APPENDICES

APPENDIX I: CRITICAL PROPERTIES (PARAMETERS)

The critical properties (parameters) of the Alternatives previously identified are listed in Table 3 below.

Table 3: Critical Properties (Parameters) of Chemical Cement Alternatives and Their Relevance [1]

Critical Parameters (Applicable Protocol Number)	Definition	Units	Importance of the Property to the Chemical Cement Alternative Testing
Permeability (I)	Measure of the ability of a porous material to transmit fluids under a pressure differential.	Darcy	Provides an estimate of the lag time between placement and breakthrough and release rate of fluid below a given length of material under a set pressure differential
Diffusion coefficient (I)	Proportionality constant between the gradient of concentration driving the diffusion process and the corresponding flux of the moving fluid	m^2s^{-1}	Provides an estimate of the lag time between placement and breakthrough and release rate of fluid below a given length of material under a set concentration differential
Absorption (I, II)	Mass of fluid taken up by porosity within a substance	% mass/ % vol.	Allows an indication of swelling, from which resulting stresses may be projected
Chemical Resistance (II, III, IV)	Indication of reactivity of a material. Described with terms non resistant, limited resistance, resistant		Allows an indication of the degree to which properties of the material may change
Volume Change (I, II)	Change in volume	strain or % by vol.	Variable required to calculate stresses from expansion or shrinkage
Modulus of elasticity (III)	Uniaxial stress over uniaxial strain.	Pressure	Variable required to determined degree of deformation under a given pressure, and under temperature change
Poisson's ratio (III)	Ratio of lateral strain to axial strain under uniaxial stress	None	Variable required to determine lateral deformation under a given pressure and under temperature change
Cohesion (III)	Describes a granular material's cementation strength between grains under shear stress.	Pressure	Variable required to determine shear failure
Internal friction angle (III)	Describes a granular material's ability to increase load-capacity or shear stress with confinement	Degrees	Variable required to determine reduction in ultimate compressive strength and loss in cohesion
Hydrostatic yield (III)	Stress applied uniformly in all directions when plastic deformation happens	Pressure	Above this threshold material will undergo irreversible plastic deformation causing loss of cohesion and load-bearing capacity. Provides indication of pore collapse in granular materials
Tensile Strength (III)	Threshold at which failure occurs under a tensile load	Pressure	Describes maximum tensile stress
Unconfined compressive strength (III)	Threshold at which failure occurs under axial compressive stress	Pressure	Maximum compressive stress that a Chemical Cement Alternative can withstand
Hardness (III)	Describes a material's resistance to surface deformation		QA/QC control test. For some materials, provides indication of yield strength in shear
Shear bond strength (I, III)	Threshold at which bond between two materials fails under shear loading	Pressure	Variable required to calculate pressure differential value resulting in the movement of Chemical Cement Alternative
Tensile bond strength (I, III)	Threshold at which bond between two materials fails under tensile loading	Pressure	Maximum tensile at the Chemical Cement Alternative casing interface prior to failure

Creep (III)	Linear deformation over time at a set load	Strain rate/time %/s	Provides an estimate of the ultimate dimensional change of a Chemical Cement Alternative under a given pressure differential or other load
Fatigue life	Threshold number of stress cycles of a given property prior to failure		Provides an indication of longevity at a specified cyclical stress regime.
Decomposition temperature (III)	Threshold temperature at which Chemical Cement Alternative begins to thermally decompose for a given pressure and environment composition	Temperature	Provides an indication of the degree of deterioration and gives a prediction of maximum operating temperature of the material
Density (V)	Mass per unit volume	Mass per unit volume	QA/QC test. Provides an indication of the likelihood of Chemical Cement Alternative moving due to differences between densities of Chemical Cement Alternative and well fluids

APPENDIX II: ACCEPANTANCE CRITERIA TABLES

Acceptance Values

Table 4: Alberta Tier 1 Table B-2. Groundwater Remediation Guideline Values for Agricultural Land - All Water Uses [5]

