Best Practicable Environmental Option Study for Management of Radioactive Waste Arisings from the Dounreay Site Restoration Plan (A3 tables)

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A3 Tables

Table 4.2: Representative waste treatment options for the DSRP wastes in each of the 12 strategy options.

Table 6.1: Scores for the three strategy options related to the environmental issue of liquid discharges.

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Table 7.3: Scores for the optimised strategy options related to the environmental issue of liquid discharges.

Table 7.4: Scores for the optimised strategy options related to the environmental issue of airborne discharges.

Table 7.5: Scores for the optimised strategy options related to the environmental issue of solid ILW volumes.

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Table C2.1: Assessment of Risks

Note that Tables 2.1, 2.2, 2.3, 4.1, 4.3, 5.1, 5.2, 7.2, 7.6, 8.1, 8.2, 8.3, 8.4, 8.5 and 8.6 are in their respective sections of the main text.

Table 4.2: Representative waste treatment options for the DSRP wastes in each of the 12 strategy options. These are chosen from the lists of 'Options for Management Methods' (both for Limitation of Arisings and Treatment Process).

Waste		Options for Management Methods		Liquid discharges			Airborne discharges			ILW volumes			LLW volumes		
No.	**Description**	**Limitation of Arisings**	**Treatment Process**	Liq_{Min}	Liq_{Max}	Liq_{Inter}	Atm_{Min}	Atm_{Max}	Atm_{Inter}	ILW_{Min}	ILW_{Max}	ILW_{Inter}	LLW_{Min}	LLW_{Max}	LLW_{Inter}
Airborne Wastes															
A1	Particulates from active process and building ventilation	1. Current practice 2. Ventilate only when access required 3. Hermetically seal plants 4. Reduce flow rates 5. Increase flow rates	1. Direct discharge 2. Appropriate HEPAs 3. Wet scrubbers 4. Dry scrubbers 5. Mechanical removal (e.g. cyclones)	Current practice and HEPAs	Current practice and wet scrubbing	Current practice and HEPAs	All practical minimisation of arisings methods and scrubbers and HEPAs	Increase flow and direct discharge	Current practice and HEPAs	Min arisings and direct discharge	Increase flow rates and HEPAs	AECP 1054 and HEPAs	Min arisings and direct discharge	Increase flow rates and HEPAs	Current practice and HEPAs
A2	Particulates from treating contaminated ground	1. Influenced by choice of process 2. Influenced by operating method (including means of remediating contaminated land and dismantling buildings)	1. Direct discharge 2. Wet treatment (spraying) 3. Dry treatment 4. Appropriate HEPAs 5. Wet scrubbers 6. Dry scrubbers 7. Mechanical removal (e.g. cyclones) 8. In-situ encapsulation	Dry treatment (none)	Wet treatment	Dry treatment	In situ encapsulatio n	Lift and shift with direct discharge	Tent and HEPA on ventilation	None – cannot generate ILW	None – cannot generate ILW	None – cannot generate ILW	Direct discharge	HEPAs and grout	Scrub and grout
A3	H-3	1. Where contained do not release (e.g. from tritiated metal or irradiated fuel materials) 2. Control humidity (for HTO) 3. See treatment options for S1.2	1. Direct discharge 2. Hydrogen 'getter' 3. Thermal oxidation and condensation 4. Catalyst and condensation 5. Catalyst and absorption 6. Scrubber	Direct discharge	Catalyst and total condensation	Partial condensation	All practical minimisation of arisings methods and scrubbers and HEPAs: condense where not contained, And control humidity	Direct discharge	Where contained do not release and partial condensation	Direct discharge	Catalyst and absorption (multi-stage process producing only solid)	Catalyst and condense	Direct discharge	Catalyst and absorption (multi-stage process producing only solid)	Catalyst and condense
A4	C-14	1. See treatment options for L4, S6.2, S8.1, S8.2	1. Direct discharge 2. Scrub and barium carbonate 3. Wet scrubber 4. Scrubber circulating tank	Direct discharge	Wet scrubber	Scrub and barium carbonate	Wet scrubber	Direct discharge	Dry scrub	Direct discharge	Scrub and grout barium carbonate	Scrub and grout	Direct discharge	Scrub and grout barium carbonate	Scrub and grout
A5	Kr-85	1. No options (main arisings from management of fuel materials)	1. Direct discharge 2. Cryogenic distillation 3. Zeolite separation 4. Liquid absorption	Direct discharge	Liquid absorption	Direct discharge	Cryogenic distillation	Direct discharge	Liquid absorption	Direct Discharge	Zeolite Separation	Cryogenic distillation	Direct Discharge	Zeolite Separation	Cryogenic distillation
A6	Iodines	1. No options (main arisings from management of fuel materials)	1. Direct discharge 2. Wet scrubber 3. Absorption on silver 4. Corona discharge 5. Scrubber circulating tank 6. Activated carbon 7. Barium carbonate	Direct discharge	Wet scrubber	Scrub and barium carbonate	Activated carbon and, or scrubbing	Direct discharge	Absorption on silver	Direct discharge	Activated carbon	Absorption on silver	Direct discharge	Activated carbon	Absorption on silver
Liquid Wastes															
L1	Low level liquid	1. Current practice 2. Increased recycle (e.g. D1203, D1206) 3. Hydraulic Isolation of LLW pits 4. Separate SAD from LAD 5. See treatment options for solids and solvents	1. Zone specific evaporators 2. Central evaporator 3. Ion exchange columns 4. Direct discharge 5. Maximise activity in sludge	All minimisation arisings methods and central evaporator	Direct discharge	Current practice and zone specific treatment	All minimisation arisings methods and any except evaporator	Any and evaporator without abatement	Current practice and direct discharge	All min arisings and direct discharge	Current practice and central evaporator and cement	Min arisings and zone specific and evaporate and cement	All min arisings and direct discharge	Current practice and central evaporator and cement	Min arisings and zone specific and evaporate and cement
L2	MALs														
L2.1	MALs from decommissioning	1. Robotic dismantling 2. Do not decontaminate 3. Dry decontamination 4. Do not washout	1. Cement 2. Evaporate and vitrify 3. Treat to liquid LLW 4. Direct discharge	No treatment and robotic dismantling	Washout and direct discharge	Washout and chemical activity removal, discharge	No treatment and robotic dismantling	Wash out and evaporate without abatement	Washout and chemical activity removal, discharge	Washout and direct discharge	Washout and direct cement	Washout and activity removal and cement	No treatment and robotic dismantling	Wash out and cement directly as LLW	Washout and treat to liquid LLW and cement

Waste		Options for Management Methods		Liquid discharges			Airborne discharges			ILW volumes			LLW volumes		
No.	**Description**	**Limitation of Arisings**	**Treatment Process**	Liq_{Min}	Liq_{Max}	Liq_{Inter}	Atm_{Min}	Atm_{Max}	Atm_{Inter}	ILW_{Min}	ILW_{Max}	ILW_{Inter}	LLW_{Min}	LLW_{Max}	LLW_{Inter}
L2.2	Legacy MALs	1. None	1. Cement 2. Evaporate and vitrify 3. Treat to liquid LLW 4. Direct discharge	Cement	Direct discharge	Chemical activity removal (floc)	Cement	Evaporate without abatement	Chemical activity removal (floc)	Direct Discharge	Cement	Activity removal and cement	Direct Discharge	Treat to liquid LLW and cement	Treat as MALs
L3	DFR raffinate	1. None	1. Cement 2. Vitrification 3. Evaporation 4. Direct discharge 5. Chemical separation (e.g. of α and β,γ)	Cement	Direct discharge	Chemical separation and treatment	Cement	Vitrification without abatement	Vitrification with abatement	Direct Discharge	Cement	Vitrify	Direct Discharge	Dilute and cement as LLW	Dilute and cement as LLW
L4	PFR raffinate	1. None	1. Cement 2. Vitrification 3. Evaporation 4. Direct discharge 5. Chemical separation (e.g. of α and β,γ)	Vitrification	Direct discharge	Chemical separation and treatment	Cement	Vitrification without abatement	Vitrification with abatement	Direct Discharge	Cement	Vitrify	Direct Discharge	Dilute and cement as LLW	Dilute and cement as LLW
L5	Solvents and oils	1. None	1. Incinerate 2. Direct discharge 3. Chemical treatment 4. Pre-wash before treatment 5. Solidification	Solidification	Direct discharge	Pre-wash and incinerate and dry scrubbers	Solidification	Incinerate without abatement	Incinerate with abatement	Direct Discharge	Solidification	Incinerate (not likely to produce ILW as pretreatment is likely)	Direct Discharge	Dilute and solidify as LLW	Incinerate with abatement
L6	Flocs and sludges														
L6.1	Ammonium diuranate	1. None	1. Cement 2. Vitrification 3. Polymerisation 4. Solvent extraction 5. Dissolve floc and direct discharge	Direct cementation	Dissolve floc and direct discharge	Solvent extraction	Direct cementation	Vitrification without abatement	Solvent extraction	Dissolution and Direct Discharge	Cement	Solvent Extraction and cement	Dissolution and Direct Discharge	Dilute and cement	Solvent extraction and cement
L6.2	LLLETP sludge	1. Current practice 2. Increased recycle (e.g. D1203, D1206) 3. Hydraulic Isolation of LLW pits 4. Separate SAD from LAD 5. See treatment options for solids and solvents	1. Cement 2. Dewatering and cementation 3. Incineration 4. De-watering 5. Discharge to sea 6. Concentrate to ILW 7. Vitrification	Minimise liquid arisings and direct cementation	Dissolve and direct discharge	De-water, cement sludge and discharge liquid	Minimise arisings and direct cementation	Vitrification without abatement	De-water and cement	Min liquid LLW arisings and Direct Discharge	Max liquid arisings and direct cement	Some min arisings and direct cement	Min all liquid arisings and discharge	Max liquid arisings and cement	Some min arisings and De-water and cement
L6.3	Shaft and Silo sludge	1. None	1. Cement 2. Dewatering and cementation 3. Incineration 4. De-watering 5. Discharge to sea 6. Concentrate to ILW 7. Vitrification	Direct cementation	Dissolve and direct discharge	Dewater, cement sludge, treat liquid and discharge	Freeze and cement	Vitrification without abatement	Dewater and cement	Direct Discharge	Cement	Dewater and cement	Dissolution and Direct Discharge	Dilute and cement	De-water and cement
L6.4	Fuel storage pond sludges	1. None	1. Cement 2. Dewatering and cementation 3. Incineration 4. De-watering 5. Discharge to sea 6. Concentrate to ILW 7. Vitrification	Direct cementation	Dissolve and discharge	Dewater, cement sludge, treat liquid and discharge	Direct cementation	Vitrification without abatement	Dewater and cement	Direct Discharge	Cement	Dewater and cement	Dissolution and Direct Discharge	Dilute and cement	De-water and cement
Solid Wastes															
S1	LLW														
S1.1	General metals	1. Sorting and segregation (by activity level or by activity level and half-life)	1. Cut and package 2. Wet decontaminate, cut and package 3. Dry decontaminate, cut and package	Any (except liquid decontamina te), and cut and package	Any and decontamina tion	Any and cut and package	Minimum handling and sealing prior to removal	Dry decontamina tion and recycling	Volume reduction and pack	Any	Decontamina te, concentrate on solid (e.g. Ion exchange)	Any	Segregate, decontamina te to free release	No segregation, pack	Segregate, pack

Waste		Options for Management Methods		Liquid discharges			Airborne discharges			ILW volumes			LLW volumes		
No.	**Description**	**Limitation of Arisings**	**Treatment Process**	**Liq_{Min}**	**Liq_{Max}**	**Liq_{Inter}**	**Atm_{Min}**	**Atm_{Max}**	**Atm_{Inter}**	**ILW_{Min}**	**ILW_{Max}**	**ILW_{Inter}**	**LLW_{Min}**	**LLW_{Max}**	**LLW_{Inter}**
S1.2	Tritiated metals	1. None	1. Smelt 2. Decay store 3. Out-gassing at ambient temperatures	Decay store	Smelt and scrub	Smelt and condense	Decay store and store in unventilated building	Smelt without abatement	Volume reduce and pack	N/A (cannot produce ILW)	N/A (cannot produce ILW)	N/A (cannot produce ILW)	Smelt	Grout	Grout
S1.3	Concrete and building materials	1. Sorting and segregation (by activity level or by activity level and half-life)	1. None 2. Decontamination 3. Volume reduction 4. Segregate for free release	Any except liquid decontamination	Any and decontaminate	Any and none	Minimum handling and sealing prior to removal	Dry decontamination and recycling	Volume reduce and pack	N/A (cannot produce ILW)	No segregation, decontaminate, concentrate on solid (e.g. Ion exchange)	N/A (cannot produce ILW)	Segregation, decontaminate, re-use	No segregation, grout	Segregate for free release, grout remainder
S1.4	Cellulosic materials	1. Sorting and segregation (by activity level or by activity level and half-life)	1. Incineration 2. Compact and grout 3. Segregate for free release	Any	Any	Any	Grout	No sort, incinerate without abatement	Super-compact and grout	N/A (cannot produce ILW)	No segregation, decontaminate, concentrate on solid (e.g. Ion exchange)	N/A (cannot produce ILW)	Incinerate without abatement	No segregation, grout	Segregation, compact and grout.
S1.5	Non-cellulosic compactables	1. Sorting and segregation (by activity level or by activity level and half-life)	1. Compact and grout 2. Grout 3. Segregate for free release	Any	Any	Any	Grout	Compact and store	Compact and grout	N/A (cannot produce ILW)	No segregation, decontaminate, concentrate on solid (e.g. Ion exchange)	N/A (cannot produce ILW)	Segregate, compact and grout	No segregation, grout	Segregate, compact grout
S1.6	Pits wastes	1. Do not empty pits 2. Sorting and segregation after retrieval (by activity level or by activity level and half-life)	1. Grout 2. Decontaminate and grout (to concentrate activity on a solid treatment media e.g. ion exchange) 3. Segregate for free release	Retrieve and grout	Do not empty	Do not retrieve and grout	In situ encapsulation	Retrieve, sort and compact and store	Current practice	Treat as LLW	No segregation, decontaminate, concentrate on solid (e.g. Ion exchange)	Treat as LLW	Do not empty	No segregation, grout	Segregate, decontaminate and grout
S1.7	Bulk non-compactables, non-combustible	1. Sorting and segregation (by activity level or by activity level and half-life)	1. Package 2. Cut and package 3. None 4. Segregate for free release	Any	Any	Any	Minimum handling and sealing prior to removal	Dry decontamination and recycling	Volume reduce and pack	Any	Any	Any	Segregate, decontaminate to free release	No segregation, pack	Segregate, pack
S1.8	Soils	1. Segregation in situ (by activity level or by activity level and half-life)	1. None 2. Decontamination (soil washing) 3. In-situ immobilisation	Any and none	Any and decontaminate	Any and none	In situ encapsulation	Lift + shift	No treatment	N/A	N/A	N/A	Leave in-situ	Retrieve and store/dispose	Any and decontaminate
S2	Short-lived and long lived CHILW, inc. PCM	1. Sorting and segregation (by activity level or by activity level and half-life)	1. Supercompact and grout 2. Grout 3. Decontaminate and grout 4. Decontaminate and direct discharge	Any other than decontaminate and direct discharge	Decontaminate and direct discharge	Decontaminate and treat liquids arisings	Grout	Supercompact and grout	Supercompact and grout	Segregate, decontaminate, supercompact and grout	No segregation or decontamination	Segregation, supercompact and grout	Treat as ILW and grout	Decontaminate and grout	Treat as ILW and grout
S3	Short-lived and long lived shaft and silo RHILW	1. Sorting and segregation (by activity level or by activity level and half-life)	1. Grout 2. Decontaminate and grout	Any except liquid decontamination	Liquid decontamination and direct discharge	Liquid decontamination and direct discharge	Grout	Grout	Grout	Segregate, decontaminate and grout	No segregation, grout	Segregate, grout	Treat as ILW and grout	Decontaminate and grout	Treat as ILW and grout
S4	Short-lived and Long-lived RHILW in Stores	1. Sorting and segregation (by activity level or by activity level and half-life)	1. Grout 2. Decontaminate and grout	Any except liquid decontamination	Liquid decontamination and direct discharge	Decontaminate and treat liquids arisings.	Decay then grout	Segregate, treat and grout	Segregate, treat and grout	Segregate, decontaminate and grout	No segregation or decontamination	Segregate, grout	Treat as ILW and grout	Decontaminate and grout	Treat as ILW and grout
S5	Boron carbide	1. None	1. Grout 2. Release ^3H by heat, wash or dissolve	Grout	Dissolve and discharge boron	Wash and discharge liquid	Grout	Release ^3H by Wash or Dissolve	Grout	Release ^3H by Wash or Dissolve	Grout	Release ^3H by Wash or Dissolve	Treat as ILW and grout	Release ^3H by Wash or Dissolve	Treat as ILW and grout

Waste		Options for Management Methods		Liquid discharges			Airborne discharges			ILW volumes			LLW volumes		
No.	Description	Limitation of Arisings	Treatment Process	Liq_{Min}	Liq_{Max}	Liq_{Inter}	Atm_{Min}	Atm_{Max}	Atm_{Inter}	ILW_{Min}	ILW_{Max}	ILW_{Inter}	LLW_{Min}	LLW_{Max}	LLW_{Inter}
S6	Decommissioning ILW														
S6.1	Metals (including surface contamination)	1. Sorting and segregation (by activity level or by activity level and half-life)	1. Grout 2. Decontaminate and grout 3. Cut and pack	Any except liquid decontamination	Liquid decontamination and direct discharge	Liquid decontamination and treatment prior to discharge	Any	Any	Any	Max segregation, decontaminate, cut and pack, grout	No segregation or decontamination	Segregate, decontaminate, grout	Treat as ILW and grout	Decontaminate and grout	Treat as ILW and grout
S6.2	Graphite	1. None	1. Grout 2. Incinerate and grout residues	Grout	Incinerate and scrub off-gas	Grout	Grout	Incinerate without abatement	Grout	Incinerate and grout	Grout	Grout	Treat as ILW and grout	Incinerate and grout residues	Treat as ILW and grout
S6.3	Concrete	1. Sorting and segregation (by activity level or by activity level and half-life)	1. Grout 2. Decontaminate and grout	Dry decontamination	Wet decontamination and discharge	Wet decontamination and treatment → discharge	No decontamination	Any and decontaminate	Any and none	Segregate and decontaminate and grout	No segregation or decontamination	Segregate, grout	Treat as ILW and grout	Decontaminate and grout	Segregate and grout

Table 6.1: Scores for the three strategy options related to the environmental issue of liquid discharges. Liq_{Min} = minimum liquid discharges; Liq_{Max} = maximum liquid discharges; Liq_{Inter} = intermediate liquid discharges. All scores of 5 ('very good' performance) are coloured green, all scores of 0 ('intolerable' performance) are coloured red, and the lowest scores in each strategy option, other than 0, are coloured yellow.

