trial pits), which have enabled a good conceptual site model to be built up. Information obtained from these phases of investigation, together with improvements in borehole design, sampling, analytical techniques, statistical techniques and data management, allowed the monitoring programme to become more focused. At the peak of the land quality investigation programme AWE was periodically monitoring 400 boreholes. A separate assurance programme, which in 2009 utilised 38 boreholes, enabled AWE to use the accumulated data to justify a reduction to 18 boreholes. Monitoring data are provided to the Environment Agency and to the Local Authority. In addition to satisfying these stakeholders, the monitoring programme has been very useful in supporting planning applications for new build on the site.

Q&A

There was a comment that there is a need for a common understanding of a few key terms, such as "compliance monitoring", "reassurance monitoring" and "routine monitoring". There was then a question about what AWE mean by "long-term" and who would decide when to end such monitoring. Sean said that there were two areas of the Aldermaston site where there has been solvent contamination, that had been remediated, but where monitoring continues in order to determine whether natural attenuation is progressing as expected. This monitoring will continue for as long as the Environment Agency deems it necessary. More generally, routine monitoring across the site is likely to carry on until delicensing and perhaps after that (depending on future use of the site). In answer to another question, Sean said that off-site groundwater monitoring (with independent analysis of samples) will probably continue for as long as Aldermaston is carrying out weapons-related work.

Another questioner asked whether it is worthwhile to carry out real-time groundwater monitoring, with alerts for unusual findings. Sean said that real-time monitoring is most useful for surface and near-surface water but groundwater data could help to support decisions in the event of alerts.

Development of a Nuclear Industry Code of Practice for Routine Water Quality Monitoring

<u>Presentation</u>

Hugh Richards (Magnox Ltd) gave this presentation on behalf of the Nuclear Decommissioning Authority (NDA). A nuclear industry code of practice (NICoP) for routine water quality monitoring is being developed with funding from NDA under its Direct Research Portfolio. The NICoP is sponsored by the Nuclear Industry Group for Land Quality (NIGLQ) and there is oversight of its development by the Nuclear Waste Research Forum's (NWRF's) Land Quality Working Group. The work is being carried out by a contractor (AMEC). It follows other successful nuclear industry projects to produce guidance (e.g. on clearance and exemption, on Best Available Techniques (BAT), on qualitative risk assessments for contaminated land).

Reasons for developing the nuclear industry routine water quality monitoring NICoP include:

- water quality monitoring has increased over time and there is a need to review programmes and prioritise objectives
- most water quality monitoring is specified by nuclear site operators, so it is appropriate for the industry to produce its own guidance
- there is inertia in water quality monitoring at nuclear sites, with a tendency to continue to use out-dated techniques
- capital and on-going costs of water quality monitoring are relatively high and there is scope for reducing them
- there are technical and practical issues in routine water quality monitoring that are specific to the nuclear industry and are not covered in other guidance
- staff knowledge of and experience in water quality monitoring varies considerably from one nuclear site to another
- circumstances at nuclear sites will change over the next few years: in particular some NDA sites will be demanned as they enter their care and maintenance period but will still need to be monitored.

The NICoP will deal with monitoring of groundwater, surface water and suspended solids. Inter-tidal surface waters will be included but not marine waters. Deep lakes will also be excluded. The NICoP will signpost other guidance where possible (e.g. on some non-radiological aspects). It will cover: setting objectives for routine monitoring; designing monitoring networks; design, maintenance and decommissioning of monitoring points, choice of analytical suites, sample collection, field measurements, some aspects of data management (validation, screening out errors) and assessing results.

A first draft of the NICoP was produced in May 2013. A second draft, incorporating the comments of the NIGLQ reviewers, is due in August 2013. The intention is to send this second draft out for wider review, probably in September 2013. Hugh suggested that it be sent to CIRIA, for distribution to SAFESPUR members, and also invited representatives of other industry networks to contact him.

<u>Q&A</u>

The SAFESPUR members present said that they would like to see the draft NICoP. It was therefore agreed that it would be sent to CIRIA for distribution.