Water Use	Lowest Guideline		Potable	Inhalation		Eco Soil Contact		Aquatic Life		Irrigation	Livestock	Wildlife Watering	
Soil Type	Fine	Coarse	All	Fine	Coarse	Fine	Coarse	Fine	Coarse	All	All	Fine	Coarse
Unit	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)
General and Inorganic Parameters													
pH	6.5-8.5	6.5-8.5	6.5-8.5	-	-	-	-	6.5-9	6.5-9	-	-	-	-
Ammonia	see note d	see note d	-	-	-	-	-	see note d	see note d	-	-	-	-
Bromate	0.01	0.01	0.01	-	-	-	-	-	-	-	-	-	-
Chloride	100	100	250	-	-	-	-	120	120	100	-	-	-
Cyanide (free)	0.005	0.005	0.2	-	-	-	-	0.005	0.005	-	-	-	-
Electrical Conductivity (dS/m)	1	1								1			
Fluoride	1	1	1.5	-	-	-	-	-	-	1	1	-	-
Nitrate (as nitrogen)	3	3	10	-	-	-	-	3	3	-	-	-	-
Nitrate + Nitrite (as nitrogen)	100	100	-	-	-	-	-	-	-	-	100	-	-
Nitrite (as nitrogen)	see note e	see note e	1.0	-	-	-	-	see note d	see note d	-	10	-	-
Sodium	200	200	200	-	-	-	-	-	-	-	-	-	-
Sodium Adsorption Ratio	5	5								5			
Sulphate	see note e	see note e	500	-	-	-	-	see note d	see note d	-	1000	-	-
Sulphide – Total (as S)[f]	0.0019	0.0019	0.05	-	-	-	-	0.0019	0.0019	-	-	-	-
Total Dissolved Solids (TDS)	500	500	500	-	-	-	-	-	-	-	3000	-	-
Metals													
Aluminum	see note e	see note e	-	-	-	-	-	see note d	see note d	5	5	-	-
Antimony	0.006	0.006	0.006	-	-	-	-	-	-	-	-	-	-
Arsenic	0.005	0.005	0.01	-	-	-	-	0.005	0.005	0.16	0.025	-	-
Barium	1	1	1	-	-	-	-	-	-	-	-	-	-
Boron	1.0	1.0	5	-	-	-	-	1.5	1.5	1.0	5	-	-
Cadmium	see note e	see note e	0.005	-	-	-	-	see note d	see note d	0.0082	0.08	-	-
Chromium (trivalent)	0.0049	0.0049	-	-	-	-	-	0.0089	0.0089	0.0049	0.05	-	-
Chromium (hexavalent)	0.001	0.001	-	-	-	-	-	0.001	0.001	0.008	0.05	-	-
Chromium (total)	0.05	0.05	0.05	-	-	-	-	-	-	-	-	-	-
Copper	0.007	0.007	1	-	-	-	-	0.007	0.007	0.2	0.5	-	-

