# Project Acceleration through the Application of Innovation on the Pile Fuel Storage Pond at Sellafield – 15060

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## ABSTRACT

The Pile Fuel Storage Pond (PFSP) at Sellafield was built between 1948 and 1950 to receive, store and de-can fuel and isotopes from the Windscale Piles. Since closure of the Piles in 1957, the facility has been used to store materials from the UK nuclear programme. The pond has built up a large inventory of miscellaneous items and pond sludge, which combine to create a challenging nuclear clean up job.

To enable clean up, the operator required a capability to encapsulate the pond sludge for long term storage, the operator initiated a project. Applying conventional project delivery processes resulted in an unacceptable cost and schedule for provision of this capability.

To address this issue, the project to deliver the plant was restarted with a study to look at the selection of process routing for the sludge. In the decision making processes for this study increased weighting was given to innovative re-use of existing facilities and speed of deployment. Innovation was also applied to the study process to enable early option selection where this was clearly of benefit. This focus on innovation produced the first significant improvement for the project with the scheme selected offering a 30% reduction in baseline cost and schedule.

The focus on schedule acceleration was carried through into the early design phases of the new project. In the concept stage process simplification was achieved through functional analysis of the plant combined with a drive to utilise technology and learning from other industries. This resulted in a plant concept which could be delivered more quickly than the baseline schedule with a high level of confidence.

Once the main benefits associated with innovation of the plant concept had been achieved focus was switched to how the project was to be delivered. The project looked at where delivery in the nuclear environment tended to be complex and time consuming. Focusing on these areas and learning from other industries led to significant innovation in delivery processes, with particular success in the rigorous application of value transition point analysis and minimisation of onsite works. The combination of innovative design and delivery processes led to a further reduction in the project baseline cost and schedule.

Application of engineering innovation, focused on engineering simplification and challenge of the engineering norms, reduced the cost of the project by £50m (65%) and reduced the schedule for delivery by over 3 years. The project has been recognised as an exemplar of how to apply the “decommissioning mindset”, which is the cultural change being targeted by Sellafield Ltd to deliver the decommissioning of its high hazard facilities.

## INTRODUCTION

The Pile Fuel Storage Pond (PFSP) at Sellafield, shown in figure 1, was built and commissioned between the late 1940s and early 1950s as a storage and cooling facility for irradiated fuel and isotopes from the Windscale reactors. The pond was linked via submerged water ducts to each reactor, where fuel and isotopes were discharged into skips for transfer to the pond. In the pond the fuel was cooled then decanned underwater, prior to export in flasks for reprocessing.

Fig. 1. Pile Fuel Storage Pond during construction

The plant operated successfully processing Winscale reactor and then Calder Hall fuel, until it was taken out of operation in 1962 when the First Magnox Fuel Storage Pond took over fuel storage and decanning operations on the site. The pond was then used for storage of miscellaneous Intermediate Level Waste (ILW) and fuel, from the National Nuclear Programme, for which no defined disposal route was available. By the mid 1970s, the import of waste ceased and the plant, with its inventory, were placed into a passive care and maintenance regime.

By the mid 1990s, driven by the age of the facility and concern over the potential scale of the programme to dispose of the various wastes and fuels being stored, the plant operator initiated a programme of work to remediate the facility.

A key element of this programme is to deal with the pond sludge, which has built up as the pond has no containment building and is not dosed. At the start of the clean up activities there was in excess of $300m^3$ of sludge dispersed across the bottom of the pond, in the pond storage skips and throughout the facility decanning and withdrawal bays. The sludge generally consists of inorganic material such as fuel and metal corrosion products, wind blown debris, and bio-organic materials such as algae and bird guano. Figure 2 shows the sludge in situ within the pond and under examination in laboratory conditions.

To deal with this sludge the operator initiated 3 separate project workstreams,

- The Sludge Retrieval Project - provided the equipment required to retrieve sludge from the pond and transfer it to an in-pond corral.
- Local Sludge Treatment Plant Storage (LSTP(S)) - provided a local storage plant in which the sludge could be stored in modern conditions while the final project was developed.
- Local Sludge Treatment Plant Export Project (LSTP(E)) – to provide a treatment route to prepare the sludge for long term storage.