A questioner asked whether, given its status as industry guidance, there would be enough buy in and incentive to follow the NICoP. Hugh said that the NICoP would contain a foreword by NDA stating its expectation that its sites and their contractors would use the NICoP or give reasons for not doing so. Experience with other guidance showed that other nuclear sites would follow the NICoP if it was helpful to them to do so. Sean Amos said that AWE, who had been involved in developing the NICoP, would certainly use it.

Data Integration: Sellafield Case Study

<u>Presentation</u>

This presentation was given by Helen McKenzie of Sellafield Ltd (as client) and Tom Weeks of Informed Solutions (the contractor). Helen explained that there is a need to understand, control, manage and remediate contaminated land and groundwater on the Sellafield site. Sellafield Ltd is currently carrying out a BAT study on groundwater management, the results of which will influence future activities on the site. Integration of existing groundwater data, and integration of new data as they become available, is seen as essential for effective groundwater management in the future.

The integration task is a large one because there are many different data sets for groundwater and these differ in format and quality. Formal groundwater monitoring began at Sellafield in 1978 but there are data from as far back as the 1950s. At present the site is generating about 5,000 field records and 8,500 analytical records for groundwater each year. Professional judgement is being used to assign a quality level to each data set, using a scale from one to five (where five is "fully trusted"). Integration challenges include differing units, differing names for boreholes and potential duplication (where contractors have "cleaned" original data before adding to them and reporting their results to Sellafield). Integration is being carried out in phases, focusing on key challenges first.

Tom said that the opportunities and benefits presented by better data integration warrant the project being treated as a business transformation and improvement project, not simply an IT one. Ultimately, once all data are integrated, it will completely change how Sellafield Ltd is able to visualise, analyse and report the 'big picture' of groundwater monitoring around the site. Sellafield Ltd had spent a great deal of time developing a clear data integration vision before going out to tender. Informed Solutions had carried out a trial dataset migration before Sellafield Ltd began major investment in data integration and migration; this helped to ensure that effort and expenditure focused on areas that would bring the greatest benefit. A key aim of the project is to transfer all of Sellafield Ltd's groundwater data to a centralised installation of the Informed LANDQUALITY platform, with all data being validated according to a consistent set of data quality rules. (In the past, data in different systems had been maintained to different quality standards). Informed LANDQUALITY has modules for: data capture and integration (including both manual data input via web forms and bulk data input); data validation and storage; analysis and reporting (including spatial analysis, fixed format reports and responses to ad hoc questions); and auditing (so that a complete audit trail of all changes made to data over time is retained).

Helen concluded the presentation with some key lessons learned from the project. These included recognising the need to consider what data are used for now and what they may be used for in future, and gaining an appreciation of the whole task and the key challenges, so that work can be phased appropriately.

Q&A
A questioner asked whether the data reporting formats of the Association of Geotechnical Specialists (AGS) were being used. The reply was not explicitly at this stage but such external standards could be brought into the project in future. In answer to another question, Tom noted that Informed Solutions had been able to make use of its extensive experience from non-nuclear sectors (e.g. oil and gas, telecommunications) in carrying out the work for Sellafield Ltd. Tom said that, in his view, all the sectors face similar data integration challenges; the main differences are in the overarching regulatory and business contexts that the integrated pictures will support.

Design of Long-Term Monitoring

Presentation
The fourth presentation was by John Shevelan of Low Level Waste Repository Ltd. He began by giving a brief history of groundwater monitoring at the Low Level Waste Repository (LLWR). The first borehole was drilled at the site in 1939, for construction of an ordnance factory. Many boreholes have been drilled on site during its use for LLW disposal; these were part of various investigation programmes (e.g. for construction of vault 8, for building the cut-off wall around the trenches). Off-site groundwater data have largely been obtained from boreholes drilled for other purposes, such as investigations related to the Sellafield site and to the proposed Nirex Rock Characterisation Facility.