Water Use	Lowest Guideline		Potable	Inhalation		Eco Soil Contact		Aquatic Life		Irrigation	Livestock	Wildlife Watering	
Soil Type	Fine	Coarse	All	Fine	Coarse	Fine	Coarse	Fine	Coarse	All	All	Fine	Coarse
Unit	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)
Iron	0.3	0.3	0.3	-	-	-	-	0.3	0.3	5	-	-	-
Lead	see note e	see note e	0.01	-	-	-	-	see note d	see note d	0.2	0.1	-	-
Manganese	0.05	0.05	0.05	-	-	-	-	-	-	0.2	-	-	-
Mercury (total)	0.000005	0.000005	0.001	-	-	-	-	0.000005	0.000005	-	0.003	-	-
Nickel	see note e	see note e	-	-	-	-	-	see note d	see note d	0.2	1	-	-
Selenium	0.002	0.002	0.05	-	-	-	-	0.002	0.002	0.02	0.05	-	-
Silver	0.0001	0.0001	-	-	-	-	-	0.0001	0.0001	0.02	0.05	-	-
Uranium	0.01	0.01	0.02	-	-	-	-	0.015	0.015	0.01	0.2	-	-
Zinc	0.03	0.03	5	-	-	-	-	0.03	0.03	1	50	-	-
Hydrocarbons													
Benzene	0.005	0.005	0.005	2.8	0.14	100	61	3.6	0.074	-	0.088	6.8	0.14
Toluene	0.024	0.021	0.024	NGR	74	82	59	12,000	0.021	-	4.9	NGR	180
Ethylbenzene	0.0016	0.0016	0.0016	NGR	16	42	20	NGR	41	-	3.2	NGR	NGR
Xylenes	0.02	0.02	0.02	80	3.9	21	31	NGR	2.9	-	13	NGR	NGR
Styrene	0.072	0.072	2.8	90	4.3	-	-	0.072	0.072	-	-	-	-
F1	2.2	0.81	2.2	19	0.81	6.5	7.1	NGR	9.8	-	53	NGR	NGR
F2	1.1	1.1	1.1	NGR	1.5	1.8	1.8	NGR	1.3	-	NGR	NGR	NGR
Acenaphthene	0.0060	0.0058	1.4	NGR	NGR	-	-	0.0060	0.0058	-	NGR	NGR	NGR
Anthracene	0.0034	0.000012	NGR	NGR	NGR	0.025	0.025	0.0034	0.000012	-	NGR	NGR	NGR
Fluoranthene	0.24	0.000057	NGR	NGR	NGR	0.24	0.24	NGR	0.000057	-	NGR	NGR	NGR
Fluorene	0.0042	0.003	0.94	NGR	NGR	-	-	0.0042	0.003	-	NGR	NGR	NGR
Naphthalene	0.001	0.001	0.47	14	0.6	-	-	0.001	0.001	-	NGR	NGR	NGR
Phenanthrene	0.00086	0.0004	-	-	-	-	-	0.00086	0.0004	-	NGR	NGR	NGR
Pyrene	0.71	0.000092	0.71	NGR	NGR	-	-	NGR	0.000092	-	NGR	NGR	NGR
Carcinogenic PAHs (as B(a)P TPE) [a]	0.00004	0.00004	0.00004	-	-	-	-	-	-	-	-	-	-
Benz[a]anthracene	-	-	-	-	-	-	-	NGR	NGR	-	NGR	NGR	NGR

Water Use	Lowest Guideline		Potable	Inhalation		Eco Soil Contact		Aquatic Life		Irrigation	Livestock	Wildlife Watering	
Soil Type	Fine	Coarse	All	Fine	Coarse	Fine	Coarse	Fine	Coarse	All	All	Fine	Coarse
Unit	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)
Benzo[b+j]fluoranthene	-	-	-	-	-	-	-	-	-	-	NGR	NGR	NGR
Benzo[k]fluoranthene	-	-	-	-	-	-	-	-	-	-	NGR	NGR	NGR
Benzo[g,h,i]perylene	-	-	-	-	-	-	-	-	-	-	-	-	-
Benzo[a]pyrene [b]	0.0018	0.0018	-	-	-	0.0018	0.0018	NGR	NGR	-	NGR	NGR	NGR
Chrysene	-	-	-	-	-	-	-	-	-	-	NGR	NGR	NGR
Dibenz[a,h]anthracene	-	-	-	-	-	-	-	-	-	-	NGR	NGR	NGR
Indeno[1,2,3-c,d]pyrene	-	-	-	-	-	-	-	-	-	-	-	-	-
Halogenated Aliphatics													
Vinyl chloride	0.002	0.0011	0.002	0.018	0.0011	-	-	-	-	-	-	-	-
1,1-Dichloroethene	0.014	0.014	0.014	0.68	0.039	-	-	-	-	-	-	-	-
Trichloroethene (Trichloroethylene, TCE)	0.005	0.005	0.005	0.41	0.02	4.4	5	0.27	0.029	-	0.05	-	-
Tetrachloroethene (Tetrachloroethylene, Perchloroethylene, PCE)	0.010	0.010	0.010	0.25	0.012	-	-	0.11	0.11	-	-	-	-
1,2-Dichloroethane	0.005	0.005	0.005	0.17	0.01	-	-	0.1	0.1	-	0.005	-	-
Dichloromethane (Methylene chloride)	0.05	0.05	0.05	61	3.4	-	-	0.098	0.098	-	0.05	-	-
Trichloromethane (Chloroform) [i]	0.08	0.018	0.08	0.53	0.030	-	-	0.10	0.018	-	0.1	-	-
Tetrachloromethane (Carbon tetrachloride)	0.002	0.00057	0.002	0.012	0.00057	-	-	0.013	0.013	-	0.005	-	-
Dibromochloromethane	0.1	0.1	0.19	26	1.1	-	-	-	-	-	0.1	-	-
Chlorinated Aromatics													
Chlorobenzene	0.0013	0.0013	0.03	0.3	0.014	-	-	0.0013	0.0013	-	-	-	-
1,2-Dichlorobenzene	0.0007	0.0007	0.003	116	5.4	-	-	0.0007	0.0007	-	-	-	-
1,4-Dichlorobenzene	0.001	0.001	0.001	4.6	0.22	-	-	0.026	0.026	-	-	-	-
1,2,3-Trichlorobenzene	0.008	0.008	0.014	0.8	0.032	-	-	0.008	0.008	-	-	-	-
1,2,4-Trichlorobenzene	0.015	0.015	0.015	0.71	0.028	-	-	0.024	0.024	-	-	-	-