Fig.2. Pile Fuel Storage Pond Sludge

This strategy allowed earliest start to sludge retrieval and accelerated risk reduction, and has been reported previously [1][2].

The work to deliver the first two projects is now complete and significant progress has been made in clearing sludge from the pond floor, bays and skips. However, finding a solution to the problems associated with preparing the sludge for long term storage, that is acceptable to all stakeholders, has proved more challenging. The way this has been achieved through the application of both technical and procedural innovation is described below.

## Project Background

The overall objective for the export project was to provide the capability to retrieve sludge from the new storage plant and treat it, such that it forms a suitable package for long term storage. Initially this storage would be in the Sellafield above ground stores, before eventual transfer to a national repository for ILW waste.

The sludge accumulated in the pond, is just one of a large number of sludges and other ILW waste streams accumulated on the Sellafield Site. The standard technology for treatment of this waste on site is cement encapsulation. The relatively low volume of the PFSP sludge stream, compared to the site inventory and the infrastructure already in place to support disposal in this way, made the choice of cement encapsulation for this waste compelling.

In 2008 a project was put in place to implement an encapsulation based solution to the problem. Initial work discounted direct pumped transfer to an existing site facility, due to the length and complexity of the pipe routing. This would have involved pumping the radiologically challenging sludge over 1 mile, across the congested Sellafield site. Transfer by shielded road tanker or bowser was discounted due to the dose associated with the sludge. This left the options of either small volume sludge transfer to an existing plant or local encapsulation. The traditional approach to either of these options would require infrastructure to fill containers with sludge in concrete containment cells and handle shielded transfer flasks weighing around 50t. As the additional equipment required to encapsulate the sludge could be provided at minimal additional cost, once the sludge was transferred to a suitable container, the project down selected a local encapsulation option.

The plant concept was developed the cost and schedule for implementing this project were calculated.

This resulted in a project baseline which failed to meet the programme's requirement for accelerated hazard reduction and was not seen to deliver stakeholder value. A review of the project underpinning confirmed that stakeholder aspirations on cost and time could not simply be met by marginal reductions in scope or more effective project delivery, a fundamental re-think was required.

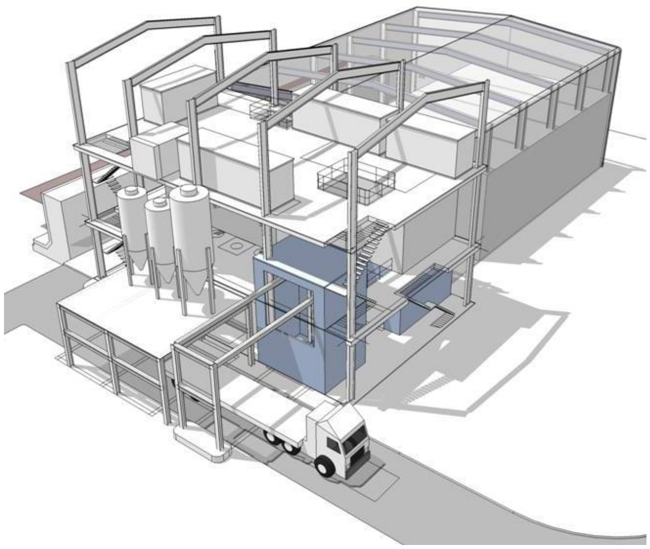

Fig.3. Initial Local Sludge Treatment Export Plant Concept

## METHODS

In order to meet stakeholder expectations, it was clear that the capability would have to be delivered significantly more quickly and at much lower cost. However, when the project team reviewed the work that had been done, it was clear that, if normal criteria and methods were applied to the project, it was unlikely to generate a significantly different outcome. It was also clear that, given the existent site infrastructure and expertise for storing encapsulated waste drums, changing the fundamental treatment technology would not achieve the desired outcome. Therefore the only way to achieve a better outcome was to find innovative ways of selecting, delivering and subsequently operating the new facility. The co-incident launch of a drive to implement a "decommissioning mindset" at Sellafield to accelerate hazard reduction, gave the opportunity to do this.