	Liquid discharges			**Notes**
Sub-attribute	**Liq_{Min}**	**Liq_{Max}**	**Liq_{Inter}**	
1 Public heath and safety (individuals)				
1.1 Routine radiation doses	4	0	4	Liq_{min} results in low doses to members of the public (14.2 µSv y^{-1}) because all liquids are immobilised. The dose that does arise is due to direct discharge of I129. Liq_{max} allows direct discharge of active liquids to the marine environment and therefore results in high doses (5921 µSv y^{-1}) to members of the public. Most significant are the raffinates. Liq_{inter} results in small doses to members of the public (20 µSv y^{-1}). In this strategy option, some liquids are discharged but all are treated to remove activity and all airborne discharge routes are abated with filter and scrubber systems. See Appendix C1 for full discussion.
1.2 Radiological accident risks	3	3	3	All strategy options result in similar radiological accident risks to members of the public in the range $3x10^{-5}$ – 10^{-5} y^{-1}. This is because the technologies employed in each option can be similarly engineered such that the risk to members of the public are below the BSO. See Appendix C2 for full discussion.
1.3 Non-radioactive hazards and risks	5	5	5	No significant non-radiological risks to members of the public have been identified with any of the strategy options and therefore all three were allocated a score of 5, corresponding to risks < 10^{-6} y^{-1}. See Appendix C2 for full discussion.
2 Public health and safety (societal)				
2.1 Routine radiation doses	5	0	4	Liq_{min} results in collective doses to members of the public of < 1 Person Sv resulting from direct discharge of C14 and I129 without any abatement . Liq_{max} results in unacceptable collective doses to members of the public (> 100 Person Sv) resulting from direct discharge of PFR raffinate. Liq_{inter} results in low collective doses to members of the public (around 2 Person Sv) from washing of Boron Carbide which releases H3. In this strategy option, liquids are discharged but all are treated to remove activity and all airborne discharge routes are abated with filter and scrubber systems. See Appendix C1 for full discussion.
3 Worker health and safety (individuals)				
3.1 Routine radiation doses	4	5	3	These three strategy options involve significantly different processes, which may result in significantly different collective doses to workers, and scores were therefore related to the required number of processes and worker interventions. See Appendix C1 for full discussion. Liq_{min} involves few processes, the most significant being concreting of arisings. Intervention involves monitoring the process and some maintenance of the plant. Liq_{max} involves the minimal number of processes and very little operator action. Liq_{inter} is the most complex strategy, from the point of view of operator action, requiring the greatest number of processes, and worker intervention and plant maintenance.
3.2 Radiological accident risks	3	3	3	All strategy options result in similar radiological accident risks to workers in the range 10^{-4} – $3x10^{-5}$ y^{-1}. This is because the technologies employed in each option can be similarly engineered such that the risk to workers are below the BSO. See Appendix C2 for full discussion.
3.3 Non-radioactive hazards and risks	3	3	3	All strategy options are associated with some non-radiological hazards to workers (e.g. chemical treatments and manual accidents) but all of the existing safety cases identified the radiological risk as being greater than that due to non-radiological hazards. See Appendix C2 for full discussion.
4 Physical environment				
4.1 Air quality	5	5	5	No option should result in any discernible reduction in air quality in the off-site regions because all airborne discharge routes are abated with filter and scrubber systems.
4.2 Water quality	5	0	4	Liq_{min} results in no significant impact on the water quality because all liquids are immobilised and all airborne discharge routes are abated with filter and scrubber systems. Liq_{max} allows direct discharge of active liquids, and solvents and oils, to the marine environment and therefore results in effective sterilisation of the water resource (stopping economic and leisure uses of the coastal waters). Liq_{inter} results in a small impact on the water quality resulting from the additional chemical treatments and washouts that are required and the increased likelihood of discharge of chemicals, although all liquids are treated to remove activity.
4.3 Land	5	3	5	None of the strategy options should result in any direct contamination of the land. Indirect contamination may, however, occur as a result of sea-to-land transfer (e.g. sea spray). Liq_{min} results in no significant impact on the land quality because no liquids are discharged to sea. Liq_{max} will result in some significant impact on the land quality because of sea-to-land transfer of contaminated seawater (especially of PFR raffinate). Liq_{inter} will also result in no impact on the land quality because the minimal amounts of contamination are discharged to sea will be diluted prior to sea-to-land transfer.
4.4 Visual impact	4	4	4	All strategy options will require some new plant to be built (e.g. central evaporator and potential second cementation plant) but nothing grossly out of context with existing buildings and, therefore, the visual impact will be marginal.
4.5 Nuisances (noise, traffic etc.)	4	4	4	All strategy options will result in a marginal nuisance impact to the local community resulting from increased lorry traffic during plant construction and during operations (e.g. to bring in cement for the cementation and grouting plants) but the traffic will not be grossly increased from current operations.
4.6 Energy usage	1	3	3	These three strategy options require different energy supplies. See Appendix C3 for full discussion. Liq_{min} has the largest, and most substantial, energy requirement to run the central evaporator. Liq_{max} and Liq_{inter} require somewhat less energy (between 50 – 25% of Liq_{min}) to run the ventilation system through filters and scrubbers.
5 Flora and fauna				

	Liquid discharges			Notes
Sub-attribute	**Liq_{Min}**	**Liq_{Max}**	**Liq_{Inter}**	
5.1 Preservation of habitat	5	3	5	Both Liq_{min} and Liq_{inter} result in no discernible changes to the natural habitats because liquid and gaseous discharges are either minimised or are treated / abated with appropriate systems to remove active and non-active contamination. Liq_{max} will result in substantial impacts to the local natural habitats because of the direct discharge of active liquids to the marine environment (especially the PFR raffinate), and unabated aerial discharges from solvents and oils, but no unusual, rare or sensitive habitats will be affected.
5.2 Conservation of species	5	3	5	Both Liq_{min} and Liq_{inter} result in no discernible changes to the species occurring on or off site because liquid and gaseous discharges are either minimised or are treated / abated with appropriate systems to remove active and non-active contamination. Liq_{max} will result in substantial impacts to the local species because of the direct discharge of active liquids to the marine environment (especially the PFR raffinate), and unabated aerial discharges from solvents and oils, but no rare or sensitive species will be affected.
6 Viability				
6.1 Maturity of technology	4	2	3	Liq_{min} involves robotic dismantling techniques to treat L2.1 (Wastes from decommissioning) and these techniques will require some further development prior to being used on site. Liq_{max} requires liquid absorption technology for 85Kr using freon, which has been banned under the Montreal Protocol. It also requires catalyst and condensation treatment of 3H which has only been developed in pilot studies. Liq_{inter} involves chemical separation techniques to treat L3 and L4 (DFR and PFR raffinates) which will need some development work to optimise to these waste streams at an industrial scale.
7 Flexibility				
7.1 Ability to cope with various endpoints for solid wastes	4	N/A	4	Both Liq_{min} and Liq_{inter} adopt cementation as a key technology for treating liquids and grouting as a key technology for treating many solid wastes. These cement formulations provide a considerable degree of flexibility in the characteristics of the solid end products. Liq_{max} aims to minimise solid wastes and, where possible, waste streams are discharged directly to sea. As a consequence, this sub-attribute is not applicable to Liq_{max}.
7.2 Ability to cope with various timescales	5	5	5	All of the strategy options are fully flexible with regard to the timing and ordering in which the different waste streams are managed by the different processes.
7.3 Accept other waste streams	4	5	5	Liq_{min} relies heavily on cementation of liquids and grouting of solids. Both of these processes have the ability to deal with a wide variety of waste streams but there is some uncertainty about the viability of cementing L5 (solvents and oils) to produce a stable wasteform. Liq_{inter} is similar to Liq_{min} in relying heavily on cementation and grouting but L5 (solvents and oils) are incinerated. Liq_{max} is based on liquid decontamination of solids and discharges of liquids to sea. This is a very flexible operation and can deal with most waste streams.
8 Local				
8.1 Economic impacts	3	0	3	Neither Liq_{min} nor Liq_{inter} require construction of major plant. Neither strategy option results in any discernible changes to the environment because discharges are either minimised or are treated / abated with appropriate systems. The net effect on the local economy through impacts on tourism, inward investment and jobs will therefore be negligible. Liq_{max} also requires no construction of major plant and, therefore, will not impact on jobs. The release of untreated wastes to sea (particularly the PFR raffinate) would, however, cause severe damage to the local economy by affecting marine based industries (e.g. fishing) and tourism.
8.2 Culture and heritage	3	1	3	Neither Liq_{min} nor Liq_{inter} require influx of new workers and, therefore, the community, culture and heritage of the area would be unaffected. Liq_{max} may result in the depopulation of the area as people seek to move away from the contamination caused by release of the PFR raffinate. Similarly, cultural activities supported by tourism would also be seriously affected as the numbers of tourists is likely to decrease.
9 Elsewhere				
9.1 Economic impacts	3	3	3	None of the strategy options would affect job creation and investment opportunities in areas located away from Dounreay and, therefore, there would be no net economic impacts elsewhere. Note Liq_{min} and Liq_{inter} require a lot of cement and thus quarrying away from Dounreay would be necessary but this would be only a small proportion of the total national cement production and, therefore, of limited economic impact elsewhere.
9.2 Culture and heritage	3	3	3	None of the strategy options would affect community, culture and heritage in areas away from Dounreay.
10 Environmental objectives				
10.1 Waste minimisation	2	5	3	Liq_{min} is likely to generate more solid wastes than are assumed in the DSRP because liquid discharges are avoided and all liquid wastes are immobilised in cement instead. Liq_{max} would generate substantially less solid waste than assumed in the DSRP because direct discharge of liquid wastes is actively promoted (including the raffinates), minimising the volume of liquid waste requiring immobilisation. In addition, the Pits wastes would not be retrieved. This effectively leaves only the solid legacy and decommissioning solid wastes. Liq_{inter} is likely to generate similar volumes of solid waste to that assumed in the DSRP. Although different treatment methods are sometimes adopted (e.g. chemical separation of PFR raffinate rather than vitrification), overall volumes would broadly be unchanged.
10.2 Progressive discharge reductions	5	0	3	Liq_{min} would reduce discharges at the fastest rate because discharges are avoided and all liquid wastes are immobilised in cement instead, although some airborne waste streams are directly discharged. Liq_{max} would not reduce discharges during the lifetime of the DSRP because it is assumed that the raffinates would be bled to sea at a constant rate over the 50 year period and this waste stream would dominate the activity released. Liq_{inter} would reduce discharges at a rate similar to that assumed in the DSRP because it adopts similar, although not identical, management strategies for the different waste streams.

	Liquid discharges			Notes
Sub-attribute	Liq_{Min}	Liq_{Max}	Liq_{Inter}	
10.3 Concentrate and contain	5	1	3	Liq_{min} would concentrate and contain the greatest proportion of the inventory because discharges are avoided and all liquid wastes are immobilised in cement instead, although some airborne waste streams are directly discharged. Liq_{max} would concentrate and contain the smallest proportion of the inventory because direct discharge of liquid wastes is actively promoted, including the raffinates. Liq_{inter} would concentrate and contain a similar proportion of the inventory to that assumed in the DSRP because it adopts similar, although not identical, management strategies for the different waste streams.
10.4 Precautionary action	4	2	3	Liq_{min} would reduce the hazard on site at a faster rate than assumed in the DSRP because it involves cementation of the PFR raffinate, rather than vitrification. Cementation could be achieved more rapidly with the existing DCP (with suitable modifications) compared to the time necessary to design, build and licence a new vitrification plant. Liq_{max} would reduce the hazard on site at a slower rate than assumed in the DSRP because it is assumed that the raffinates would be bled to sea at a constant rate over the 50 year period of the DSRP. Liq_{inter} would reduce the hazard on site at a rate similar to that assumed in the DSRP because it adopts similar, although not identical, management strategies for the different waste streams.
10.5 Protection beyond national borders	5	0	5	Neither Liq_{min} nor Liq_{inter} are likely to give rise to any significant concern amongst Governments and other stakeholder groups in neighbouring countries because both of them aim to reduce the hazard on site in an environmentally sound manner, and the majority of the inventory is immobilised in passively safe solid forms, although this is achieved to a greater extent in Liq_{min} than Liq_{inter}. Liq_{max} is likely to give rise to significant concern amongst Governments and other stakeholder groups in neighbouring countries, and it is probable that formal legal challenges would result (e.g. through the European Courts).
11 Overall cost				
11.1 Undiscounted cost	2	4	4	Liq_{min} is more expensive than the DSRP to implement because of the high costs from the extra amount of waste from not performing liquid decontamination of solids, the use of robotic dismantling and the running costs for a central evaporator for low-level liquids (L1). Liq_{max} would be cheaper than the waste management strategy assumed in the DSRP because direct discharge of liquid wastes is actively promoted (including the raffinates), saving the costs of the vitrification plant but there is a significant cost in treating the gaseous radionuclides (3H, 14C and 85Kr). Liq_{inter} is also likely to be cheaper to implement than the waste management strategy assumed in the DSRP because it involves chemical separation of the PFR raffinate using small scale chemical plant, rather than vitrification in an expensive, newly built vitrification plant. See Appendix C5 for details.

Table 6.2: Scores for the three strategy options related to the environmental issue of airborne discharges. Atm_{min} = minimum airborne discharges; Atm_{max} = maximum airborne discharges; Atm_{inter} = intermediate airborne discharges. All scores of 5 ('very good' performance) are coloured green, all scores of 0 ('intolerable' performance) are coloured red, and the lowest scores in each strategy option, other than 0, are coloured yellow.

	Airborne discharges			Notes
Sub-attribute	**Atm_{Min}**	**Atm_{Max}**	**Atm_{Inter}**	
1 Public heath and safety (individuals)				
1.1 Routine radiation doses	5	0	4	Atm_{min} results in small doses to members of the public (< 0.1 μSv y^{-1}) because most liquids are immobilised and all airborne discharge routes are abated with filter and scrubber systems. Atm_{max} involves vitrification and incineration without abatement and therefore results in high doses to members of the public. Atm_{inter} results in doses to members of the public (22 μSv y^{-1}). In this strategy option, liquid and gaseous waste streams are immobilised, and vitrification and incineration systems are abated with filter and scrubber systems. See Appendix C1 for full discussion.
1.2 Radiological accident risks	3	0	3	Atm_{min} and Atm_{inter} result in similar radiological accident risks to members of the public in the range $3x10^{-5}$ – 10^{-5} y^{-1}. This is because the technologies employed in these options can be similarly engineered such that the risk to members of the public are below the BSO. Atm_{max} results in higher risks due to the releases from unabated vitrification plants and incinerators. See Appendix C2 for full discussion.
1.3 Non-radioactive hazards and risks	5	4	5	Atm_{min} and Atm_{inter} result in no significant non-radiological risks to members of the public because no non-radiological hazardous materials are released to the environment. Atm_{max} results in some non-radiological risks to members of the public as a consequence of NOx and SOx releases from unabated vitrification and incineration systems. See Appendix C2 for full discussion.
2 Public health and safety (societal)				
2.1 Routine radiation doses	5	0	4	Atm_{min} results in low collective doses to members of the public (< 1 Person Sv) because all liquid discharges are directly cemented and gaseous discharges are abated with efficient HEPAs and scrubbing systems. Atm_{inter} also results in low collective doses to members of the public (1 Person Sv) because most liquid discharges are treated to remove activity and gaseous discharges (e.g. in the vitrification plant) are abated with efficient HEPAs to minimise gaseous discharges of ^{129}I. In both Atm_{min} and Atm_{inter}, graphite is grouted and therefore results in no gaseous discharges of 14C. Atm_{max} allows unabated discharge of active particulate and I129 and C14, and employs vitrification and incineration plants without abatement, resulting in a collective dose of 8800 Person Sv. See Appendix C1 for full discussion.
3 Worker health and safety (individuals)				
3.1 Routine radiation doses	4	0	3	These three strategy options involve significantly different processes, which may result in significantly different collective doses, and scores were therefore related to the required number of processes and worker interventions. See Appendix C1 for full discussion. Atm_{min} involves few processes, the most significant being concreting of arisings. Intervention involves monitoring the process and some maintenance of the plant. Atm_{max} involves vitrification and incineration plants without abatement causing high doses to workers. Atm_{inter} is the most complex strategy, from the point of view of operator action, requiring the greatest number of processes, and worker intervention and plant maintenance, although discharges are abated.
3.2 Radiological accident risks	3	3	3	All strategy options result in similar radiological accident risks to workers in the range 10^{-4} – $3x10^{-5}$ y^{-1}. This is because the technologies employed in each option can be similarly engineered such that the risk to workers are below the BSO. See Appendix C2 for full discussion.
3.3 Non-radioactive hazards and risks	3	2	3	All of the strategy options are associated with some non-radiological hazards to workers (e.g. chemical treatments and manual accidents). There is a greater risk associated with Atm_{max} as a consequence of NOx and SOx releases from unabated vitrification and incineration systems. See Appendix C2 for full discussion.
4 Physical environment				
4.1 Air quality	5	1	4	Atm_{min} largely employs cementation of liquids which is a low temperature process which results in insignificant airborne releases, plus all airborne discharge routes are abated with filter and scrubber systems. Atm_{inter} uses an abated vitrification plant for treating the L3 and L4 (DFR and PFR raffinates, and solvents and oils) and an abated incineration plant for treating L5 (solvents and oils). These systems may be a little worse for air quality than cementation because they are high temperature processes. Atm_{max} has no abatement on the vitrification and incineration plants and therefore has a very significant impact on air quality.
4.2 Water quality	5	4	5	None of the strategy options discharge radioactively contaminated liquids to sea without some form of treatment. Water quality is therefore affected to a large extent by fall-out from gaseous discharges. Both Atm_{min} and Atm_{inter} abate gaseous discharges with filter and scrubber systems and therefore cause no significant impact on the water quality. Atm_{max} has no abatement on the vitrification and incineration plants but the fall-out from these is quickly and substantially diluted in the sea, causing minimal overall impact to the water quality.
4.3 Land	4	3	5	Land quality is partly affected by fall-out from gaseous discharges. Both Atm_{min} and Atm_{inter} abate gaseous discharges with filter and scrubber systems and therefore cause no significant impact on the water quality from fall-out but Atm_{min} also employs in situ encapsulation of S1.6 and S1.8 (Pits wastes and soils), resulting in some direct localised degradation to the land quality. Atm_{max} has no abatement on the vitrification and incineration plants and consequently the fall-out will have a detrimental affect on land quality.
4.4 Visual impact	4	4	4	All strategy options will require some new plant to be built (e.g. central evaporator, potential second cementation plant or vitrification plant) but nothing grossly out of context with existing buildings and, therefore, the visual impact will be marginal.