Water Use	Lowest Guideline		Potable	Inhalation		Eco Soil Contact		Aquatic Life		Irrigation	Livestock	Wildlife Watering	
Soil Type	Fine	Coarse	All	Fine	Coarse	Fine	Coarse	Fine	Coarse	All	All	Fine	Coarse
Unit	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)
1,3,5-Trichlorobenzene	0.014	0.014	0.014	0.38	0.015	-	-	-	-	-	-	-	-
1,2,3,4-Tetrachlorobenzene	0.0018	0.0018	0.032	NGR	0.14	-	-	0.0018	0.0018	-	-	-	-
1,2,3,5-Tetrachlorobenzene	0.0038	0.0038	0.0038	0.41	0.017	-	-	-	-	-	-	-	-
1,2,4,5-Tetrachlorobenzene	0.002	0.002	0.002	0.21	0.0088	-	-	-	-	-	-	-	-
Pentachlorobenzene	0.0094	0.0069	0.0094	NGR	0.038	-	-	NGR	0.0069	-	-	-	-
Hexachlorobenzene	0.00052	0.00052	0.00057	0.029	0.0012	-	-	-	-	-	0.00052	-	-
2,4-Dichlorophenol	0.0002	0.0002	0.0003	NGR	1500	-	-	0.0002	0.0002	-	-	-	-
2,4,6-Trichlorophenol	0.002	0.002	0.002	NGR	54	-	-	0.018	0.018	-	-	-	-
2,3,4,6-Tetrachlorophenol	0.001	0.001	0.001	NGR	NGR	-	-	0.001	0.001	-	-	-	-
Pentachlorophenol	0.00051	0.0005	0.03	NGR	NGR	0.87	0.88	0.00051	0.0005	-	-	-	-
Dioxins & Furans [c]	0.00000012	0.00000012	1.2E-07	-	-	-	-	-	-	-	-	-	-
PCBs	0.0094	0.0094	0.0094	-	-	-	-	-	-	-	-	-	-
Pesticides													
Aldicarb	0.001	0.001	0.009	-	-	-	-	0.001	0.001	0.073	0.011	-	-
Aldrin	0.0007	0.0007	0.0007	-	-	-	-	-	-	-	-	-	-
Atrazine and metabolites	0.0018	0.0018	0.005	-	-	-	-	0.0018	0.0018	0.01	0.005	-	-
Azniphos-methyl (Guthion)	0.00001	0.00001	0.02	-	-	-	-	0.00001	0.00001	-	-	-	-
Bendiocarb	0.04	0.04	0.04	-	-	-	-	-	-	-	-	-	-
Bromacil [g]	0.0002	0.0002	0.95	-	-	0.44	0.30	0.005	0.005	0.0002	1.1	-	-
Bromoxynil	0.00044	0.00044	0.005	-	-	-	-	0.005	0.005	0.00044	0.011	-	-
Carbaryl	0.0002	0.0002	0.09	-	-	-	-	0.0002	0.0002	-	1.1	-	-
Carbofuran	0.0018	0.0018	0.09	-	-	-	-	0.0018	0.0018	-	0.045	-	-
Chlorothalonil	0.00018	0.00018	0.14	-	-	-	-	0.00018	0.00018	0.0093	0.17	-	-
Chlorpyrifos	0.0000046	0.000002	0.09	-	-	-	-	0.0000046	0.000002	-	0.024	-	-
Cyanazine	0.0005	0.0005	0.01	-	-	-	-	0.002	0.002	0.0005	0.01	-	-
2,4-D	0.004	0.004	0.1	-	-	-	-	0.004	0.004	-	0.1	-	-
DDT	0.093	0.093	0.093	-	-	-	-	-	-	-	0.1	-	-