### Study

The study phase of a Sellafield Ltd project is used to confirm that a project is technically viable and to select a preferred technology for delivering the solution. A traditional approach to delivering this work would have been to generate a wide range of options, then work all the options to sufficient detail to allow a multi-attribute decision making process to be applied. The logic of this approach being that, if the attributes are weighted to reflect the principles such as Best Available technique (BAT) and As Low as Reasonably Practicable (ALARP) along with the stated needs of the project stakeholders, a robust justification for the selection should underpin the project going forward.

However as previously stated, following this traditional process had resulted in the project generating a solution which was not acceptable to the stakeholders. The process is also very time consuming, as it tends to lead to many options remaining open for a long time, generating a significant amount of work.

The project therefore had to find a way of accurately assessing project stakeholder needs and accelerating the selection process.

To deal with the issue of assessing stakeholder needs, a number of in depth stakeholder engagements were undertaken. While this had been done in the initial work, it was clear that without significant challenge the true requirements for the project would not come out. For example, all stakeholders would clearly state that early nuclear hazard reduction was top priority, however it was clear that this was not at any cost, few however were comfortable quantifying this qualification. To ensure that the attributes were correctly weighted when selecting the final solution, a number of techniques to enable this debate where used. The most useful technique was found to be “balanced pair” analysis, where after identifying all of the important attributes they are paired with each other and the group are required to decide which of the pair is most important.

The outcome of this stakeholder analysis identified that what stakeholders wanted for the project was a solution which:

- looked demonstrably value for money
- offered an acceleration to the overall decommissioning programme
- demonstrated novel thinking and decommissioning mindset

The analysis also identified that the stakeholders were prepared to accept

- Solutions which had a bias towards operational controls rather than engineered protection to mitigate hazards if they allowed the solution to be delivered more quickly
- Short term increase in risk where this results in early hazard reduction in the facility

With a clear view of what the stakeholders wanted from the project focus could then switch to changing the way studies were done to get to an acceptable solution as early as possible . It was recognised at this stage that by encouraging innovation in the way the project was being delivered, the team could meet the stakeholder’s key needs for novel thinking before physical delivery of the plant even started. This offered the opportunity of maintaining stakeholder engagement and support which would be necessary to deliver the project in an innovative way.

**Study Method**

It was clear from the stakeholder analysis that there was a strong driver not only to come up with a new solution to the problem, but also to be seen to be working in a way that reflected the drive for acceleration and value for money. With this in mind, the project challenged the traditional way of doing a study and gained agreement to try a new strategy. Instead of working up a large number of technical options to allow thorough down selection, the project proposed an early down selection to a favoured option based on more limited data. The chosen option would then be worked up in detail and continuously tested to ensure it remained a feasible solution. Should the option pass all the feasibility challenges it would remain the selected option for the project. In parallel a limited number of fallback options would be developed to mitigate the risk that the front runner scheme would fail a feasibility challenge. Work on these would cease immediately once the feasibility of the front runner had been confirmed. Should the front runner fail, then the next fallback option would take over as the chosen option for the project and so on.

This in itself represented a fundamental shift for the project and its stakeholders, in particular because it required that stakeholders accepted that the solution adopted would not necessarily be underpinned as the best solution to the problem it would just be one feasible solution, which met the project drivers. A diagrammatic representation of the process used is shown in figure 4

**Study Outcome**

Focusing on the agreed key stakeholder drivers, the team selected a primary option which utilised an existing site facility to encapsulate the sludge; minimising the cost and complexity associated with transferring material to this facility, by using an existing transfer flask to provide shielding and containment. This concept did away with the requirement for concrete containment and shielded cells, drum transfer equipment and very large nuclear rated cranes.