The current LLWR groundwater monitoring programme is primarily designed to meet requirement 14 in the environment agencies' Guidance on Requirements for Authorisation (GRA). This necessitates monitoring for changes caused by construction, operation and closure of a disposal facility, in order to support the Environmental Safety Case (ESC). LLWR Ltd expects monitoring to be continued until site closure (which at present is scheduled for 2130) and from then until the end of the period of authorisation (which is anticipated to be in 2230). The current programme consists of:

- hourly automatic logging of groundwater levels at about 100 locations on site (to be reduced to 34 locations, with quarterly data downloads)
- use of regional groundwater data from Environment Agency boreholes
- quarterly radiological contaminant monitoring at about 30 locations
- non-radiological contaminant monitoring at 65 locations, on a 3 yearly cycle (to correspond to updates of the ESC).

Data management issues include dealing with the large number of data points (about 3 million) generated each year, and integrating old radiological and non-radiological data with newer data. There are also knowledge management issues, particularly ensuring that staff are aware of the rationale for the monitoring programme and recording the reasons for changes to it.

The LLWR groundwater monitoring programme is still being developed. It will always have a degree of flexibility because there will be changes at the site over the 200 year period over which monitoring is expected to be needed. It will be necessary to repair and replace boreholes, to decide where boreholes should be drilled for monitoring after capping of the site, to take account of technological advances, and to be prepared to adjust the monitoring programme in the light of changes in climate and sea level.

Q&A

A questioner asked whether LLWR Ltd had experienced difficulties because staff who design monitoring programmes are not those who will use the data for modelling. John said that there had been no such difficulties at LLWR, where all those involved in monitoring knew how data would be used and where the monitoring programmes were tailored to revisions of the ESC. He also noted that regulators checked whether staff carrying out monitoring understood the rationale for the programme and could spot unusual results. There was also a question about the quality of the geological data for the LLWR. John said that the more recent geological data are of good quality. Earlier data are of interest but are not as reliable.

Long-Term Trends in Groundwater Water Quality and Sampling Techniques

Presentation

This was a joint presentation by Sam Wood (SKM Enviros) and Kayleigh Smith (Waterra-In-Situ). Sam began the presentation by distinguishing between time-dependent and time-independent variability in contaminant concentrations in groundwater. Time-dependent variations can arise from, for example, reductions in the contaminant source, changes in the attenuation capacity of the aquifer, and long-term changes in hydrogeological conditions such as recharge patterns. Time-independent variations can be caused by monitoring well, hydrogeological and contaminant characteristics, and by operational factors such as changes in sampling methods and in the handling of samples. They can be sufficiently large to mask long-term trends. For example, in one study for VOCs it was concluded that 60-70% of the variability in concentrations was time-independent and only 30-40% arose from long-term trends. Minimising time-independent variability is essential in order to save time and money in long-term monitoring. It also increases the chances of gaining regulatory approval for a monitoring programme.

Kayleigh described three alternatives to traditional groundwater sampling, each with the potential to reduce time-independent variability. These are:

- low flow sampling (using a peristaltic or bladder pump)
- hydrasleeve (a plastic sleeve that fills with water as it is pulled up through a borehole)
- equilibrator (a plastic container filled with deionised water that is left in place in a borehole or trial pit so that contaminants can diffuse into it over time).

In the case of low flow sampling, contaminant concentrations can be measured automatically on site and the data sent to a tablet or smart phone. With the other two methods the water samples are sent to a laboratory for analysis. Although the set up costs for low flow sampling are higher, it can produce high quality data more quickly. Most of the R&D on these and other advanced sampling methods has been carried out in the US, where boreholes tend to have short (1-3m) screens. There is UK R&D in progress for boreholes with longer screens.

Sam said that, in his experience, the Environment Agency preferred low flow sampling. He recommended that, when changing sampling methods, there should be some overlap so that systematic differences can be identified. He also listed some useful guidance documents on sampling and statistics.

Q&A

In response to a question about which types of UK sites the newer sampling techniques had been used on, Sam said that his most recent experience had been on Part 2A Special Sites, where the newer techniques were faster and less expensive than traditional methods. Another question was whether UK laboratories are set up to deal with samples obtained by the newer techniques. Kayleigh said that all UK laboratories accept liquid samples produced by the newer techniques but most do not accept the solids on to which contaminants are adsorbed in some techniques (because they require special methods for analysis).