Water Use	Lowest Guideline		Potable	Inhalation		Eco Soil Contact		Aquatic Life		Irrigation	Livestock	Wildlife Watering	
Soil Type	Fine	Coarse	All	Fine	Coarse	Fine	Coarse	Fine	Coarse	All	All	Fine	Coarse
Unit	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)
Diazinon	0.00017	0.00017	0.02	-	-	-	-	0.00017	0.00017	-	-	-	-
Dicamba	0.000008	0.000008	0.12	-	-	-	-	0.01	0.01	0.000008	0.12	-	-
Diclofop-methyl	0.00024	0.00024	0.009	-	-	-	-	0.56	0.0061	0.00024	0.009	-	-
Dieldrin	0.0007	0.0007	0.0007	-	-	-	-	-	-	-	-	-	-
Dimethoate	0.003	0.003	0.02	-	-	-	-	0.0062	0.0062	-	0.003	-	-
Dinoseb	0.000055	0.00005	0.01	-	-	-	-	0.000055	0.00005	0.021	0.15	-	-
Diquat	0.07	0.07	0.07	-	-	-	-	-	-	-	-	-	-
Diuron	0.15	0.15	0.15	-	-	-	-	-	-	-	-	-	-
Endosulfan	0.0019	0.0000031	0.057	-	-	-	-	0.0019	0.0000031	-	-	-	-
Endrin	0.0028	0.0028	0.0028	-	-	-	-	-	-	-	-	-	-
Glyphosate	0.065	0.065	0.28	-	-	-	-	0.065	0.065	-	0.28	-	-
Heptachlor epoxide	0.000052	0.000052	0.000052	0.0043	0.00024	-	-	-	-	-	-	-	-
Lindane	0.00001	0.00001	0.0028	-	-	-	-	0.00001	0.00001	-	0.004	-	-
Linuron	0.00011	0.00011	0.019	-	-	-	-	0.007	0.007	0.00011	-	-	-
Malathion	0.0001	0.0001	0.19	-	-	-	-	0.0001	0.0001	-	-	-	-
MCPA	0.00004	0.00004	0.1	-	-	-	-	0.0026	0.0026	0.00004	0.025	-	-
Methoxychlor	0.9	0.00017	0.9	-	-	-	-	NGR	0.00017	-	-	-	-
Metolachlor	0.0078	0.0078	0.05	-	-	-	-	0.0078	0.0078	0.028	0.05	-	-
Metribuzin	0.0005	0.0005	0.08	-	-	-	-	0.001	0.001	0.0005	0.08	-	-
Paraquat (as dichloride)	0.01	0.01	0.01	-	-	-	-	-	-	-	-	-	-
Parathion	0.000013	0.000013	0.05	-	-	-	-	0.000013	0.000013	-	-	-	-
Phorate	0.002	0.002	0.002	-	-	-	-	-	-	-	-	-	-
Picloram	0.029	0.029	0.19	-	-	-	-	0.029	0.029	-	0.19	-	-
Simazine	0.0005	0.0005	0.01	-	-	-	-	0.01	0.01	0.0005	0.01	-	-
Tebuthiuron [h]	0.00043	0.00043	0.66	-	-	0.20	0.25	0.0016	0.0016	0.00043	0.13	-	-
Terbufos	0.001	0.001	0.001	-	-	-	-	-	-	-	-	-	-
Toxaphene	0.00043	0.00043	0.00043	6.4	0.31	-	-	-	-	-	-	-	-