The selected option was subjected to each of the feasibility tests agreed in the study process and was found to be a robust solution to the problem. Detailed cost and schedule for the project were then developed. The outcome of the study was not only a plant concept which was forecast for delivery at a saving of £40m to the baseline and 3 years more quickly, but also one that received universal stakeholder approval. The study was delivered in 6 months against a norm of around 12 – 24 months for similar projects of this type on the site.

**Re-Engineering and Innovation**

In light of the stakeholder driver to be seen to "demonstrate novel thinking and decommissioning mindset"; the project took the themes of the study in the main project delivery phase. A further re-evaluation of the equipment was undertaken, to see where innovative products could help to meet the project goals. Very quickly the team concluded that due to the nature of nuclear clean up work, trying to implement new technologies into the design would delay completion. This was principally due to the requirement for underpinning information and experience required to substantiate a design to meet its nuclear safety case, which, by definition, in not available for new technology.

A much more fertile area for deriving cost and schedule efficiencies was the innovative application of equipment from other industries and application of innovation to the design process. Value management techniques, such as functional analysis were used to understand the key requirements for the facility. Then, focusing on the remaining elements of the design, which were driving technical complexity the team were able to identify areas where utilising innovative application of technologies from the rail, road and water industries could generate significant benefits.

Some of the more significant examples of innovative use of technology are:

- Adapting tanker filling technologies to develop a movable enclosure in which the operators could fill sludge drums within the transport flask.

- Using train maintenance jacking systems to move the drum filling enclosure, avoiding movement of the heavily shielded flask.

- Using sludge pumping technology from the water industry and a simple tundish to avoid a complex drum filling head and flask positioning systems.

- Application of techniques such as optical metrology to the design process, to design the components required to modify the existing active flask, reducing risk and dose uptake during measurement of built status.