	Airborne discharges			Notes
Sub-attribute	Atm_{Min}	Atm_{Max}	Atm_{Inter}	
4.5 Nuisances (noise, traffic etc.)	4	3	4	All strategy options will result in a marginal nuisance impact to the local community resulting from increased lorry traffic during plant construction and during operations (e.g. to bring in cement for the cementation and grouting plant) but the traffic will not be grossly increased from current operations. Atm_{max} will, however, result in additional nuisance from the plume rising from the unabated incinerator and unabated vitrification plant (e.g. from soot deposition).
4.6 Energy usage	3	1	3	These three strategy options require different energy supplies. See Appendix C3 for full discussion. Atm_{max} has the largest, and most substantial, energy requirement to run the central evaporator plus a vitrification plant. Atm_{min} requires somewhat less energy to run a cementation plant and ventilation systems, whilst Atm_{inter} requires similarly less energy to run an abated vitrification plant.
5 Flora and fauna				
5.1 Preservation of habitat	5	3	5	Both Atm_{min} and Atm_{inter} result in no discernible changes to the natural habitats because liquid and gaseous discharges are either minimised or are treated / abated with appropriate systems to remove active and non-active contamination, and there are no rare or particularly sensitive habitats in the vicinity. Atm_{max} has no abatement on the vitrification and incineration plants and consequently the fall-out will have some impact on the local natural habitats.
5.2 Conservation of species	5	3	5	Both Atm_{min} and Atm_{inter} result in no discernible changes to the species occurring on or off site because liquid and gaseous discharges are either minimised or are treated / abated with appropriate systems to remove active and non-active contamination. Atm_{max} has no abatement on the vitrification and incineration plants and consequently the fall-out will have some impact on living organisms but no rare or sensitive species will be affected.
6 Viability				
6.1 Maturity of technology	2	4	4	Atm_{min} uses cryogenic distillation to treat A5 (^{85}Kr) which is a technique that is only in pilot development and there is no direct experience of its use at Dounreay and, therefore, significant development work will be required. Both Atm_{max} and Atm_{inter} employ vitrification plants which, although are standard technology for vitrifying HALs, have experienced practical problems at other sites in terms of incorporation rates and failure of melters. Vitrification may also not be able to cope well with sludges as applied in Atm_{max}.
7 Flexibility				
7.1 Ability to cope with various endpoints for solid wastes	4	3	4	Atm_{min} adopts cementation as a key technology for treating liquids and grouting as a key technology for treating many solid wastes. Atm_{inter} adopts cementation and vitrification as joint technologies for treating liquids, and uses grouting as a key technology for treating many solid wastes. Cement formulations provide a considerable degree of flexibility in the characteristics of the solid end products and glass provides a lesser degree of flexibility. Atm_{max} discharges directly to the atmosphere, where possible, and vitrifies most liquid wastes which is a less flexible strategy than one that also employs cementation.
7.2 Ability to cope with various timescales	5	5	5	All of the strategy options are fully flexible with regard to the timing and ordering in which the different waste streams are managed by the different processes.
7.3 Accept other waste streams	4	3	4	Atm_{min} relies heavily on cementation of liquids and grouting of solids. Both of these processes have the ability to deal with a wide variety of waste streams but there is some uncertainty about the viability of cementing L5 (solvents and oils) to produce a stable wasteform. Atm_{max} relies heavily on vitrification of liquids and grouting of solids. Vitrification has a limited ability to deal with some waste streams, and there is uncertainty about the viability of vitrifying L6 (Flocs and sludges). Atm_{inter} employs both cementation and vitrification and thus allows for a flexible operation that can deal with most waste streams.
8 Local				
8.1 Economic impacts	3	0	3	Neither Atm_{min} nor Atm_{inter} will require substantial numbers of new workers. Neither strategy option results in any discernible changes to the environment because discharges are either minimised or are treated / abated with appropriate systems. The net effect on the local economy through impacts on tourism, inward investment and jobs will therefore be negligible. Atm_{max} also requires no substantial numbers of new workers. The release of unabated gaseous discharges wastes to the atmosphere (particularly from the incinerator and vitrification plant) would, however, cause severe damage to the local economy by affecting agriculture and tourism.
8.2 Culture and heritage	3	1	3	Neither Atm_{min} nor Atm_{inter} require influx of new workers and, therefore, the community, culture and heritage of the area would be unaffected. Atm_{max} may result in the depopulation of the area as people seek to move away from the contamination caused by unabated gaseous discharges wastes to the atmosphere. Similarly, cultural activities supported by tourism would also be seriously affected as the numbers of tourists is likely to decrease.
9 Elsewhere				
9.1 Economic impacts	3	3	3	None of the strategy options would affect job creation and investment opportunities in areas located away from Dounreay and, therefore, there would be no net economic impacts elsewhere. Note Atm_{min} requires a lot of cement and thus quarrying away from Dounreay would be necessary but this would be only a small proportion of the total national cement production and, therefore, of limited economic impact elsewhere.
9.2 Culture and heritage	3	3	3	None of the strategy options would affect community, culture and heritage in areas away from Dounreay.
10 Environmental objectives				

	Airborne discharges			Notes
Sub-attribute	Atm_{Min}	Atm_{Max}	Atm_{Inter}	
10.1 Waste minimisation	3	3	3	Atm_{min} is likely to generate similar volumes of solid wastes than are assumed in the DSRP because, although all liquid wastes are immobilised in cement, instead of treatment and immobilisation of HALs by vitrification, the Pits wastes and soils are immobilised in situ. The net effect will be no significant change in volumes. Both Atm_{max} and Atm_{inter} would also generate similar volumes of solid wastes than are assumed in the DSRP because they adopt similar, although not identical, management strategies for the different waste streams.
10.2 Progressive discharge reductions	5	2	3	Atm_{min} would reduce discharges at the fastest rate because discharges are avoided and all liquid wastes are immobilised in cement and gaseous waste streams are immobilised. Atm_{max} maximises discharges to the atmosphere and therefore the rate at which discharges is reduced is slowest. Atm_{inter} would reduce discharges at a rate similar to that assumed in the DSRP because it adopts similar, although not identical, management strategies for the different waste streams.
10.3 Concentrate and contain	5	3	5	Both Atm_{min} and Atm_{inter} concentrate and contain a large proportion of the inventory because discharges are avoided and all liquid wastes are immobilised in cement or glass. Atm_{max} would concentrate and contain the smallest proportion of the inventory because direct discharge of airborne wastes is actively promoted, and incinerator and vitrification plants are unabated.
10.4 Precautionary action	4	2	3	Atm_{min} would reduce the hazard on site at a faster rate than assumed in the DSRP because it involves cementation of the PFR raffinate, rather than vitrification. Cementation could be achieved more rapidly with the existing DCP (with suitable modifications) compared to the time necessary to design, build and licence a new vitrification plant. Atm_{max} is based on vitrification of HALs and Flocs and sludges and therefore the rate of hazard reduction would be controlled by the time take to design, build and licence a new vitrification plant. Atm_{inter} uses a mixture of cementation and vitrification and, therefore, would reduce the hazard on site at an intermediate rate.
10.5 Protection beyond national borders	5	2	5	Neither Atm_{min} nor Atm_{inter} are likely to give rise to any significant concern amongst Governments and other stakeholder groups in neighbouring countries because both of them aim to reduce the hazard on site in an environmentally sound manner, and the majority of the inventory is immobilised in passively safe solid forms. Atm_{max} is likely to give rise to significant concern amongst Governments and other stakeholder groups in neighbouring countries because of the unabated incinerator and vitrification plants.
11 Overall cost				
11.1 Undiscounted cost	3	2	2	Atm_{min} is likely to be similar in cost to the DSRP to implement because the high cost of cryogenic distillation of Kr-85 and direct cementation of MALs and sludges etc. is offset by cementation of the PFR raffinate using the existing DCP, rather than vitrification in an expensive, newly built vitrification plant. Atm_{max} is more expensive to implement that the DSRP because of the costs associated with running the central evaporator for low level liquids and the vitrification of raffinates, flocs and sludges, especially the large volumes of LLETP sludge. Atm_{inter} is likely to be more expensive than the DSRP to implement because of the high cost of vitrifying the DFR raffinate and ADU floc instead of cementation. See Appendix C5 for details.

Table 6.3: Scores for the three strategy options related to the environmental issue of solid ILW volumes. ILW_{min} = minimum ILW volumes; ILW_{max} = maximum ILW volumes; ILW_{inter} = intermediate ILW volumes. All scores of 5 ('very good' performance) are coloured green, all scores of 0 ('intolerable' performance) are coloured red, and the lowest scores in each strategy option, other than 0, are coloured yellow.

	Solid ILW volumes			Notes
Sub-attribute	**ILW_{Min}**	**ILW_{Max}**	**ILW_{Inter}**	
1 Public heath and safety (individuals)				
1.1 Routine radiation doses	0	3	3	ILW_{min} allows direct discharge of active liquids to the marine environment and therefore results in high doses to members of the public (6106 μSv y^{-1}) . Most significant are the raffinates. ILW_{max} and ILW_{inter} both result in low doses to members of the public (34 μSv y-1 and 42 μSv y-1 respectively). See Appendix C1 for full discussion.
1.2 Radiological accident risks	3	3	3	All strategy options result in similar radiological accident risks to members of the public in the range $3x10^{-5}$ – 10^{-5} y^{-1}. This is because the technologies employed in each option can be similarly engineered such that the risk to members of the public are below the BSO. See Appendix C2 for full discussion.
1.3 Non-radioactive hazards and risks	4	5	5	ILW_{min} would present some non-radiological risks to members of the public because HEPAs are not used when ventilating buildings and because solvents and oils are discharged directly to sea. Neither ILW_{max} nor ILW_{inter} present any significant non-radiological risks to members of the public because all discharges are abated. See Appendix C2 for full discussion.
2 Public health and safety (societal)				
2.1 Routine radiation doses	0	5	4	ILW_{min} results in unacceptable collective doses to members of the public (> 100 Person Sv) resulting from direct discharge of PFR raffinate. ILW_{max} results in low collective doses to members of the public (< 1 Person Sv) because all liquids are either directly immobilised or are treated to remove activity, and all airborne discharge routes are abated with filter and scrubber systems. ILW_{inter} results in low doses (2.9 Person Sv) due to washing of Boron Carbide which releases H3. See Appendix C1 for full discussion.
3 Worker health and safety (individuals)				
3.1 Routine radiation doses	3	5	4	ILW_{min} adopts a strategy of segregation and decontamination of solid wastes to minimise the final ILW volumes. This requires intensive worker intervention resulting in raised worker doses. ILW_{max} involves few processes, the most significant being concreting of arisings. Intervention involves monitoring the process and some maintenance of the plant but these are routine. ILW_{inter} is similar to ILW_{min} but adopts only segregation and not decontamination, meaning that worker intervention and worker doses are reduced.
3.2 Radiological accident risks	3	3	3	All strategy options result in similar radiological accident risks to workers in the range 10^{-4} – $3x10^{-5}$ y^{-1}. This is because the technologies employed in each option can be similarly engineered such that the risk to workers are below the BSO. See Appendix C2 for full discussion.
3.3 Non-radioactive hazards and risks	3	3	3	All strategy options are associated with some non-radiological hazards to workers (e.g. chemical treatments and manual accidents) but all of the existing safety cases identified the radiological risk as being greater than that due to non-radiological hazards. See Appendix C2 for full discussion.
4 Physical environment				
4.1 Air quality	3	5	4	ILW_{min} involves the direct discharge of iodines and ^{85}Kr and does not use HEPAs on building ventilation. As a consequence, air quality will be significantly reduced. ILW_{max} largely employs cementation of liquids which is a low temperature process which results in insignificant airborne releases, plus all airborne discharge routes are abated with filter and scrubber systems. ILW_{inter} uses an abated vitrification plant for treating the L3 and L4 (DFR and PFR raffinates) and an abated incineration plant for treating L5 (solvents and oils). These systems may be a little worse for air quality than cementation because they are high temperature processes.
4.2 Water quality	0	5	4	ILW_{min} allows direct discharge of active liquids, especially the PFR raffinate, to the marine environment and therefore results in effective sterilisation of the water resource (stopping economic and leisure uses of the coastal waters). ILW_{max} results in no significant impact on the water quality because all liquids are immobilised and all airborne discharge routes are abated with filter and scrubber systems. ILW_{inter} results in a small impact on the water quality resulting from the additional chemical treatments and washouts that are required and the increased likelihood of discharge of chemicals, although all liquids are treated to remove activity.
4.3 Land	3	5	5	None of the strategy options should result in any direct contamination of the land. Indirect contamination may, however, occur as a result of sea-to-land transfer (e.g. sea spray). ILW_{min} will result in some significant impact on the land quality because of sea-to-land transfer of contaminated seawater (especially of PFR raffinate). ILW_{max} results in no significant impact on the land quality because no liquids are discharged to sea. ILW_{inter} will also result in no impact on the land quality because the minimal amounts of contamination that are discharged to sea will be diluted prior to sea-to-land transfer.
4.4 Visual impact	4	4	4	All strategy options will require some new plant to be built (e.g. central evaporator and potential second cementation plant) but nothing grossly out of context with existing buildings and, therefore, the visual impact will be marginal.
4.5 Nuisances (noise, traffic etc.)	4	4	4	All strategy options will result in a marginal nuisance impact to the local community resulting from increased lorry traffic during plant construction and during operations (e.g. to bring in cement for the cementation and grouting plants) but the traffic will not be grossly increased from current operations.
4.6 Energy usage	4	1	2	These three strategy options require different energy supplies. See Appendix C3 for full discussion. ILW_{min} needs no significant plant nor energy requirements. ILW_{max} requires a central evaporator. ILW_{inter} requires a number of smaller zone specific evaporators.
5 Flora and fauna				