Case Study: Harwell

Presentation

The last presentation was by Jon Blackmore of Research Sites Restoration Ltd (RSRL) and was about groundwater contamination at Harwell. He explained that the two main sources of groundwater contamination on the site were the Southern Storage Area (which had been an RAF munitions store and then a waste disposal site from the 1940s to the 1970s and where there were chemicals, beryllium and solvents) and the Western Storage Area (which had been used for disposal of chemical wastes, including solvents and acids, from the 1970s to the late 1980s).

In 1989 solvent had been found in a public water supply borehole 6km from the Harwell site. The water from the affected borehole was blended with other supplies before distribution such that potable supplies met drinking water standards. There was a major programme of investigations, followed by remediation and monitoring. Groundwater containment is still carried out at the Western Storage Area and is expected to continue until 2025. The Southern Storage Area has been remediated and groundwater containment there has ceased.

Prior to the investigations related to movement of solvent off site, there were some boreholes on the Harwell site related to landfill disposals and some for radiological monitoring. There were also eight boreholes drilled by the Institute of Geological Sciences in the late 1970s and early 1980s as part of the UK high level waste disposal programme; one of these boreholes was 550m deep. Few of the existing boreholes were useful for the solvent plume. A new series of boreholes were drilled on site in the 1990s to determine the extent of the plume, to provide data for designing remediation and to monitor the effects of remediation.

The current groundwater monitoring programme is designed to continue to assess the effects of remediation, to meet requirements under the Water Framework Directive, and to inform delicensing and de-designation cases, decommissioning projects and plans for construction of new facilities. The monitoring network is being protected and maintained as decommissioning proceeds. This entails replacing some boreholes and ensuring access to other boreholes after release of land for non-nuclear uses. Off-site groundwater monitoring is now largely carried out by the Environment Agency (e.g. in water supply boreholes). It is expected that on-site groundwater monitoring will continue until the end of the decommissioning programme at Harwell and possibly beyond (i.e. after the site has ceased to be NDA's responsibility).

Q&A

In answer to a question about abandoning boreholes, Jon said that the usual procedure has been to backfill with bentonite and cement. In future RSRL would need to decide whether to remove borehole casings before backfilling. The second question was about compensation for water users following the discovery of the solvent plume and about gaining access to drill investigative boreholes off site. Jon said that measures had been put in place to provide alternative water supplies to parties affected by the plume. Where monitoring boreholes have been required off site, formal legal agreements have to be put in place, which can represent a significant cost.

There was then a question about using old records of groundwater monitoring. Jon replied that RSRL did use old records where it could but there were difficulties (e.g. it was unclear why some of the old boreholes had been drilled). A questioner asked whether the off-site solvent plume was becoming smaller. Jon said that the plume was still about $10km^2$ in area but concentrations in it were decreasing. A further question was about ground vapours. Jon replied that developers had checked for ground vapours before starting to build houses on land that had been delicensed and sold and no special construction measures had been necessary.

Discussion and Conclusion

Before the meeting ended there was a short discussion of what is meant by "reassurance monitoring" and "compliance monitoring" and how judgements are made as to whether the results of each type of monitoring are significant. RSRL uses the term "reassurance monitoring" to refer to all monitoring that is not specified in its environmental permit and uses qualitative judgements about the significance of the results. In contrast, AWE has its own numerical criteria for the significance of the results of all its groundwater monitoring, whether "reassurance" or "compliance".

Only one Magnox site has monitoring of groundwater specified in its environmental permit. Most groundwater monitoring at Magnox sites is regarded as necessary under condition 34 in nuclear site licences and is thus also classed as "compliance monitoring". Magnox has used WHO drinking water levels as significance criteria but the Environment Agency points out that these do not have any statutory basis.

Peter Booth concluded the meeting by thanking the speakers and participants. He emphasised that SAFESPUR belongs to its members and reminded everyone to let CIRIA have ideas for future events.

Marion Hill for CIRIA / SAFESPUR
2 September 2013