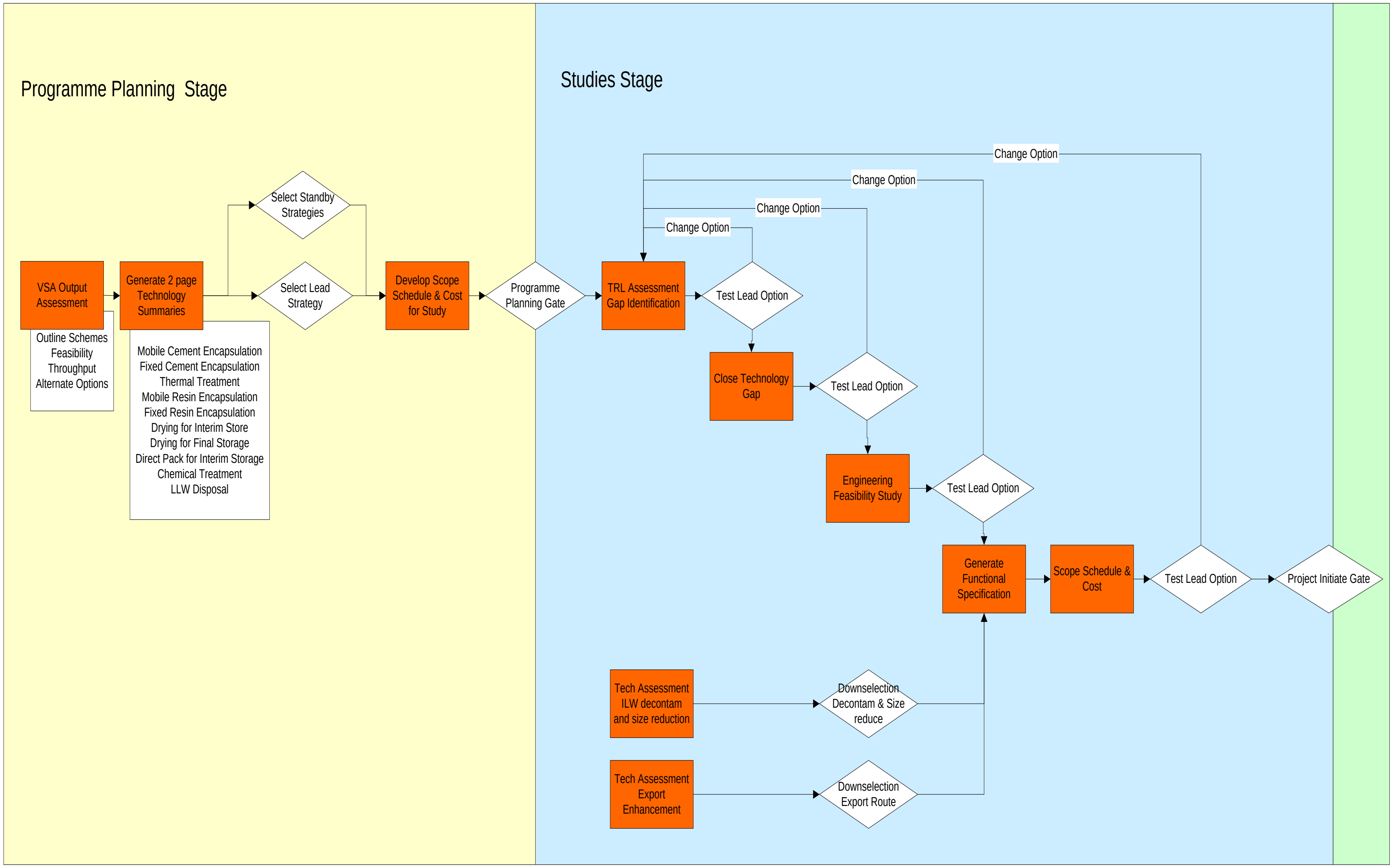


Fig. 4 Agreed Study Process

To maximise the benefit gained from the application of commercially available technology, the team focussed on reducing the nuclear requirements for the plant and equipment. To do this the plant hazard management strategy focussed on minimising stored inventory and the speed of fault progression. By doing this the consequences of potential faults was reduced sufficiently to allow a safety case to be made based on operator controls rather than engineered protection. This in turn avoided the need to modify commercial equipment to “nuclearise” it.

This focus on simplifying areas of complexity and utilising commercial technology allowed the plant concept to be further simplified, as shown in figure 5. This in turn reduced the cost and schedule for the project.

Fig.5. Final Drum Filling Plant Concept

**Delivery Innovation**

In a final drive to improve value for the project, the way the work was to be delivered was subject to review to identify where cost and schedule could be saved by working differently.

**Value Transition Points**

In developing the Project delivery strategy, the team faced a number of strongly held but very different stakeholder views on the best way to engage the supply chain. At one extreme was a view that innovation and value could only be driven into the work by moving to an Engineering, Procurement and Construction contract covering all the works at the earliest opportunity. At the other end of the spectrum was a view that, given that the requirement to modify existing facilities and develop an integrated solution, a contractor would be unable to deliver the project vision. To resolve this issue the project embraced the Value Transition Point concept and analysed where in the project lifecycle maximum value could be added to the project by both in house and supply chain delivery. This analysis identified that a single solution could not deliver all the benefits expected, however, values could be maximised by splitting into smaller workpacks, and differing the transition point for each.

In doing this the project focussed on creating a work pack where there was significant flexibility in what and how work was delivered. This work could be released early to the supply chain. Other work, with complex operational interfaces was consolidated into work packs which would be delivered largely in-house. This not only had the benefit of creating a work pack with the flexibility to allow the supply chain to be rewarded for innovation, but one which was much less likely to be subject to commercial changes as the complex plant interfaces had been removed. The detailed transition point analysis was crucial in ensuring all stakeholders were bought into the strategy.

**Modular Building**

The nature of the Sellafield site, which is a highly congested, very complex nuclear site, makes delivering any construction work time consuming and resource intensive. This has typically led to long construction and commissioning schedules. Modular building clearly represents an opportunity to minimise the on site activities required. This had been tried before on a number of projects with varying degrees of success. This past experience was reviewed along with successful modular build methodology in oil and ship building industry. It was identified that where the use of modular build was successful, and transformed the project, the concept had been driven right through the job. This drive essentially created modules which were plug and play, even if this created a little extra complexity or required some additional equipment.