	Solid ILW volumes			Notes
Sub-attribute	ILW_{Min}	ILW_{Max}	ILW_{Inter}	
5.1 Preservation of habitat	3	5	5	ILW_{min} will result in substantial impacts to the local natural habitats because of the direct discharge of active liquids to the marine environment (especially the PFR raffinate) but no unusual, rare or sensitive habitats will be affected. Neither ILW_{max} nor ILW_{inter} will result in any discernible changes to the natural habitats because liquid and gaseous discharges are either minimised or are treated / abated with appropriate systems to remove active and non-active contamination.
5.2 Conservation of species	3	5	5	ILW_{min} will result in substantial impacts to the local species because of the direct discharge of active liquids to the marine environment (especially the PFR raffinate) but no unusual, rare or sensitive habitats will be affected. Neither ILW_{max} nor ILW_{inter} will result in any discernible changes to the species occurring on or off site because liquid and gaseous discharges are either minimised or are treated / abated with appropriate systems to remove active and non-active contamination.
6 Viability				
6.1 Maturity of technology	5	2	2	ILW_{min} requires only technologies that are well established, easy to implement and require no further development. ILW_{max} requires zeolite separation for 85-Kr and catalyst and absorption treatment of 3H which have only been developed in pilot studies. ILW_{inter} requires cryogenic distillation treatment for 85-Kr and catalyst and condensation treatment of 3H which have only been developed in pilot studies and there is no direct experience of its use at Dounreay and, therefore, some development work will be required.
7 Flexibility				
7.1 Ability to cope with various endpoints for solid wastes	N/A	4	4	ILW_{min} aims to minimise solid wastes and, where possible, waste streams are discharged directly to sea. As a consequence, this sub-attribute is not applicable to ILW_{min}. Both ILW_{max} and ILW_{inter} adopt cementation as a key technology for treating liquids, and segregation and grouting as a key technology for treating many solid wastes. These technologies provide a considerable degree of flexibility in the characteristics of the solid end products.
7.2 Ability to cope with various timescales	5	5	5	All of the strategy options are fully flexible with regard to the timing and ordering in which the different waste streams are managed by the different processes.
7.3 Accept other waste streams	5	4	5	ILW_{min} is based on liquid decontamination of solids and discharges of liquids to sea. This is a very flexible operation and can deal with most waste streams. ILW_{max} relies heavily on cementation of liquids and grouting of solids. Both of these processes have the ability to deal with a wide variety of waste streams but there is some uncertainty about the viability of cementing L5 (solvents and oils) to produce a stable wasteform. ILW_{inter} is similar to ILW_{max} in using cementation and grouting but L5 (solvents and oils) are incinerated and vitrification is also used for the MALs and HALs.
8 Local				
8.1 Economic impacts	0	3	3	ILW_{min} requires no construction of major plant and, therefore, will not impact on jobs. The release of untreated wastes to sea (particularly the PFR raffinate) would, however, cause severe damage to the local economy by affecting marine based industries (e.g. fishing) and tourism. ILW_{max} does not require construction of major plant. ILW_{inter} requires construction of a vitrification plant. Neither ILW_{max} nor ILW_{inter} results in any discernible changes to the environment because discharges are either minimised or are treated / abated with appropriate systems. The net effect on the local economy through impacts on tourism, inward investment and jobs will therefore be negligible.
8.2 Culture and heritage	1	3	3	ILW_{min} may result in the depopulation of the area as people seek to move away from the contamination caused by release of the PFR raffinate. Similarly, cultural activities supported by tourism would also be seriously affected as the numbers of tourists is likely to decrease. Neither ILW_{max} nor ILW_{inter} require influx of new workers and, therefore, the community, culture and heritage of the area would be unaffected.
9 Elsewhere				
9.1 Economic impacts	3	3	3	None of the strategy options would affect job creation and investment opportunities in areas located away from Dounreay and, therefore, there would be no net economic impacts elsewhere. Note ILW_{max} and ILW_{inter} require a lot of cement and thus quarrying away from Dounreay would be necessary but this would be only a small proportion of the total national cement production and, therefore, of limited economic impact elsewhere.
9.2 Culture and heritage	3	3	3	None of the strategy options would affect community, culture and heritage in areas away from Dounreay.
10 Environmental objectives				
10.1 Waste minimisation	5	2	3	ILW_{min} would generate substantially less solid waste than assumed in the DSRP because direct discharge of liquid wastes is actively promoted (including the raffinates), minimising the volume of liquid waste requiring immobilisation. ILW_{max} is likely to generate more solid wastes than are assumed in the DSRP because liquid discharges are avoided and all liquid wastes are immobilised in cement instead. ILW_{inter} is likely to generate similar volumes of solid waste to that assumed in the DSRP because it adopts similar, although not identical, management strategies for the different waste streams.
10.2 Progressive discharge reductions	0	5	3	ILW_{min} would not reduce discharges because it is assumed that the raffinates would be bled to sea at a constant rate over the 50 year period of the DSRP and this waste stream would dominate the activity released. ILW_{max} would reduce discharges at the fastest rate because discharges are avoided and all liquid wastes are immobilised in cement instead. ILW_{inter} would reduce discharges at a rate similar to that assumed in the DSRP because it adopts similar, although not identical, management strategies for the different waste streams.

	Solid ILW volumes			Notes
Sub-attribute	ILW_{Min}	ILW_{Max}	ILW_{Inter}	
10.3 Concentrate and contain	1	5	3	ILW_{min} would concentrate and contain the smallest proportion of the inventory because direct discharge of liquid wastes is actively promoted, including the raffinates. ILW_{max} would concentrate and contain the greatest proportion of the inventory because discharges are avoided and all liquid wastes are immobilised in cement instead. ILW_{inter} would concentrate and contain a similar proportion of the inventory to that assumed in the DSRP because it adopts similar, although not identical, management strategies for the different waste streams.
10.4 Precautionary action	2	4	3	ILW_{min} would reduce the hazard on site at a slower rate than assumed in the DSRP because it is assumed that the raffinates would be bled to sea at a constant rate over the 50 year period of the DSRP. ILW_{max} would reduce the hazard on site at a faster rate than assumed in the DSRP because it involves cementation of the PFR raffinate, rather than vitrification. Cementation could be achieved more rapidly with the existing DCP (with suitable modifications) compared to the time necessary to design, build and licence a new vitrification plant. ILW_{inter} would reduce the hazard on site at a rate similar to that assumed in the DSRP because it adopts similar, although not identical, management strategies for the different waste streams.
10.5 Protection beyond national borders	0	5	5	ILW_{min} is likely to give rise to significant concern amongst Governments and other stakeholder groups in neighbouring countries, and it is probable that formal legal challenges would result (e.g. through the European Courts). Neither ILW_{max} nor ILW_{inter} are likely to give rise to any significant concern amongst Governments and other stakeholder groups in neighbouring countries because both of them aim to reduce the hazard on site in an environmentally sound manner, and the majority of the inventory is immobilised in passively safe solid forms.
11 Overall cost				
11.1 Undiscounted cost	5	3	3	ILW_{min} would be substantially cheaper than the waste management strategy assumed in the DSRP because direct discharge of liquid wastes is actively promoted (including the raffinates), saving the costs of the vitrification plant. ILW_{max} and ILW_{inter} are likely to be similar in cost to the DSRP. See Appendix C5 for details.

Table 6.4: Scores for the three strategy options related to the environmental issue of solid LLW volumes. LLW_{min} = minimum LLW volumes; LLW_{max} = maximum LLW volumes; LLW_{inter} = intermediate LLW volumes. All scores of 5 ('very good' performance) are coloured green, all scores of 0 ('intolerable' performance) are coloured red, and the lowest scores in each strategy option, other than 0, are coloured yellow.

	Solid LLW volumes			**Notes**
Sub-attribute	**LLW_{Min}**	**LLW_{Max}**	**LLW_{Inter}**	
1 Public heath and safety (individuals)				
1.1 Routine radiation doses	0	4	5	LLW_{min} allows direct discharge of active liquids to the marine environment and therefore results in high does to members of the public (5914 μSv y^{-1}). Most significant are the raffinates. LLW_{max} results in low doses to members of the public (15 μSv y-1) due to washing of Boron Carbide and incineration of graphite. LLW_{inter} also results in low doses to members of the public (< 0.1 μSv y-1). In this strategy option, some liquids are discharged but all are treated to remove activity and all airborne discharge routes are abated with filter and scrubber systems. See Appendix C1 for full discussion.
1.2 Radiological accident risks	3	3	3	All strategy options result in similar radiological accident risks to members of the public in the range $3x10^{-5}$ – 10^{-5} y^{-1}. This is because the technologies employed in each option can be similarly engineered such that the risk to members of the public are below the BSO. See Appendix C2 for full discussion.
1.3 Non-radioactive hazards and risks	4	5	5	LLW_{min} would present some non-radiological risks to members of the public because solvents and oils are discharged directly to sea. Neither LLW_{max} nor LLW_{inter} present any significant non-radiological risks to members of the public because all discharges are abated. See Appendix C2 for full discussion.
2 Public health and safety (societal)				
2.1 Routine radiation doses	0	4	5	LLW_{min} results in unacceptable collective doses to members of the public (> 100 Person Sv) resulting from direct discharge of PFR raffinate. LLW_{max} results in low collective doses to members of the public (22 Person Sv) due to washing of Boron Carbide which releases H3 and graphite incineration. In LLW_{inter} all liquids are either directly immobilised or are treated to remove activity, and all airborne discharge routes are abated with filter and scrubber systems. See Appendix C1 for full discussion.
3 Worker health and safety (individuals)				
3.1 Routine radiation doses	4	3	4	LLW_{min} treats ILW as it is, without attempting to segregate, meaning that worker intervention and worker doses are reduced. LLW_{max} involves decontamination of ILW in an attempt to reclassify, and grouting of decontamination liquids. This will increase worker intervention and worker doses. LLW_{inter} treats ILW as it is, without attempting to segregate, meaning that worker intervention and worker doses are reduced.
3.2 Radiological accident risks	3	3	3	All strategy options result in similar radiological accident risks to workers in the range 10^{-4} – $3x10^{-5}$ y^{-1}. This is because the technologies employed in each option can be similarly engineered such that the risk to workers are below the BSO. See Appendix C2 for full discussion.
3.3 Non-radioactive hazards and risks	3	3	3	All strategy options are associated with some non-radiological hazards to workers (e.g. chemical treatments and manual accidents) but all of the existing safety cases identified the radiological risk as being greater than that due to non-radiological hazards. See Appendix C2 for full discussion.
4 Physical environment				
4.1 Air quality	3	5	5	LLW_{min} involves the direct discharge of iodines and ^{85}Kr and does not use HEPAs on building ventilation. As a consequence, air quality will be significantly reduced. LLW_{max} and LLW_{inter} largely employ cementation of liquids which is a low temperature process which results in insignificant airborne releases, plus all airborne discharge routes are abated with filter and scrubber systems.
4.2 Water quality	0	5	5	LLW_{min} allows direct discharge of active liquids, especially the PFR raffinate, to the marine environment and therefore results in effective sterilisation of the water resource (stopping economic and leisure uses of the coastal waters). LLW_{max} and LLW_{inter} result in no significant impact on the water quality because no contaminated liquids are discharged to sea and all airborne discharge routes are abated with filter and scrubber systems.
4.3 Land	3	5	5	None of the strategy options should result in any direct contamination of the land. Indirect contamination may, however, occur as a result of sea-to-land transfer (e.g. sea spray). LLW_{min} will result in some significant impact on the land quality because of sea-to-land transfer of contaminated seawater (especially of PFR raffinate). LLW_{max} and LLW_{inter} results in no significant impact on the land quality because no contaminated liquids are discharged to sea.
4.4 Visual impact	4	1	3	All strategy options will require some new plant to be built (e.g. central evaporator and potential second cementation plant) but, in LLW_{min}, nothing grossly out of context with existing buildings and, therefore, the visual impact will be marginal. LLW_{max} dilutes waste streams to LLW and cements them, creating very large volumes of waste which will need to be housed in a very large store causing significant visual impact. LLW_{inter} treats less waste as LLW and, therefore, requires a small store.
4.5 Nuisances (noise, traffic etc.)	4	3	4	All strategy options will result in some nuisance impact to the local community resulting from increased lorry traffic during plant construction and during operations (e.g. to bring in cement for the cementation and grouting plants) but the traffic will not be grossly increased from current operations except in case of LLW_{max} where larger amounts of cement are required and a larger store must be constructed.
4.6 Energy usage	4	1	2	These three strategy options require different energy supplies. See Appendix C3 for full discussion. LLW_{min} needs no significant plant nor energy requirements. LLW_{max} requires a central evaporator with high energy usage. LLW_{inter} requires a number of smaller zone specific evaporators, also with high energy usage but less than for a central evaporator.

	Solid LLW volumes			**Notes**
Sub-attribute	**LLW_{Min}**	**LLW_{Max}**	**LLW_{Inter}**	
5 Flora and fauna				
5.1 Preservation of habitat	3	5	5	LLW_{min} will result in substantial impacts to the local natural habitats because of the direct discharge of active liquids to the marine environment (especially the PFR raffinate) but no unusual, rare or sensitive habitats will be affected. Neither LLW_{max} nor LLW_{inter} will result in any discernible changes to the natural habitats because liquid and gaseous discharges are either minimised or are treated / abated with appropriate systems to remove active and non-active contamination.
5.2 Conservation of species	3	5	5	LLW_{min} will result in substantial impacts to the local species because of the direct discharge of active liquids to the marine environment (especially the PFR raffinate) but no unusual, rare or sensitive species will be affected. Neither LLW_{max} nor LLW_{inter} will result in any discernible changes to the species occurring on or off site because liquid and gaseous discharges are either minimised or are treated / abated with appropriate systems to remove active and non-active contamination.
6 Viability				
6.1 Maturity of technology	5	2	2	LLW_{min} requires only technologies that are well established, easy to implement and require no further development. LLW_{max} requires zeolite separation for 85-Kr and catalyst and absorption treatment of 3H which have only been developed in pilot studies. LLW_{inter} requires cryogenic distillation treatment for 85-Kr and catalyst and condensation treatment of 3H which have only been developed in pilot studies and there is no direct experience of its use at Dounreay and, therefore, some development work will be required.
7 Flexibility				
7.1 Ability to cope with various endpoints for solid wastes	N/A	4	4	LLW_{min} aims to minimise solid wastes and, where possible, waste streams are discharged directly to sea. As a consequence, this sub-attribute is not applicable to LLW_{min}. Both LLW_{max} and LLW_{inter} adopt cementation as a key technology for treating liquids, and segregation and grouting as a key technology for treating many solid wastes. These technologies provide a considerable degree of flexibility in the characteristics of the solid end products.
7.2 Ability to cope with various timescales	5	5	5	All of the strategy options are fully flexible with regard to the timing and ordering in which the different waste streams are managed by the different processes.
7.3 Accept other waste streams	5	4	5	LLW_{min} is based on liquid decontamination of solids and discharges of liquids to sea. This is a very flexible operation and can deal with most waste streams. LLW_{max} relies heavily on cementation of liquids and grouting of solids. Both of these processes have the ability to deal with a wide variety of waste streams but there is some uncertainty about the viability of cementing L5 (solvents and oils) to produce a stable wasteform. LLW_{inter} is similar to LLW_{max} in using cementation and grouting but L5 (solvents and oils) are incinerated.
8 Local				
8.1 Economic impacts	0	3	3	LLW_{min} requires no construction of major plant and, therefore, will not impact on jobs. The release of untreated wastes to sea (particularly the PFR raffinate) would, however, cause severe damage to the the local economy by affecting marine based industries (e.g. fishing) and tourism. Neither LLW_{max} nor LLW_{inter} require construction of major plant and would not result in any discernible changes to the environment because discharges are either minimised or are treated / abated with appropriate systems. The net effect on the local economy through impacts on tourism, inward investment and jobs will therefore be negligible.
8.2 Culture and heritage	1	3	3	LLW_{min} may result in the depopulation of the area as people seek to move away from the contamination caused by release of the PFR raffinate. Similarly, cultural activities supported by tourism would also be seriously affected as the numbers of tourists is likely to decrease. Neither LLW_{max} nor LLW_{inter} require influx of new workers and, therefore, the community, culture and heritage of the area would be unaffected.
9 Elsewhere				
9.1 Economic impacts	3	3	3	None of the strategy options would affect job creation and investment opportunities in areas located away from Dounreay and, therefore, there would be no net economic impacts elsewhere. Note LLW_{max} and LLW_{inter} require a lot of cement and thus quarrying away from Dounreay would be necessary but this would be only a small proportion of the total national cement production and, therefore, of limited economic impact elsewhere.
9.2 Culture and heritage	3	3	3	None of the strategy options would affect community, culture and heritage in areas away from Dounreay.
10 Environmental objectives				
10.1 Waste minimisation	5	1	3	LLW_{min} would generate substantially less solid waste than assumed in the DSRP because direct discharge of liquid wastes is actively promoted (including the raffinates), minimising the volume of liquid waste requiring immobilisation. LLW_{max} will generate substantially more solid wastes than are assumed in the DSRP because wastes are actively diluted to LLW and cemented, creating very large volumes of solid product. LLW_{inter} is likely to generate similar volumes of solid waste to that assumed in the DSRP because it adopts similar, although not identical, management strategies for the different waste streams.
10.2 Progressive discharge reductions	0	5	5	LLW_{min} would not reduce discharges because it is assumed that the raffinates would be bled to sea at a constant rate over the 50 year period of the DSRP and this waste stream would dominate the activity released. LLW_{max} and LLW_{inter} would both reduce discharges at a fast rate because discharges are avoided and all liquid wastes are immobilised in cement instead.

	Solid LLW volumes			Notes
Sub-attribute	LLW_{Min}	LLW_{Max}	LLW_{Inter}	
10.3 Concentrate and contain	1	5	5	LLW_{min} would concentrate and contain the smallest proportion of the inventory because direct discharge of liquid wastes is actively promoted, including the raffinates. LLW_{max} and LLW_{inter} would both concentrate and contain a large proportion of the inventory because discharges are avoided and most liquid wastes are immobilised in cement instead.
10.4 Precautionary action	2	4	3	LLW_{min} would reduce the hazard on site at a slower rate than assumed in the DSRP because it is assumed that the raffinates would be bled to sea at a constant rate over the 50 year period of the DSRP. LLW_{max} and LLW_{inter} would both reduce the hazard on site at a faster rate than assumed in the DSRP because it involves cementation of the PFR raffinate, rather than vitrification. Cementation could be achieved more rapidly with the existing DCP (with suitable modifications) compared to the time necessary to design, build and licence a new vitrification plant.
10.5 Protection beyond national borders	0	5	5	LLW_{min} is likely to give rise to significant concern amongst Governments and other stakeholder groups in neighbouring countries, and it is probable that formal legal challenges would result (e.g. through the European Courts). Neither LLW_{max} nor LLW_{inter} are likely to give rise to any significant concern amongst Governments and other stakeholder groups in neighbouring countries because both of them aim to reduce the hazard on site in an environmentally sound manner, and the majority of the inventory is immobilised in passively safe solid forms.
11 Overall cost				
11.1 Undiscounted cost	5	0	3	LLW_{min} would be substantially cheaper than the waste management strategy assumed in the DSRP because direct discharge of liquid wastes is actively promoted (including the raffinates), saving the costs of the vitrification plant, plus the Pits wastes are left in situ. LLW_{max} would be substantially more expensive than the waste management strategy assumed in the DSRP because it involves zeolite separation for 85-Kr, and catalyst and absorption treatment of 3H, plus the cementation of a large volume of material as LLW which will generate very large volumes of waste product to be stored. LLW_{inter} is also likely to be similar in cost to the DSRP because the high cost of treating the gaseous radionuclides (3H, 14C and 85Kr) and the costs from additional waste storage from not decontaminating LLW solids is offset by the saving from encapsulating the PFR raffinate in cement instead of vitrifying it. See Appendix C5 for details.