A very clear success criteria was set for the project to avoid on site installation work by designing for modular build. This followed through into the use of plugs and sockets and pre manufactured cables to connect the modules together, mounting of services on the modules rather than the weather envelope, and the use of flanged connections for process and services pipework. By doing this the on site construction work associated with the new facility was reduced to creation of the foundation, installation of the modules and the erection of the steelwork and cladding for the weather envelope. The need for on site mechanical and electrical construction work was virtually eliminated with an associated reduction in cost and schedule.

**Off site testing**

Because the scale and complexity of the project had been reduced, and the modular build concept maximised, the opportunity to maximise the use of works testing to minimise site works was identified. While works testing had been used on other projects, standard practices often involved retesting on site, items which had been tested at works but could not be confirmed to be unchanged during installation. The project set the target to get all of the plant equipment to a single integrated works test and putting in place arrangements to ensure credit could be taken for this testing when bringing the plant into service.

As discussed above, the plant was designed in fully modular fashion which allowed it to be built off site and tested, then dismantled for installation. By ensuring all field wiring was designed to connect using plugs and sockets and putting in place a number of controls to prevent modification to equipment, the project team were able to take full credit for the off site work and avoid repeat testing. This allowed the overall commissioning programme to be reduced to a few weeks rather than the traditional months of work. An emergent benefit of this strategy was that by building the plant off site, all of the project stakeholders could gain an early and accurate sight of the facility. This allowed operator and maintainer training to be completed, early validation of construction plans and other risk assessment tasks to be done in a highly realistic environment.

### Outcome

The focus on achieving stakeholder outcomes through application of innovative thinking to scheme concept, equipment design and execution processes, resulted in a 65% reduction in cost and an acceleration of over 3 years on delivery of the facility. The methods used to achieve this have been recognised as an exemplar of how to apply the “decommissioning mindset”.

## CONCLUSIONS

The drive for innovation within nuclear clean up work is often focused around the application of new and clever technologies. These, however, are often difficult to apply because of the limited experience of use, which makes generation of a safety case for the work very difficult. Innovative use of proven technology elsewhere or changes in “how we do things” can be much easier to implement and just as rewarding.

Several key lessons were learned in the delivery of the innovative approach to delivery of the Sellafield Drum Filling Plant Project.

- A clear view of stakeholder values and drivers is necessary to attain the high levels of support required to deliver an innovative project; this may mean drilling significantly deeper than openly stated views.
- Thorough analysis of what drives complexity in the design, and therefore project cost and schedule, will identify the key areas where innovation will add maximum benefit.
- Focus on reducing the significance of the nuclear and radiological aspects of the work allow greater scope for innovation and change. This can be achieved by good hazard management strategies, such as minimising plant inventories and reducing the speed of fault progression.
- Creation of workpacks with well controlled interfaces, maximises the opportunity for supply chain innovation, and focuses in-house delivery on work with complex interfaces and significant uncertainties.

## REFERENCES

1. Carlisle, D, Decommissioning Sellafield’s First Fuel Storage Pond, WM2010 Conference, Phoenix, AZ, March 7 - 11, 2010, 10070 (2010), WM Symposia

2. Carlisle, D and Adamson, K, Fuel Pond Sludge – Lessons Learned from Initial Desludging of the Pile Fuel Storage Pond - WM2012 Conference, Phoenix, AZ, February 26 - March 1 - 11, 2012, 10070 (2012), WM Symposia

## GLOSSARY

| | |
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| ALARP | As Low as Reasonably Practicable |
| BAT | Best Available Technique |
| EPC | Engineering, Procurement and Construction |
| ILW | Intermediate Level Waste |
| LLW | Low Level Waste |
| LSTP (S) | Local Sludge Treatment Plant Storage |
| LSTP (E) | Local Sludge Treatment Plant Export |
| PFSP | Pile Fuel Storage Pond |