Table 7.1: Representative waste treatment options for the DSRP wastes in each of the 8 optimised strategy options. Where a representative treatment has changed as a result of optimisation, it is highlighted in yellow. The original treatment option can be found by reference to Table 4.2.

Waste		**Options for Management Methods**		**Liquid discharges**		**Airborne discharges**		**ILW volumes**		**LLW volumes**	
No.	**Description**	**Limitation of Arisings**	**Treatment Process**	Liq_{MinOpt}	Liq_{MaxOpt}	Atm_{MinOpt}	Atm_{MaxOpt}	ILW_{MinOpt}	ILW_{MaxOpt}	LLW_{MinOpt}	LLW_{MaxOpt}
Airborne Wastes											
A1	Particulates from active process and building ventilation	1. Current practice 2. Ventilate only when access required 3. Hermetically seal plants 4. Reduce flow rates 5. Increase flow rates	1. Direct discharge 2. Appropriate HEPAs 3. Wet scrubbers 4. Dry scrubbers 5. Mechanical removal (e.g. cyclones)	Current practice and HEPAs	Current practice	All practical minimisation of arisings methods and HEPAs	Current practice and HEPAs	Min arisings and HEPAs	Increase flow rates and HEPAs	Min arisings and HEPAs	Increase flow rates and HEPAs
A2	Particulates from treating contaminated ground	1. Influenced by choice of process 2. Influenced by operating method (including means of remediating contaminated land and dismantling buildings)	1. Direct discharge 2. Wet treatment (spraying) 3. Dry treatment 4. Appropriate HEPAs 5. Wet scrubbers 6. Dry scrubbers 7. Mechanical removal (e.g. cyclones) 8. In-situ encapsulation	Dry treatment (none)	Dry treatment	In situ encapsulatio n	Lift and shift with direct discharge	N/A (no more active particulate)	N/A (no more active particulate)	N/A (no more active particulate)	N/A (no more active particulate)
A3	H-3	1. Where contained do not release (e.g. from tritiated metal or irradiated fuel materials) 2. Control humidity (for HTO) 3. See treatment options for S1.2	1. Direct discharge 2. Hydrogen 'getter' 3. Thermal oxidation and condensation 4. Catalyst and condensation 5. Catalyst and absorption 6. Scrubber 7. Dehumidifier	Direct discharge	Dehumidifier	Dehumidifier	Direct discharge	Direct discharge	Dehumidifier	Direct discharge	Dehumidifier
A4	C-14	1. See treatment options for L4, S6.2, S8.1, S8.2	1. Direct discharge 2. Scrub and barium carbonate 3. Wet scrubber 4. Scrubber circulating tank	Direct discharge	Wet scrubber	Wet scrubber	Direct discharge	N/A (no more active solid)	N/A (no more active solid)	N/A (no more active solid)	N/A (no more active solid)
A5	Kr-85	1. No options (main arisings from management of fuel materials)	1. Direct discharge 2. Cryogenic distillation 3. Zeolite separation 4. Liquid absorption	Direct discharge	Direct discharge	Direct discharge	Direct discharge	Direct Discharge	Direct discharge	Direct Discharge	Direct discharge
A6	Iodines	1. No options (main arisings from management of fuel materials)	1. Direct discharge 2. Wet scrubber 3. Absorption on silver 4. Corona discharge 5. Scrubber circulating tank 6. Activated carbon 7. Barium carbonate	Direct discharge	Wet scrubber and direct discharge	Activated carbon and, or scrubbing	Direct discharge	Direct discharge	Activated carbon	Direct discharge	Activated carbon
Liquid Wastes											
L1	Low level liquid	1. Current practice 2. Increased recycle (e.g. D1203, D1206) 3. Hydraulic Isolation of LLW pits 4. Separate SAD from LAD 5. See treatment options for solids and solvents	1. Zone specific evaporators 2. Central evaporator 3. Ion exchange columns 4. Direct discharge 5. Maximise activity in sludge	All minimisation arisings methods and ion exchange columns	Direct discharge	All minimisation arisings methods and any except evaporator	Any and ion exchange columns	All min arisings and direct discharge	Current practice and ion exchange columns	All min arisings and direct discharge	Current practice and ion exchange columns
L2	MALs										
L2.1	MALs from decommissioning	1. Robotic dismantling 2. Do not decontaminate 3. Dry decontamination 4. Do not washout	1. Cement liquor 2. Evaporate and cement 3. Treat to liquid LLW 4. Direct discharge	Do not decontamina te	Cement	Do not decontamina te	Wash out and evaporate	Cement	Washout and cement	Do not decontamina te	Washout and cement
L2.2	Legacy MALs	1. None	1. Cement 2. Evaporate and cement 3. Treat to liquid LLW 4. Direct discharge	Cement	Cement	Cement	Evaporate	Cement	Cement	Cement	Cement

Waste		Options for Management Methods		Liquid discharges		Airborne discharges		ILW volumes		LLW volumes	
No.	Description	Limitation of Arisings	Treatment Process	Liq_{MinOpt}	Liq_{MaxOpt}	Atm_{MinOpt}	Atm_{MaxOpt}	ILW_{MinOpt}	ILW_{MaxOpt}	LLW_{MinOpt}	LLW_{MaxOpt}
L3	DFR raffinate	1. None	1. Cement 2. Vitrification 3. Evaporation 4. Direct discharge 5. Chemical separation (e.g. of α and β,γ)	Cement	Cement	Cement	Vitrification	Vitrification	Cement	Cement	Cement
L4	PFR raffinate	1. None	1. Cement 2. Vitrification 3. Evaporation 4. Direct discharge 5. Chemical separation (e.g. of α and β,γ)	Cement	Cement	Cement	Vitrification	Vitrification	Cement	Cement	Cement
L5	Solvents and oils	1. None	1. Incinerate 2. Direct discharge 3. Chemical treatment 4. Pre-wash before treatment 5. Solidify	Solidify	Solidify or incinerate	Solidify	Incinerate	Incinerate	Solidify	Incinerate	Solidify
L6	Flocs and sludges										
L6.1	Ammonium diuranate	1. None	1. Cement both floc and supernate 2. Cement floc and discharge supernate 3. Vitrification 4. Polymerisation 5. Solvent extraction 6. Dissolve floc and direct discharge	Cement floc and discharge supernate	Cement floc and discharge supernate	Cement floc and discharge supernate	Vitrification	Cement floc and discharge supernate	Cement both floc and supernate	Cement floc and discharge supernate	Cement floc and discharge supernate
L6.2	LLLETP sludge	1. Current practice 2. Increased recycle (e.g. D1203, D1206) 3. Hydraulic Isolation of LLW pits 4. Separate SAD from LAD 5. See treatment options for solids and solvents	1. Cement 2. Dewatering and cementation 3. Incineration 4. De-watering 5. Dissolve and direct discharge to sea 6. Concentrate to ILW 7. Vitrification	Minimise liquid arisings and direct cementation	Dissolve and direct discharge	Minimise arisings and direct cementation	Cement	Min liquid LLW arisings and Direct Discharge	Max liquid arisings and direct cement	Min all liquid arisings and discharge	Cement
L6.3	Shaft and Silo sludge	1. None	1. Cement 2. Dewatering and cementation 3. Incineration 4. De-watering 5. Discharge to sea 6. Concentrate to ILW 7. Vitrification	Direct cementation	Cement	Freeze and cement	Cement	Cement	Cement	Cement	Cement
L6.4	Fuel storage pond sludges	1. None	1. Cement 2. Dewatering and cementation 3. Incineration 4. De-watering 5. Discharge to sea 6. Concentrate to ILW 7. Vitrification	Direct cementation	Cement	Direct cementation	Cement	Cement	Cement	Cement	Cement
Solid Wastes											
S1	LLW										
S1.1	General metals	1. Sorting and segregation (by activity level or by activity level and half-life)	1. Cut and package 2. Wet decontaminate, cut and package 3. Dry decontaminate, cut and package	Any (except liquid decontaminate), and cut and package	Any and decontamination	Minimum handling and sealing prior to removal	Dry decontamination and recycling	Any	Decontaminate, concentrate on solid (e.g. Ion exchange)	Segregate, decontaminate to free release	Segregation, pack
S1.2	Tritiated metals	1. None	1. Smelt 2. Decay store 3. Out-gassing at ambient temperatures	Decay store	Smelt and scrub	Decay store and store in unventilated building	Smelt	N/A (cannot produce ILW)	N/A (cannot produce ILW)	Smelt	Grout

Waste		Options for Management Methods		Liquid discharges		Airborne discharges		ILW volumes		LLW volumes	
No.	Description	Limitation of Arisings	Treatment Process	Liq MinOpt	Liq MaxOpt	Atm MinOpt	Atm MaxOpt	ILW MinOpt	ILW MaxOpt	LLW MinOpt	LLW MaxOpt
S1.3	Concrete and building materials	1. Sorting and segregation (by activity level or by activity level and half-life)	1. None 2. Decontamination 3. Volume reduction 4. Segregate for free release	Any except liquid decontamination	Any and decontaminate	Minimum handling and sealing prior to removal	Dry decontamination and recycling	N/A (cannot produce ILW)	Segregation, decontaminate, concentrate on solid (e.g. Ion exchange)	Segregation, decontaminate, re-use	Segregation, grout
S1.4	Cellulosic materials	1. Sorting and segregation (by activity level or by activity level and half-life)	1. Incineration 2. Compact and grout 3. Segregate for free release	Any	Any	Grout	No sort, incinerate	N/A (cannot produce ILW)	Segregation, decontaminate, concentrate on solid (e.g. Ion exchange)	Incinerate	Segregation, grout
S1.5	Non-cellulosic compactables	1. Sorting and segregation (by activity level or by activity level and half-life)	1. Compact and grout 2. Grout 3. Segregate for free release	Any	Any	Grout	Compact and store	N/A (cannot produce ILW)	Segregation, decontaminate, concentrate on solid (e.g. Ion exchange)	Segregate, compact and grout	Segregation, grout
S1.6	Pits wastes	1. Do not empty pits 2. Sorting and segregation after retrieval (by activity level or by activity level and half-life)	1. Grout 2. Decontaminate and grout (to concentrate activity on a solid treatment media e.g. ion exchange) 3. Segregate for free release	Retrieve and grout	Do not empty	In situ encapsulation	Retrieve, sort and compact and store	Treat as LLW	Segregation, decontaminate, concentrate on solid (e.g. Ion exchange)	Do not empty	Segregation, grout
S1.7	Bulk non-compactables, non-combustible	1. Sorting and segregation (by activity level or by activity level and half-life)	1. Package 2. Cut and package 3. None 4. Segregate for free release	Any	Any	Minimum handling and sealing prior to removal	Dry decontamination and recycling	Any	Any	Segregate, decontaminate to free release	Segregation, pack
S1.8	Soils	1. Segregation in situ (by activity level or by activity level and half-life)	1. None 2. Decontamination 3. In-situ immobilisation	Any and none	Any and decontaminate	In situ encapsulation	Lift + shift	N/A	N/A	Leave in-situ	Retrieve and store/dispose
S2	Short-lived and long lived CHILW, inc. PCM	1. Sorting and segregation (by activity level or by activity level and half-life)	1. Supercompact and grout 2. Grout 3. Decontaminate and grout 4. Decontaminate and direct discharge	Any other than decontaminate and direct discharge	Decontaminate and direct discharge	Grout	Supercompact and grout	No segregation or decontamination	Segregation, grout	Treat as ILW and grout	Decontaminate and grout
S3	Short-lived and long lived shaft and silo RHILW	1. Sorting and segregation (by activity level or by activity level and half-life)	1. Grout 2. Decontaminate and grout	Any except liquid decontamination	Liquid decontamination and direct discharge	Grout	Grout	Segregate, decontaminate and grout	Segregation, grout	Treat as ILW and grout	Decontaminate and grout
S4	Short-lived and Long-lived RHILW in Stores	1. Sorting and segregation (by activity level or by activity level and half-life)	1. Grout 2. Decontaminate and grout	Any except liquid decontamination	Liquid decontamination and direct discharge	Decay → grout	Segregate, treat and grout	No segregation or decontamination	Segregation, grout	Treat as ILW and grout	Decontaminate and grout
S5	Boron carbide	1. None	1. Grout 2. Release ^{3}H by heat, wash or dissolve	Grout	Dissolve and discharge boron	Grout	Release ^{3}H by Wash or Dissolve	Release ^{3}H by Wash or Dissolve	Grout	Treat as ILW and grout	Release ^{3}H by Wash or Dissolve
S6	Decommissioning ILW										
S6.1	Metals (including surface contamination)	1. Sorting and segregation (by activity level or by activity level and half-life)	1. Grout 2. Decontaminate and grout 3. Cut and pack	Any except liquid decontamination	Liquid decontamination and direct discharge	Any	Any	No segregation or decontamination	Segregation, grout	Treat as ILW and grout	Decontaminate and grout
S6.2	Graphite	1. None	1. Grout 2. Incinerate and grout residues	Grout	Burn and scrub off-gas	Grout	Incinerate	Incinerate and grout	Grout	Treat as ILW and grout	Incinerate and grout residues

Waste		Options for Management Methods		Liquid discharges		Airborne discharges		ILW volumes		LLW volumes	
No.	**Description**	**Limitation of Arisings**	**Treatment Process**	**Liq$_{MinOpt}$**	**Liq$_{MaxOpt}$**	**Atm$_{MinOpt}$**	**Atm$_{MaxOpt}$**	**ILW$_{MinOpt}$**	**ILW$_{MaxOpt}$**	**LLW$_{MinOpt}$**	**LLW$_{MaxOpt}$**
S6.3	Concrete	1. Sorting and segregation (by activity level or by activity level and half-life)	1. Grout 2. Decontaminate and grout	Dry decontamination	Wet decontamination and discharge	Any and none	Any and decontaminate	No segregation or decontamination	Segregation, grout	Treat as ILW and grout	Decontaminate and grout

Table 7.3: Scores for the optimised strategy options related to the environmental issue of liquid discharges. Liq_{MinOpt} = optimised minimum liquid discharges; Liq_{MaxOpt} = optimised maximum liquid discharges. Scores in parentheses are the original scores for the unoptimised strategy options, where optimisation resulted in a change in score. All scores of 5 ('very good' performance) are coloured green.

	Liquid discharges		Notes
Sub-attribute	**Liq_{MinOpt}**	**Liq_{MaxOpt}**	
1 Public heath and safety (individuals)			
1.1 Routine radiation doses	**4**	**3 (0)**	Liq_{MaxOpt} doses to individual members of the public is improved to 60 µSv y^{-1} because the legacy and decommissioning MALs, DFR and PFR raffinates, ADU floc and Shaft, Silo and pond sludges are all now immobilised in cement rather than being discharged to the marine environment. However, unabated discharge of LLL, ADU floc supernate and LLLETP sludge continues. See Appendix C1 for full discussion.
1.2 Radiological accident risks	**3**	**3**	
1.3 Non-radioactive hazards and risks	**5**	**5**	
2 Public health and safety (societal)			
2.1 Routine radiation doses	**5**	**4 (0)**	Liq_{MaxOpt} societal doses now reduced now improved to 3.4 Person Sv because the legacy and decommissioning MALs, DFR and PFR raffinates, ADU floc and Shaft, Silo and pond sludges are all now immobilised in cement rather than being discharged to the marine environment. However, washing of Boron Carbide releases tritium and ADU floc supernate is still discharged. See Appendix C1 for full discussion.
3 Worker health and safety (individuals)			
3.1 Routine radiation doses	**4**	**4 (5)**	Liq_{MaxOpt} worker doses increased because of extra exposure from additional waste processing in an additional cementation plant. This is now consistent with Liq_{min} which is based on cementation of most liquids.
3.2 Radiological accident risks	**3**	**3**	
3.3 Non-radioactive hazards and risks	**3**	**3**	
4 Physical environment			
4.1 Air quality	**5**	**4**	
4.2 Water quality	**5**	**4 (0)**	Liq_{MaxOpt} water quality vastly increased because the legacy and decommissioning MALs, DFR and PFR raffinates, ADU floc and Shaft, Silo and pond sludges, as well as solvents and oils, are all now immobilised in cement rather than being discharged to the marine environment. However, LLLETP sludge is still being discharged which results in some small environmental detriment.
4.3 Land	**5**	**5 (3)**	Liq_{MaxOpt} water quality vastly increased because the legacy and decommissioning MALs, DFR and PFR raffinates, ADU floc and Shaft, Silo and pond sludges, as well as solvents and oils, are all now immobilised in cement rather than being discharged to the marine environment, stopping their transfer to land by sea-to-land transport processes.
4.4 Visual impact	**4**	**4**	
4.5 Nuisances (noise, traffic etc.)	**4**	**4**	
4.6 Energy usage	**3 (1)**	**3**	Liq_{MinOpt} energy usage reduced because central evaporator is replaced by ion exchange columns.
5 Flora and fauna			
5.1 Preservation of habitat	**5**	**5 (3)**	Liq_{MaxOpt} habitat better protected because the legacy and decommissioning MALs, DFR and PFR raffinates, ADU floc and Shaft, Silo and pond sludges, as well as solvents and oils, are all now immobilised in cement rather than being discharged to the marine environment.
5.2 Conservation of species	**5**	**5 (3)**	Liq_{MaxOpt} species better protected because the legacy and decommissioning MALs, DFR and PFR raffinates, ADU floc and Shaft, Silo and pond sludges, as well as solvents and oils, are all now immobilised in cement rather than being discharged to the marine environment.
6 Viability			
6.1 Maturity of technology	**5 (4)**	**5 (2)**	Liq_{MinOpt} maturity of technology improved because industry standard ion exchange columns now used instead of large scale central evaporators. Liq_{MaxOpt} maturity of technology improved because the unproven methods of catalyst and condensation for H-3 and liquid adsorption for Kr-85 are replaced with more standard methods of dehumidifier and direct discharge, respectively.

	Liquid discharges		Notes
Sub-attribute	**Liq_{MinOpt}**	**Liq_{MaxOpt}**	
7 Flexibility			
7.1 Ability to cope with various solid waste endpoints	**4**	**4 (N/A)**	Liq_{MaxOpt} ability to cope with solid waste endpoints becomes relevant because strategy intent is now to immobilise liquid waste streams, rather than direct discharge.
7.2 Ability to cope with various timescales	**5**	**5**	
7.3 Accept other waste streams	**5 (4)**	**4 (5)**	Liq_{MinOpt} ability to accept other waste streams increased because ion exchange columns are more efficient and flexible than central evaporators. Liq_{MaxOpt} ability to accept other waste streams decreased because cementation is less efficient and flexible than direct discharge for liquid wastes.
8 Local			
8.1 Economic impacts	**3**	**3 (0)**	Liq_{MaxOpt} economic impacts lessened because stopping direct discharge of DFR and PFR raffinate will not affect fishing, agriculture and tourism.
8.2 Culture and heritage	**3**	**3 (1)**	Liq_{MaxOpt} economic impacts lessened because stopping direct discharge of DFR and PFR raffinate will not affect local culture.
9 Elsewhere			
9.1 Economic impacts	**3**	**3**	
9.2 Culture and heritage	**3**	**3**	
10 Environmental objectives			
10.1 Waste minimisation	**2**	**3 (5)**	Liq_{MaxOpt} waste minimisation made worse because much larger volumes of cemented waste is generated. Most of liquid wastes are cemented with the exception of LLL and LLLETP sludge which are still discharged, hence giving higher score than Liq_{MinOpt}.
10.2 Progressive discharge reductions	**5**	**5 (0)**	Liq_{MaxOpt} progressive discharge reductions greatly improved because the legacy and decommissioning MALs, DFR and PFR raffinates, ADU floc and Shaft, Silo and pond sludges, as well as solvents and oils, are all now immobilised in cemented/solidified rather than being discharged.
10.3 Concentrate and contain	**5**	**4 (1)**	Liq_{MaxOpt} concentrate and contain greatly improved because the legacy and decommissioning MALs, DFR and PFR raffinates, ADU floc and Shaft, Silo and pond sludges, as well as solvents and oils, are all now immobilised in cement rather than being discharged to sea (does not score 5 because some liquids are still discharged such as LLL and LLLETP sludge).
10.4 Precautionary action	**4**	**4 (2)**	Liq_{MaxOpt} precautionary action improved because the legacy and decommissioning MALs, DFR and PFR raffinates, ADU floc and Shaft, Silo and pond sludges, as well as solvents and oils, are all now immobilised in cement rather than being slowly bled to sea.
10.5 Protection beyond national borders	**5**	**5 (0)**	Liq_{MaxOpt} protection across national borders greatly improved because the legacy and decommissioning MALs, DFR and PFR raffinates, ADU floc and Shaft, Silo and pond sludges, as well as solvents and oils, are all now immobilised in cement rather than being discharged to sea.
11 Overall cost			
11.1 Undiscounted cost	**3 (2)**	**4**	Liq_{MinOpt} costs decreased because use of liquid decontamination for systems containing residual MALs removes the costs associated with ILW metals and the robotic equipment for handling them but the costs associated with not decontaminating CHILW and RHILW are retained.
11.1 Undiscounted cost	**2**	**5 (4)**	Using the more sensitive scoring scheme discussed in Appendix C5.

Table 7.4: Scores for the two optimised strategy options related to the environmental issue of airborne discharges. Atm_{MinOpt} = optimised minimum airborne discharges; Atm_{MaxOpt} = optimised maximum airborne discharges. Scores in parentheses are the original scores for the unoptimised strategy options, where optimisation resulted in a change in score. All scores of 5 ('very good' performance) are coloured green.

	Airborne discharges		Notes
Sub-attribute	**Atm_{MinOpt}**	**Atm_{MaxOpt}**	
1 Public heath and safety (individuals)			
1.1 Routine radiation doses	5	4 (0)	Atm_{MaxOpt} doses to individual members of the public now improved to around 30 μSv y-1 because the evaporation of the decommissioning and legacy MALs, vitrification of the DFR and PFR raffinate and ADU floc, and the incineration of solvents and oils is now done with abatement systems to reduce gaseous discharges to the atmosphere. In addition, unabated vitrification of LLETP, Shaft, Silo and pond sludges is changed to cementation. However, I129 is still directly discharged. See Appendix C1 for full discussion.
1.2 Radiological accident risks	3	3 (0)	Now added HEPAs and current practice, so accident risk now consistent with other options.
1.3 Non-radioactive hazards and risks	5	4	
2 Public health and safety (societal)			
2.1 Routine radiation doses	5	4 (0)	Atm_{MaxOpt} societal doses now improved to around 4 Person Sv because the evaporation of the decommissioning and legacy MALs, vitrification of the DFR and PFR raffinate and ADU floc, and the incineration of solvents and oils is now done with abatement systems to reduce gaseous discharges to the atmosphere. In addition, unabated vitrification of LLETP, Shaft, Silo and pond sludges is changed to cementation. However, washing of Boron Carbide released H3. See Appendix C1 for full discussion.
3 Worker health and safety (individuals)			
3.1 Routine radiation doses	4	4 (0)	Atm_{MaxOpt} doses to workers now reduced because the evaporation of the decommissioning and legacy MALs, vitrification of the DFR and PFR raffinate and ADU floc, and the incineration of solvents and oils is now done with abatement systems to reduce gaseous discharges to the atmosphere. In addition, unabated vitrification of LLETP, Shaft, Silo and pond sludges is changed to cementation.
3.2 Radiological accident risks	3	3	
3.3 Non-radioactive hazards and risks	3	3 (2)	Atm_{MaxOpt} exposure to workers of NOx and SOx now reduced because the evaporation of the decommissioning and legacy MALs, vitrification of the DFR and PFR raffinate and ADU floc, and the incineration of solvents and oils is now done with abatement systems to reduce gaseous discharges to the atmosphere. In addition, unabated vitrification of LLETP, Shaft, Silo and pond sludges is changed to cementation.
4 Physical environment			
4.1 Air quality	5	4 (1)	Atm_{MaxOpt} air quality is now significantly improved because the evaporation of the decommissioning and legacy MALs, vitrification of the DFR and PFR raffinate and ADU floc, and the incineration of solvents and oils is now done with abatement systems to reduce gaseous discharges to the atmosphere. In addition, unabated vitrification of LLETP, Shaft, Silo and pond sludges is changed to cementation. Some gases are, however, released without treatment.
4.2 Water quality	5	5 (4)	Atm_{MaxOpt} water quality is now significantly improved because fall-out from the airborne discharge from unabated incineration and vitrification plants ceases.
4.3 Land	4	4 (3)	Atm_{MaxOpt} land quality is now significantly improved because fall-out from the airborne discharge from unabated incineration and vitrification plants ceases.
4.4 Visual impact	4	4	
4.5 Nuisances (noise, traffic etc.)	4	4 (3)	Nuisance from Atm_{MaxOpt} is reduced because the plume from the unabated incinerator is minimised through the addition of proper abatement technology.
4.6 Energy usage	3	3 (1)	Energy usage in Atm_{MaxOpt} is substantially reduced because the central evaporator is replaced with ion exchange columns.
5 Flora and fauna			
5.1 Preservation of habitat	5	5 (3)	Atm_{MaxOpt} habitat is better protected because the evaporation of the decommissioning and legacy MALs, vitrification of the DFR and PFR raffinate and ADU floc, and the incineration of solvents and oils is now done with abatement systems to reduce gaseous discharges to the environment. In addition, unabated vitrification of LLETP, Shaft, Silo and pond sludges is changed to cementation.

	Airborne discharges		Notes
Sub-attribute	**Atm_{MinOpt}**	**Atm_{MaxOpt}**	
5.2 Conservation of species	**5**	**5 (3)**	Atm_{MaxOpt} conservation of species is improved because the evaporation of the decommissioning and legacy MALs, vitrification of the DFR and PFR raffinate and ADU floc, and the incineration of solvents and oils is now done with abatement systems to reduce gaseous discharges to the environment. In addition, unabated vitrification of LLETP, Shaft, Silo and pond sludges is changed to cementation.
6 Viability			
6.1 Maturity of technology	**5 (2)**	**4**	Atm_{MinOpt} maturity of technology improved because unproven method of cryogenic distillation for Kr-85 is replaced with direct discharge.
7 Flexibility			
7.1 Ability to cope with various endpoints for solid wastes	**4**	**3**	
7.2 Ability to cope with various timescales	**5**	**5**	
7.3 Accept other waste streams	**4**	**4 (3)**	The ability of Atm_{MaxOpt} to deal with other waste streams is improved by the addition of a cementation plant to deal with LLLETP, Shaft, Silo and pond sludges.
8 Local			
8.1 Economic impacts	**3**	**3 (0)**	Atm_{MaxOpt} economic impacts lessened because stopping unabated incineration, evaporation and vitrification will no longer affect fishing, agriculture and tourism.
8.2 Culture and heritage	**3**	**3 (1)**	Atm_{MaxOpt} culture and heritage impacts lessened because stopping unabated incineration, evaporation and vitrification will no longer affect local culture.
9 Elsewhere			
9.1 Economic impacts	**3**	**3**	
9.2 Culture and heritage	**3**	**3**	
10 Environmental objectives			
10.1 Waste minimisation	**3**	**3**	
10.2 Progressive discharge reductions	**5**	**3 (2)**	Atm_{MaxOpt} progressive discharge reductions are improved because airborne discharges from evaporation, incineration and vitrification are stopped now abated and held in solid form. Some gaseous radionuclides are still discharged.
10.3 Concentrate and contain	**5**	**4 (3)**	Atm_{MaxOpt} concentrate and contain is improved because airborne discharges from evaporation, incineration and vitrification are stopped now abated and held in solid form. Some gaseous radionuclides are still discharged.
10.4 Precautionary action	**4**	**3 (2)**	Atm_{MaxOpt} precautionary action is improved because airborne discharges from evaporation, incineration and vitrification are stopped now abated and held in solid form. Some gaseous radionuclides are still discharged.
10.5 Protection beyond national borders	**5**	**4 (2)**	Atm_{MaxOpt} protection beyond national boundaries is improved because airborne discharges from evaporation, incineration and vitrification are stopped now abated and held in solid form. Some gaseous radionuclides are still discharged.
11 Overall cost			
11.1 Undiscounted cost	**4 (3)**	**3 (2)**	Atm_{MinOpt} costs are reduced because the Kr-85 is directly discharged rather than using expensive cryogenic distillation to capture it. Atm_{MaxOpt} costs are reduced because the central evaporator is replaced by ion exchange columns.
11.1 Undiscounted cost	**5 (3)**	**3 (2)**	Using the more sensitive scoring scheme discussed in Appendix C5.

Table 7.5: Scores for the two optimised strategy options related to the environmental issue of solid ILW volumes. ILW_{MinOpt} = optimised minimum ILW volumes; ILW_{MinOpt} = optimised maximum ILW volumes. Scores in parentheses are the original scores for the unoptimised strategy options, where optimisation resulted in a change in score. All scores of 5 ('very good' performance) are coloured green.

	Solid ILW volumes		**Notes**
Sub-attribute	**ILW_{MinOpt}**	**ILW_{MaxOpt}**	
1 Public heath and safety (individuals)			
1.1 Routine radiation doses	**3 (0)**	**5 (3)**	ILW_{MinOpt} doses to individual members of the public now improved because the legacy and decommissioning MALs, DFR and PFR raffinates, ADU floc and Shaft, Silo and pond sludges are all now immobilised in cement rather than being discharged to the marine environment, and HEPAs added to active building ventilation. See Appendix C1 for full discussion.
1.2 Radiological accident risks	**3**	**3**	
1.3 Non-radioactive hazards and risks	**4**	**5**	
2 Public health and safety (societal)			
2.1 Routine radiation doses	**4 (0)**	**5**	ILW_{MinOpt} societal doses now improved because the legacy and decommissioning MALs, DFR and PFR raffinates, ADU floc and Shaft, Silo and pond sludges are all now immobilised in cement rather than being discharged to the marine environment. However, iodines still discharged and graphite incinerated. See Appendix C1 for full discussion.
3 Worker health and safety (individuals)			
3.1 Routine radiation doses	**3**	**5**	
3.2 Radiological accident risks	**3**	**3**	
3.3 Non-radioactive hazards and risks	**3**	**3**	
4 Physical environment			
4.1 Air quality	**3**	**5**	
4.2 Water quality	**5 (0)**	**5**	ILW_{MinOpt} water quality vastly increased because the legacy and decommissioning MALs, DFR and PFR raffinates, ADU floc and Shaft, Silo and pond sludges are all now immobilised in cement rather than being discharged to the marine environment.
4.3 Land	**5 (3)**	**5**	ILW_{MinOpt} land quality increased because the legacy and decommissioning MALs, DFR and PFR raffinates, ADU floc and Shaft, Silo and pond sludges are all now immobilised in cement rather than being discharged to the marine environment, stopping their movement to the land by sea-to-land transport.
4.4 Visual impact	**4**	**4**	
4.5 Nuisances (noise, traffic etc.)	**4**	**4**	
4.6 Energy usage	**4**	**4 (1)**	ILW_{MaxOpt} energy usage reduced because central evaporator is replaced with ion exchange columns.
5 Flora and fauna			
5.1 Preservation of habitat	**5 (3)**	**5**	ILW_{MinOpt} habitat better protected because the legacy and decommissioning MALs, DFR and PFR raffinates, ADU floc and Shaft, Silo and pond sludges, as well as solvents and oils, are all now immobilised in cement rather than being discharged to the marine environment.
5.2 Conservation of species	**5 (3)**	**5**	ILW_{MinOpt} species better protected because the legacy and decommissioning MALs, DFR and PFR raffinates, ADU floc and Shaft, Silo and pond sludges, as well as solvents and oils, are all now immobilised in cement rather than being discharged to the marine environment.
6 Viability			

	Solid ILW volumes		Notes
Sub-attribute	ILW_{MinOpt}	ILW_{MaxOpt}	
6.1 Maturity of technology	5	5 (2)	ILW_{MaxOpt} maturity of technology improved because unproven methods of catalyst and absorption for H-3 and zeolite separation for Kr-85 are replaced with more standard methods of dehumidifier and direct discharge, respectively.
7 Flexibility			
7.1 Ability to cope with various endpoints for solid wastes	4 (N/A)	4	ILW_{MinOpt} ability to cope with solid waste endpoints becomes relevant because strategy intent is now to immobilise liquid waste streams, rather than direct discharge.
7.2 Ability to cope with various timescales	5	5	
7.3 Accept other waste streams	4 (5)	5 (4)	ILW_{MaxOpt} ability to accept other waste streams increased because ion exchange columns are more efficient and flexible than central evaporators. ILW_{MinOpt} ability to accept other waste streams decreased because cementation is less efficient and flexible than direct discharge for liquid wastes.
8 Local			
8.1 Economic impacts	3 (0)	3	ILW_{MinOpt} economic impacts lessened because stopping direct discharge of the legacy and decommissioning MALs, DFR and PFR raffinates, ADU floc and Shaft, Silo and pond sludges, as well as solvents and oils, will no longer affect fishing, agriculture and tourism.
8.2 Culture and heritage	3 (1)	3	ILW_{MinOpt} cultural impacts lessened because stopping direct discharge of the legacy and decommissioning MALs, DFR and PFR raffinates, ADU floc and Shaft, Silo and pond sludges, as well as solvents and oils, will no longer affect local culture.
9 Elsewhere			
9.1 Economic impacts	3	3	
9.2 Culture and heritage	3	3	
10 Environmental objectives			
10.1 Waste minimisation	4 (5)	3 (2)	ILW_{MinOpt} waste minimisation made worse because larger volumes of cemented waste is generated. Most of liquid wastes are cemented with the exception of LLL and LLLETP sludges which are still discharged. ILW_{MaxOpt} waste minimisation improved because no longer maximising volumes of solid wastes but still cementing both ADU floc and its supernate, and directly cementing LLLETP sludge without dewatering.
10.2 Progressive discharge reductions	5 (0)	5	ILW_{MinOpt} progressive discharge reductions greatly improved because the legacy and decommissioning MALs, DFR and PFR raffinates, ADU floc and Shaft, Silo and pond sludges, as well as solvents and oils, are all now immobilised in cement rather than being discharged.
10.3 Concentrate and contain	4 (1)	5	ILW_{MinOpt} concentrate and contain greatly improved because the legacy and decommissioning MALs, DFR and PFR raffinates, ADU floc and Shaft, Silo and pond sludges, as well as solvents and oils, are all now immobilised in cement rather than being discharged.
10.4 Precautionary action	4 (2)	4	ILW_{MinOpt} precautionary action improved because the legacy and decommissioning MALs, DFR and PFR raffinates, ADU floc and Shaft, Silo and pond sludges, as well as solvents and oils, are all now immobilised in cement rather than being slowly bled to sea.
10.5 Protection beyond national borders	4 (0)	5	ILW_{MinOpt} protection across national borders greatly improved because the legacy and decommissioning MALs, DFR and PFR raffinates, ADU floc and Shaft, Silo and pond sludges, as well as solvents and oils, are all now immobilised in cement rather than being discharged to sea.
11 Overall cost			
11.1 Undiscounted cost	3 (4)	3	ILW_{MinOpt} costs increased because of additional cost of cementation plant and waste storage.
11.1 Undiscounted cost	3 (4)	3	Using the more sensitive scoring scheme discussed in Appendix C5.

Table 7.6: Scores for the two optimised strategy options related to the environmental issue of solid LLW volumes. LLW_{MinOpt} = optimised minimum LLW volumes; LLW_{MaxOpt} = optimised maximum LLW volumes. Scores in parentheses are the original scores for the unoptimised strategy options, where optimisation resulted in a change in score. All scores of 5 ('very good' performance) are coloured green.

	Solid LLW volumes		Notes
Sub-attribute	**LLW_{MinOpt}**	**LLW_{MaxOpt}**	
1 Public heath and safety (individuals)			
1.1 Routine radiation doses	3 (0)	4	LLW_{MinOpt} doses to individual members of the public now reduced because the legacy and decommissioning MALs, DFR and PFR raffinates, ADU floc and Shaft, Silo and pond sludges are all now immobilised in cement rather than being discharged. Solvents and oils are incinerated and HEPAs are added to active building ventilation. LLW_{MaxOpt} now discharges 85Kr so doses slightly increased but does not affect score. See Appendix C1 for full discussion.
1.2 Radiological accident risks	3	3	
1.3 Non-radioactive hazards and risks	4	5	
2 Public health and safety (societal)			
2.1 Routine radiation doses	4 (0)	4	LLW_{MinOpt} societal doses now improved because the legacy and decommissioning MALs, DFR and PFR raffinates, ADU floc and Shaft, Silo and pond sludges, as well as solvents and oils, are all now immobilised in cement rather than being discharged. See Appendix C1 for full discussion.
3 Worker health and safety (individuals)			
3.1 Routine radiation doses	4	3	
3.2 Radiological accident risks	3	3	
3.3 Non-radioactive hazards and risks	3	3	
4 Physical environment			
4.1 Air quality	3	5	
4.2 Water quality	5 (0)	5	LLW_{MinOpt} water quality vastly increased because the legacy and decommissioning MALs, DFR and PFR raffinates, ADU floc and Shaft, Silo and pond sludges are all now immobilised in cement rather than being discharged to the marine environment.
4.3 Land	5 (3)	5	LLW_{MinOpt} land quality increased because the legacy and decommissioning MALs, DFR and PFR raffinates, ADU floc and Shaft, Silo and pond sludges are all now immobilised in cement rather than being discharged to the marine environment, stopping their movement to the land by sea-to-land transport.
4.4 Visual impact	4	3 (1)	LLW_{MaxOpt} visual impact improved as much smaller store is required to house the volumes of solid waste produced.
4.5 Nuisances (noise, traffic etc.)	4	4	
4.6 Energy usage	4	4 (1)	LLW_{MaxOpt} energy usage reduced because central evaporator is replaced with ion exchange columns.
5 Flora and fauna			
5.1 Preservation of habitat	4 (3)	5	LLW_{MinOpt} habitat better protected because the legacy and decommissioning MALs, DFR and PFR raffinates, ADU floc and Shaft, Silo and pond sludges, as well as solvents and oils, are all now immobilised in cement rather than being discharged to the marine environment.
5.2 Conservation of species	4 (3)	5	LLW_{MinOpt} species better protected because the legacy and decommissioning MALs, DFR and PFR raffinates, ADU floc and Shaft, Silo and pond sludges, as well as solvents and oils, are all now immobilised in cement rather than being discharged to the marine environment.
6 Viability			
6.1 Maturity of technology	5	5 (2)	LLW_{MaxOpt} maturity of technology improved because unproven methods of catalyst and absorption for H-3 and zeolite separation for Kr-85 are replaced with more standard methods of dehumidifier and direct discharge, respectively.
7 Flexibility			

	Solid LLW volumes		Notes
Sub-attribute	LLW_{MinOpt}	LLW_{MaxOpt}	
7.1 Ability to cope with various endpoints for solid wastes	4 (N/A)	4	LLW_{MinOpt} ability to cope with solid waste endpoints becomes relevant because strategy intent is now to immobilise liquid waste streams, rather than direct discharge.
7.2 Ability to cope with various timescales	5	5	
7.3 Accept other waste streams	4 (5)	4	LLW_{MinOpt} ability to accept other waste streams decreased because cementation is less efficient and flexible than direct discharge for liquid wastes.
8 Local			
8.1 Economic impacts	3 (0)	3	LLW_{MinOpt} economic impacts lessened because stopping direct discharge of the legacy and decommissioning MALs, DFR and PFR raffinates, ADU floc and Shaft, Silo and pond sludges, as well as solvents and oils, will no longer affect fishing, agriculture and tourism.
8.2 Culture and heritage	3 (1)	3	LLW_{MinOpt} cultural impacts lessened because stopping direct discharge of the legacy and decommissioning MALs, DFR and PFR raffinates, ADU floc and Shaft, Silo and pond sludges, as well as solvents and oils, will no longer affect local culture.
9 Elsewhere			
9.1 Economic impacts	3	3	
9.2 Culture and heritage	3	3	
10 Environmental objectives			
10.1 Waste minimisation	4 (5)	3 (1)	LLW_{MinOpt} waste minimisation made worse because much larger volumes of cemented waste is generated. Most of liquid wastes are cemented with the exception of LLLETP which is still discharged. LLW_{MaxOpt} waste minimisation is greatly improved because wastes are cemented as ILW instead of LLW but still large volumes of cemented waste still created, in particular, from cementing LLLETP sludge.
10.2 Progressive discharge reductions	5 (0)	5	LLW_{MinOpt} progressive discharge reductions greatly improved because the legacy and decommissioning MALs, DFR and PFR raffinates, ADU floc and Shaft, Silo and pond sludges, as well as solvents and oils, are all now immobilised in cement rather than being discharged.
10.3 Concentrate and contain	4 (1)	5	LLW_{MinOpt} concentrate and contain greatly improved because the legacy and decommissioning MALs, DFR and PFR raffinates, ADU floc and Shaft, Silo and pond sludges, as well as solvents and oils, are all now immobilised in cement rather than being discharged.
10.4 Precautionary action	4 (2)	4	LLW_{MinOpt} precautionary action improved because the legacy and decommissioning MALs, DFR and PFR raffinates, ADU floc and Shaft, Silo and pond sludges, as well as solvents and oils, are all now immobilised in cement rather than being slowly bled to sea.
10.5 Protection beyond national borders	4 (0)	5	LLW_{MinOpt} protection across national borders greatly improved because the legacy and decommissioning MALs, DFR and PFR raffinates, ADU floc and Shaft, Silo and pond sludges, as well as solvents and oils, are all now immobilised in cement rather than being discharged to sea.
11 Overall cost			
11.1 Undiscounted cost	5	2 (0)	LLW_{MaxOpt} costs reduced because the Kr-85 is directly discharged rather than using expensive zeolite separation to capture it, the central evaporator is replaced with ion exchange columns and smaller volumes of solid waste require storage.
11.1 Undiscounted cost	5	2 (0)	Using the more sensitive scoring scheme discussed in Appendix C5.

Table C2.1: Assessment of Risks to Members of the Public and Workers. Options for Strategies to Address Liquid Discharge Levels; Sources of risk.

Waste stream		Strategy Option		
		Liq$_{min}$	**Liq$_{max}$**	**Liq$_{inter}$**
Airborne Wastes				
A1	Particulates from building ventilation	M workers L Public AECP 1054 + HEPAs Filter catching fire	M workers L Public AECP 1054 + wet scrubbing	*M workers* *L Public* AECP 1054 + HEPAs Filter catching fire
A2	Particulates from contaminated ground	*L workers* *L Public* dry treatment (none) operator error	*L workers* *L Public* wet treatment (e.g. spraying) Flooding	*L workers* *L Public* dry treatment (none) operator error
A3	H-3	*L workers* *L Public* no treatment	*M workers* *M Public* catalyst + total condensation Fire. Drop load on condenser.	*M workers* *M Public* ? partial condensation Drop load on condenser
A4	C-14	*L workers* L Public no treatment	*L workers* *M Public* wet scrubber	*L workers* *M Public* scrub + barium carbonate
A5	Kr-85	*L workers* *L public* No treatment	*L workers* *L Public* Liquid aborption (?)	*L workers* L public No treatment
A6	Iodines	M workers *M Public* Activated carbon	*M workers* *M Public* Wet scrubber	*M workers* *M Public* Scrub + barium carbonate
Liquid Wastes				
L1	Low level liquid	No accident sequence leads to a consequence to the general public exceeding the threshold dose. all min. arisings methods + central evaporator W<10^{-5} P<10^{-6} Ref:D1212 Safety case.	No accident sequence leads to a consequence to the general public exceeding the threshold dose. No treatment W<10^{-5} P<10^{-6} Ref:D1212 Safety case.	No accident sequence leads to a consequence to the general public exceeding the threshold dose. current practice + zone specific W<10^{-5} P<10^{-6} Ref:D1212 Safety case.
L2	MALs			
L2.1	MALs from decommissioning	*L workers* L public no treatment and robotic dismantling Drop load on robotic dismantling equipment	*L workers* *M public* washout + direct discharge	Criticality or explosion in floc settling tanks Chemical activity removal (floc) W<10^{-5} P<10^{-6} Ref:Table 6.8 of D1208 safety case
L2.2	Legacy MALs MTR raffinate	Cell doors are open while drums are present inside solidify (e.g. cementation) W $3.6x10^{-6}$ P < 10^{-7} Ref:Table 5.8 of D2700 safety case.	*M workers* *H public* No treatment (direct discharge) W $3.6x10^{-6}$ P < 10^{-7} Ref:Table 5.8 of D2700 safety case.	Criticality or explosion in floc settling tanks Chemical activity removal (floc) W<10^{-5} P<10^{-6} Ref:Table 6.8 of D1208 safety case
L3	DFR raffinate	Cell doors are open while drums are present inside Cement	*L workers* *M public* Direct discharge	*M workers* *M Public* preparation + treatment Evaporator implosion
L4	PFR raffinate	*Cell doors are open while drums are present inside* Cement	*L workers* *M public* Direct discharge	M workers *M Public* Chemical separation separation + treatment
L5	Solvents and oils	M workers *L Public* Solidification	*M workers* *M Public* pre-wash and incinerate + wet scrubbers fire	*M workers* *M Public* pre-wash and incinerate + dry scrubbers fire

Waste stream		Strategy Option		
		Liq_{min}	Liq_{max}	Liq_{inter}
L6	Flocs and sludges			
L6.1	Ammonium diuranate	*M workers* *L Public* cement	*M workers* *M Public* wet chemical treatment + discharge Chemical spillage	*M Workers* *M Public* solven workers t extraction
L6.2	LLLETP sludge	*L workers* *L Public* min. liquid arisings and direct cement	L workers L public current practice for liquid arisings + discharge to sea	*L workers* *L Public* de-water, cement sludge + discharge liquid
L6.3	Shaft and Silo sludge	M workers *L Public* cement	*M workers* *M Public* dissolve + discharge	*M workers* *M Public* dewater, cement sludge, treat liquid + discharge
L6.4	Fuel storage pond sludge	*M workers* *L Public* do not empty	*L workers* *M public* de-water	*M workers* *L Public* cement
Solid Wastes				
S1	LLW			
S1.1	General metals	*M workers* *L Public* any (except liquid decontam)+ cut & package injury from cutting equipment	*M workers* *L Public* any + decontam	M workers L public any + cut & package injury from cutting equipment
S1.2	Tritiated metals	*L workers* *L Public* decay store	*M workers* *M Public* smelt + scrub Injuries from smelting equipment	*M workers* *M Public* smelt + condense Injuries from smelting equipment.
S1.3	Concrete & building materials	No accident sequence leads to a consequence to the general public exceeding the threshold dose. any except liquid decontamination $W<10^{-5}$ $P<10^{-6}$ Ref:D1212 Safety case.*M*	No accident sequence leads to a consequence to the general public exceeding the threshold dose any + decontam $W<10^{-5}$ $P<10^{-6}$ Ref:D1212 Safety case.*M*	No accident sequence leads to a consequence to the general public exceeding the threshold dose any + none $W<10^{-5}$ $P<10^{-6}$ Ref:D1212 Safety case.*M*
S1.4	Cellulosic materials	No accident sequence leads to a consequence to the general public exceeding the threshold dose. any $W<10^{-5}$ $P<10^{-6}$ Ref:D1212 Safety case.	No accident sequence leads to a consequence to the general public exceeding the threshold dose. any $W<10^{-5}$ $P<10^{-6}$ Ref:D1212 Safety case.	No accident sequence leads to a consequence to the general public exceeding the threshold dose. any $W<10^{-5}$ $P<10^{-6}$ Ref:D1212 Safety case.
S1.5	Non-cellulosic compactables	No accident sequence leads to a consequence to the general public exceeding the threshold dose. any $W<10^{-5}$ $P<10^{-6}$ Ref:D1212 Safety case.	No accident sequence leads to a consequence to the general public exceeding the threshold dose. any $W<10^{-5}$ $P<10^{-6}$ Ref:D1212 Safety case.	No accident sequence leads to a consequence to the general public exceeding the threshold dose. any $W<10^{-5}$ $P<10^{-6}$ Ref:D1212 Safety case.
S1.6	Pits wastes	*L workers* *L Public* retrieve + grout Injuries from grouting equipment	*L workers* *L Public* do not empty	*L workers* *L Public* Do not retrieve + & grout
S1.7	Bulk non-compactables, non-combustible	No accident sequence leads to a consequence to the general public exceeding the threshold dose. any $W<10^{-5}$ $P<10^{-6}$ Ref:D1212 Safety case.	No accident sequence leads to a consequence to the general public exceeding the threshold dose. any $W<10^{-5}$ $P<10^{-6}$ Ref:D1212 Safety case.	No accident sequence leads to a consequence to the general public exceeding the threshold dose. any $W<10^{-5}$ $P<10^{-6}$ Ref:D1212 Safety case.

Waste stream		Strategy Option		
		Liq_{min}	Liq_{max}	Liq_{inter}
S1.8	Soils	No accident sequence leads to a consequence to the general public exceeding the threshold dose. Any+none W<10^{-5} P<10^{-6} Ref:D1212 Safety case.	No accident sequence leads to a consequence to the general public exceeding the threshold dose. Any+decontam W<10^{-5} P<10^{-6} Ref:D1212 Safety case.	No accident sequence leads to a consequence to the general public exceeding the threshold dose. Any+none W<10^{-5} P<10^{-6} Ref:D1212 Safety case.
S2	CH ILW	External radiation from off-specification La Calhenes/drums. Breech of Waste Posting Glovebox containment Any W $2.8x10^{-5}$ P<$6x10^{-10}$ Ref:Table 6 of D9867 safety case.	External radiation from off-specification La Calhenes/drums. Breech of Waste Posting Glovebox containment Any W $2.8x10^{-5}$ P<$6x10^{-10}$ Ref:Table 6 of D9867 safety case.	External radiation from off-specification La Calhenes/drums. Breech of Waste Posting Glovebox containment Any W $2.8x10^{-5}$ P<$6x10^{-10}$ Ref:Table 6 of D9867 safety case.
S3	Shaft + silo RH ILW	*M Workers* *M Public* any except liquid decontamination	*M Workers* *M Public* *Public* publicliquid decontamination + direct discharge	*M Workers* *M Public* liquid decontamination + treatment prior to discharge
S4	RH ILW	*M workers* M Public any except liquid decontamination	M workers M public liquid decontamination + direct discharge	*M workers* *M public* liquid decontamination + treatment prior to discharge
S5	Boron carbide (H3 = active, boron carbide = non-active)	*M workers* *L public* cement	M workers M public dissolve + discharge boron fire from heating boron	M workers L public wash + discharge liquid
S6	Decommissioning ILW			
S6.1	Metals (including surface contamination)	M workers L public any except liquid decontamination injuries from cutting equipment	M workers L public liquid decontamination + direct discharge	*M workers* *L public* liquid decontamination + treatment prior to discharge injuries from cutting equipment
S6.2	Graphite	*M Workers* *L Public* cement?	*M workers* *M public* burn + scrub off-gas Fire	*M workers* *M public* Burn fire
S6.3	Concrete	*M workers* *L Public* dry decontamination	*M workers* *M public* wet decontamination + discharge	*M workers* *L public* wet decontamination + treatment → discharge

Table C2.1 continued: Assessment of Risks to Members of the Public and Workers. Options for Strategies to Address Airborne Discharge Levels; Sources of risk.

Waste stream		Strategy Option		
		Atm$_{min}$	**Atm**$_{max}$	**Atm**$_{inter}$
Airborne Wastes				
A1	Particulates from building ventilation	*L public* *H workers* all practical minimis'n of arisings methods + scrubbers + HEPAs) Filter catching fire	*H public* *L workers* increase flow + no treatment	H Workers M Public AECP 1054 + HEPAs Filter catching fire
A2	Particulates from contaminated ground	H workers L public In situ encapsulation	*H public* *H workers* lift + shift with no treatment Drop load	H workers M Public Tent + HEPA on ventilation Filter catching fire
A3	H-3	*H workers* *L Public* all practical minimis'n of arisings methods + scrubbers + HEPAs) → condense where not contained, & control humidity Filter catching fire	*L workers* *H Public* no treatment	*M worker* *M Public* where contained do not release + partial condensation
A4	C-14	H workers L Public wet scrubber	*L worker* *H Public* no treatment	M workers M Public dry scrub
A5	Kr-85	*H workers* *L Public* Cryogenic distillation Drop load on cryogenic equipment	L workers H public Direct discharge	M workers M Public Liquid absorption ??
A6	Iodines	H workers L Public N/A Activated carbon +/or scrubbing	L workers H public No treatment	M workers M Public Absorption on silver (slow release on solid waste, i.e. dose rate)
Liquid Wastes				
L1	Low level liquid	No accident sequence leads to a consequence to the general public exceeding the threshold dose. all min arisings methods + any except evaporator $W<10^{-5}$ $P<10^{-6}$ Ref:D1212 Safety case.	No accident sequence leads to a consequence to the general public exceeding the threshold dose. any + evap $W<10^{-5}$ $P<10^{-6}$ Ref:D1212 Safety case.	No accident sequence leads to a consequence to the general public exceeding the threshold dose. current practice + non treatment $W<10^{-5}$ $P<10^{-6}$ Ref:D1212 Safety case.
L2	MALs			
L2.1	MALs from decommissioning	do not decontaminate	H Workers H public wash out +evap evaporator implosion	H workers M public washout + chemical activity removal → discharge Chemical spillage
L2.2	Legacy MALs MTR raffinate	Cell doors are open while drums are present inside cement $W\ 3.6x10^{-6}$ $P < 10^{-7}$ Ref:Table 5.8 of D2700 safety case.	H workers H Public Evaporator Evaporator implosion	Criticality or explosion in floc settling tanks Chemical activity removal (floc) $W<10^{-5}$ $P<10^{-6}$ Ref:Table 6.8 of D1208 safety case
L3	DFR raffinate	H workers L Public cement	H workers H Public Evap + Vitrification without abatement Evaporator implosion	H workers M Public Evap + Vitrification with abatement Evaporator implosion
L4	PFR raffinate	H workers L Public solidify	H workers H Public Evap + Vitrification without abatement Evaporator implosion	H workers M Public Evap + Vitrification with abatement Evaporator implosion
L5	Solvents and oils	H workers L Public Solidify	M workers H Public incinerate without abatement	M workers M Public incinerate with abatement

Waste stream		Strategy Option		
		Atm$_{min}$	Atm$_{max}$	Atm$_{inter}$
L6	Flocs and sludges			
L6.1	Ammonium diuranate	H workers L Public cement	*H workers* *H public* vitrification + no abatement	*H workers* *M Public* solvent extraction
L6.2	LLLETP sludge	*H workers* *L Public* minimise arisings + cement	*H workers* *H Public* Vitrification + non abatement	M workers M Public any except incin or evap
L6.3	Shaft and silo sludge	H workers L Public freeze + cement	*H workers* *H Public* vitrify	*H workers* *M Public* Dewater + cement
L6.4	Fuel storage pond sludge	H workers L Public Cement	H workers H Public Vitrify	H workers M Public Dewater + cement
Solid Wastes				
S1	LLW			
S1.1	General metals	*L Public* *M workers* Minimum handling + sealing prior to removal	H workers H Public Dry decontamination + recycling	*M Public* *H workers* Volume reduce + pack Injuries from cutting equipment
S1.2	Tritiated metals	H workers L public Decay store + store in unventilated building	H workers H public Smelt	*H workers* *M public* Volume reduce + pack Injuries from cutting equipment
S1.3	Concrete & building materials	H worker L public Minimum handling + sealing prior to removal	*H worker* *H public* Dry decontamination + recycling	*H worker* *M public* volume reduce + pack injuries from cutting equipment
S1.4	Cellulosic materials	H workers L public grout	M workers *H public* no sort, incinerate	H workers M public super-compact + grout
S1.5	Non-cellulosic compactables	H workers *L public* Grout	H workers H public Compact + store	*H workers* *M public* Compact + grout
S1.6	Pits wastes Needs cross-referencing to LLW BPEO	H workers *L public* In situ encapsulation	H workers *H public* Recover, sort + store	M workers *M Public* Current practice
S1.7	Bulk non-compactables, non-combustible	M worker L Public minimum handling + sealing prior to removal	M workers H Public dry decontamination + recycling	H workers M Public volume reduce + pack injuries from cutting equipment
S1.8	Soils	H workers L Public In situ + encapsulation	H workers H Public lift + shift	M workers M Public no treatment
S2	CH ILW	External radiation from off-specification La Calhenes/drums. Breech of Waste Posting Glovebox containment grout W $2.8x10^{-5}$ P<$6x10^{-10}$ Ref:Table 6 of D9867 safety case.	External radiation from off-specification La Calhenes/drums. Breech of Waste Posting Glovebox containment supercompact + grout W $2.8x10^{-5}$ P<$6x10^{-10}$ Ref:Table 6 of D9867 safety case.	External radiation from off-specification La Calhenes/drums. *Breech of Waste Posting Glovebox containment* supercompact + grout W $2.8x10^{-5}$ P<$6x10^{-10}$ Ref:Table 6 of D9867 safety case.
S3	Shaft and silo RH ILW	H workers L Public grout	H workers H Public supercompact + grout	H workers M Public supercompact + grout
S4	RH ILW in stores	H workers L Public decay → grout	H workers H Public segregate, treat + grout	H workers M Public segregate, treat + grout

Waste stream		Strategy Option		
		Atm$_{min}$	**Atm**$_{max}$	**Atm**$_{inter}$
S5	Boron carbide	M workers M Public any	*M workers* *M Public* any	*M workers* *M Public* any
S6	Decommissioning ILW			
S6.1	Metals	*M workers* *M Public* any	*M workers* *M Public* any	*M workers* *M Public* any
S6.2	Graphite	*H workers* *L Public* cement	H workers *H Public* Burn fire	*H workers* *M Public* cement
S6.3	Concrete	*M workers* *L Public* any + none	*M workers* *M Public* any + decontam	*M workers* *M Public* any + none

Table C2.1 continued: Assessment of Risks to Members of the Public and Workers. Options for Strategies to Address ILW waste volumes; Sources of risk.

Waste stream		Strategy Option		
		ILWmin	**ILWmax**	**ILWinter**
Airborne Wastes				
A1	Particulates from building ventilation	M workers L Public min arisings & no treatment	H workers H Public increase flow rates + HEPAs Filters catching fire	H Workers M Public AECP 1054 + HEPAs Filter catching fire
A2	Particulates from contaminated ground	M workers L Public min arisings & no treatment	H workers H Public Excavate and cement in tent + HEPAs Filters catching fire	H workers M Public Tent + HEPA on ventilation Filter catching fire
A3	H-3	?	?	M worker M Public where contained do not release + partial condensation
A4	C-14	M workers L Public No treatment	H workers H Public scrub + barium carbonate	M workers M Public dry scrub
A5	Kr-85	N/A		M workers M Public Liquid absorption ??
A6	Iodines	N/A		M workers M Public Absorption on silver (slow release on solid waste, i.e. dose rate)
Liquid Wastes				
L1	Low level liquid	No accident sequence leads to a consequence to the general public exceeding the threshold dose. all min arisings + LLLETP W<10-5 P<10-6 Ref:D1212 Safety case	No accident sequence leads to a consequence to the general public exceeding the threshold dose. current practice + plant specific + LLLETP W<10-5 P<10-6 Ref:D1212 Safety case	No accident sequence leads to a consequence to the general public exceeding the threshold dose. current practice + zone specific + LLLETP W<10-5 P<10-6 Ref:D1212 Safety case
L2	MALs			
L2.1	MALs from decommissioning	workers Public	H workers H Public washout + cement	H workers M Public washout + activity removal + cement
L2.2	Legacy MALs MTR raffinate			
L3	DFR raffinate	H workers L Public decontam	H workers H Public cement	H workers M Public cement
L4	PFR raffinate	H workers L Public vitrify at Sellafield	H workers H Public cement at Dounreay	H workers M Public vitrify at Dounreay
L5	Solvents and oils	H workers M Public treat off-site Inhalation of solvents	H workers H Public oxidation/ chem treat on site Inhalation of solvents	H workers M Public incinerate
L6	Flocs and sludges			
L6.1	Ammonium diuranate	?	?	?
L6.2	LLLETP sludge	H workers L Public min all liquid arisings + evap & cement evaporator implosion	H workers H Public max liquid arisings + cement	M workers M Public some min arisings + cement

Waste stream		**Strategy Option**		
		ILWmin	**ILWmax**	**ILWinter**
L6.3	Shaft and silo sludge	H workers L public do not empty	H workers H Public cement	H workers M Public dewater + cement
L6.4	Fuel storage pond sludge	H workers L public do not empty	H workers H Public cement	H workers M Public dewater + cement
Solid Wastes				
S1	LLW			
S1.1	General metals			
S1.2	Tritiated metals	No accident sequence leads to a consequence to the general public exceeding the threshold dose. any W<10-5 P<10-6 Ref:D1212 Safety case.	No accident sequence leads to a consequence to the general public exceeding the threshold dose. any W<10-5 P<10-6 Ref:D1212 Safety case.	No accident sequence leads to a consequence to the general public exceeding the threshold dose. any W<10-5 P<10-6 Ref:D1212 Safety case.
S1.3	Concrete & building materials	No accident sequence leads to a consequence to the general public exceeding the threshold dose. any W<10-5 P<10-6 Ref:D1212 Safety case.	No accident sequence leads to a consequence to the general public exceeding the threshold dose. any W<10-5 P<10-6 Ref:D1212 Safety case.	No accident sequence leads to a consequence to the general public exceeding the threshold dose. any W<10-5 P<10-6 Ref:D1212 Safety case.
S1.4	Cellulosic materials	No accident sequence leads to a consequence to the general public exceeding the threshold dose. any W<10-5 P<10-6 Ref:D1212 Safety case.	No accident sequence leads to a consequence to the general public exceeding the threshold dose. any W<10-5 P<10-6 Ref:D1212 Safety case.	No accident sequence leads to a consequence to the general public exceeding the threshold dose. any W<10-5 P<10-6 Ref:D1212 Safety case.
S1.5	Non-cellulosic compactables	No accident sequence leads to a consequence to the general public exceeding the threshold dose. any W<10-5 P<10-6 Ref:D1212 Safety case.	No accident sequence leads to a consequence to the general public exceeding the threshold dose. any W<10-5 P<10-6 Ref:D1212 Safety case.	No accident sequence leads to a consequence to the general public exceeding the threshold dose. any W<10-5 P<10-6 Ref:D1212 Safety case.
S1.6	Pits wastes Needs cross-referencing to LLW BPEO	No accident sequence leads to a consequence to the general public exceeding the threshold dose. any W<10-5 P<10-6 Ref:D1212 Safety case.	No accident sequence leads to a consequence to the general public exceeding the threshold dose. any W<10-5 P<10-6 Ref:D1212 Safety case.	No accident sequence leads to a consequence to the general public exceeding the threshold dose. any W<10-5 P<10-6 Ref:D1212 Safety case.
S1.7	Bulk non-compactables, non-combustible	No accident sequence leads to a consequence to the general public exceeding the threshold dose. any W<10-5 P<10-6 Ref:D1212 Safety case.	No accident sequence leads to a consequence to the general public exceeding the threshold dose. any W<10-5 P<10-6 Ref:D1212 Safety case.	No accident sequence leads to a consequence to the general public exceeding the threshold dose. any W<10-5 P<10-6 Ref:D1212 Safety case.
S1.8	Soils	No accident sequence leads to a consequence to the general public exceeding the threshold dose. any W<10-5 P<10-6 Ref:D1212 Safety case.	No accident sequence leads to a consequence to the general public exceeding the threshold dose. any W<10-5 P<10-6 Ref:D1212 Safety case.	No accident sequence leads to a consequence to the general public exceeding the threshold dose. any W<10-5 P<10-6 Ref:D1212 Safety case.

Waste stream		**Strategy Option**		
		ILWmin	**ILWmax**	**ILWinter**
S2	Short-lived and long-lived CH ILW	No accident sequence leads to a consequence to the general public exceeding the threshold dose. any W<10-5 P<10-6 Ref:D1212 Safety case.	No accident sequence leads to a consequence to the general public exceeding the threshold dose. any W<10-5 P<10-6 Ref:D1212 Safety case.	No accident sequence leads to a consequence to the general public exceeding the threshold dose. any W<10-5 P<10-6 Ref:D1212 Safety case.
S3	Short and long-lived Shaft and silo RH ILW	External radiation from off-specification La Calhenes/drums. Breech of Waste Posting Glovebox containment no seg, grout at Sellafield W 2.8x10-5 P<6x10-10 Ref:Table 6 of D9867 safety case	External radiation from off-specification La Calhenes/drums. Breech of Waste Posting Glovebox containment no seg, grout on site W 2.8x10-5 P<6x10-10 Ref:Table 6 of D9867 safety case	External radiation from off-specification La Calhenes/drums. Breech of Waste Posting Glovebox containment seg, grout on site W 2.8x10-7 P<6x10-12 Ref:Table 6 of D9867 safety case
S4	Short and long-lived RH ILW in stores	M Workers L Public do not retrieve	H Workers L Public no seg, cement	H Workers M Public seg, cement
S5	Boron carbide	H Workers L Public seg, cement	H Workers L Public no seg, cement	H Workers M Public seg, cement
S6	Decommissioning ILW	H Workers L Public cement	H Workers L Public cement	H Workers M Public cement
S6.1	Metals			
S6.2	Graphite	H workers L Public max seg, cut & pack after decay injuries from cutting equipment	L Workers H Public no seg, immediate cement	H Workers M Public seg, cement after decay
S6.3	Concrete	H workers L Public burn & cement fire	H Workers H Public cement	H Workers M Public cement

Table C2.1 continued: Assessment of Risks to Members of the Public and Workers. Options for Strategies to Address LLW waste volumes; Sources of risk.

Waste stream		Strategy Option		
		LLWmin	**LLWmax**	**LLWinter**
Airborne Wastes				
A1	Particulates from building ventilation	M workers L Public min arisings & no treatment	H workers H Public increase flow rates + HEPAs filters catching fire	H workers M Public AECP 1054 + HEPAs Filters catching fire
A2	Particulates from contaminated ground	M workers L Public min arisings & no treatment	H workers H Public Excavate and cement in tent + HEPAs filters catching fire	H workers M Public Lift, sort and cement waste which cannot be cleared in tent + HEPAs filters catching fire
A3	H-3	?	?	?
A4	C-14	M workers L Public no treatment	H workers H Public scrub + barium carbonate	H workers M Public wet scrub
A5	Kr-85	N/A	N/A	N/A
A6	Iodines	N/A	N/A	N/A
Liquid Wastes				
L1	Low level liquid	No accident sequence leads to a consequence to the general public exceeding the threshold dose all min arisings + LLLETP W<10-5 P<10-6 Ref:D1212 Safety case	No accident sequence leads to a consequence to the general public exceeding the threshold dose current practice + plant specific + LLLETP W<10-5 P<10-6 Ref:D1212 Safety case	No accident sequence leads to a consequence to the general public exceeding the threshold dose current practice + zone specific + LLLETP W<10-5 P<10-6 Ref:D1212 Safety case
L2	MALs			
L2.1	MALs from decommissioning	M Workers M Public do not decontam	H Workers H Public washout + cement	H Workers M Public washout + activity removal + cement
L2.2	Legacy MALs MTR raffinate			
L3	DFR raffinate	H Workers L Public Decontam	H Workers H Public cement	H Workers M Public cement
L4	PFR raffinate	H workers L Public vitrify at Sellafield	H workers H Public cement at Dounreay	H workers M Public vitrify at Dounreay
L5	Solvents and oils	H Workers M Public treat off-site	H Workers H Public oxidation/ chem treat on site Chemical spillage	H Workers M Public incinerate
L6	Flocs and sludges			
L6.1	Ammonium diuranate			
L6.2	LLLETP sludge	H workers L Public min all liquid arisings + evap & cement evaporator implosion	H Workers H Public max liquid arisings + cement	H workers M Public some min arisings + cement
L6.3	Shaft and silo sludge	M worlers M Public do not empty	H Workers H Public cement	H workers M Public dewater + cement
L6.4	Fuel storage pond sludge	H Workers L Public do not empty	H Workers H Public cement	H Workers M Public dewater + cement
Solid Wastes				

Waste stream		Strategy Option		
		LLWmin	**LLWmax**	**LLWinter**
S1	LLW			
S1.1	General metals	H workers L Public sort, seg, decontam	L workers H Public no sort or seg, pack	H Workers M Public sort, seg,, pack injuries from cutting equipment
S1.2	Tritiated metals	H Workers L Public smelt	H Workers H Public decay store	H Workers M Public decontam
S1.3	Concrete & building materials	H workers L Public sort, seg, decontam	L workers H Public no sort, seg, none	H workers M Public sort, seg, vol reduce
S1.4	Cellulosic materials	H Workers L Public incin	L workers H Public no sort/seg, compact & grout	H workers M Public sort, seg, incin.
S1.5	Non-cellulosic compactables	H workers L Public sort, seg, compact & grout	L workers H Public no sort or seg, grout	H workers M Public sort, seg, grout
S1.6	Pits wastes	H Workers L Public do not empty	L workers H Public no sort, seg, grout	H workers M Public sort, eg, decontam & grout
S1.7	Bulk non-compactables, non-combustible	H worker L Public sort, seg, cut & pack injuries from cutting equipment	L worker H Public no sort or seg, none	H worker M Public sort, seg, none
S1.8	Soils	H Workers L Public seg, decontam	L worker H Public no seg, none	M worker M Public some seg, none
S2	CH ILW	External radiation from off-specification La Calhenes/drums. Breech of Waste Posting Glovebox containment. no seg, grout at Sellafield W 2.8x10-5 P<6x10-10 Ref:Table 6 of D9867 safety case	External radiation from off-specification La Calhenes/drums. Breech of Waste Posting Glovebox containment. no seg, grout on site W 2.8x10-5 P<6x10-10 Ref:Table 6 of D9867 safety case.	External radiation from off-specification La Calhenes/drums. Breech of Waste Posting Glovebox containment. seg, grout on site W 2.8x10-7 P<6x10-12 Ref:Table 6 of D9867 safety case
S3	Shaft and silo RH ILW	H Workers L Public do not retrieve	L Workers H Public no seg, cement	H Workers M Public seg, cement
S4	RH ILW in stores	H Workers L Public do not retrieve	L Workers H Public no seg, cement	H Workers M Public seg, cement
S5	Boron carbide	H Workers L Public seg, cement	L Workers H Public no seg, cement	H Workers M Public seg, cement
S6	Decommissioning ILW	H Workers L Public cement	H Workers H Public cement	H Workers M Public cement
S6.1	Metals			
S6.2	Graphite	H workers L Public max seg, cut & pack after decay injuries from cutting equipment	H Workers H Public no seg, immediate cement	H Workers M Public seg, cement after decay
S6.3	Concrete	H workers L Public burn & cement fire	H Workers H Public cement	H Workers M Public cement