Water Use	Lowest Guideline		Potable	Inhalation		Eco Soil Contact		Aquatic Life		Irrigation	Livestock	Wildlife Watering	
Soil Type	Fine	Coarse	All	Fine	Coarse	Fine	Coarse	Fine	Coarse	All	All	Fine	Coarse
Unit	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)
Triallate	0.00024	0.00024	0.12	-	-	-	-	0.00024	0.00024	-	0.23	-	-
Trifluralin	0.0012	0.0002	0.045	-	-	-	-	0.0012	0.0002	-	0.045	-	-
Other Organics													
Aniline	0.0022	0.0022	0.066	1,900	87	-	-	0.0022	0.0022	-	-	-	-
Dibutyl phthalate	0.019	0.019	0.59	NGR	NGR	-	-	0.019	0.019	-	-	-	-
Dichlorobenzidine	0.007	0.007	0.007	NGR	NGR	-	-	-	-	-	-	-	-
Diethanolamine	0.06	0.06	0.06	-	-	-	-	65,000	5.0	-	-	-	-
Diethylene glycol	6.0	6.0	6.0	-	-	-	-	4,000	200	-	-	-	-
Diisopropanolamine	1.6	1.6	3.6	-	-	160	160	1.6	1.6	3.2	-	-	-
Ethylene glycol	31	31	31	NGR	NGR	9,200	16,000	190	190	-	-	-	-
Hexachlorobutadiene	0.0013	0.0013	0.006	0.031	0.0013	-	-	0.0013	0.0013	-	-	-	-
Methanol	19	19	19	270,000	19,000	-	-	630	32	-	-	-	-
Methylmethacrylate	0.47	0.47	0.47	17	0.84	-	-	-	-	-	-	-	-
Monoethanolamine	0.6	0.6	0.6	-	-	-	-	30,000	1.0	-	-	-	-
MTBE	0.015	0.015	0.015	6.1	0.34	-	-	10	10	-	-	-	-
Nitrilotriacetic acid	0.4	0.4	0.4	-	-	-	-	-	-	-	-	-	-
Nonylphenol + ethoxylates	0.0081	0.0081	-	-	-	0.0081	0.0081	NGR	0.61	-	-	-	-
Phenol	0.002	0.002	0.57	73,000	3,700	110	150	0.004	0.004	-	0.002	-	-
Sulfolane	0.09	0.09	0.09	-	-	1,700	2,800	50	50	0.8	-	-	-
Triethylene glycol	60	60	60	-	-	-	-	25,000	550	-	-	-	-
Trihalomethanes - total (THMs)	0.1	0.1	0.1	-	-	-	-	-	-	-	-	-	-

Notes:

a. B[a]P TPE (Total Potency Equivalents) are calculated by multiplying the groundwater concentration of individual carcinogenic PAHs by a standardized Benzo[a]pyrene Potency Equivalence Factor (PEF) to produce a Benzo[a]pyrene relative potency concentration, and by subsequently summing the relative potency concentrations for the entire PAH mixture. B[a]P PEFs are order of magnitude estimates of carcinogenic potential and are based on the World Health Organization (1999) scheme, as follow:

Carcinogenic PAH Compound	PEF
Benz[a]anthracene	0.1
Benzo(b+j)fluoranthene	0.1
Benzo[k]fluoranthene	0.1
Benzo[ghi]perylene	0.01
Benzo[a]pyrene	1
Chrysene	0.01
Dibenz[a,h]anthracene	1
Indeno[1,2,3-c,d]pyrene	0.1

b. For ecological receptors only.

c. Expressed as toxic equivalents (TEQs) based on 2,3,7,8-PCDD (See CCME, 1999 and updates)

d. See Environmental Quality Guidelines for Alberta Surface Waters (ESRD, 2014) for further guidance on aquatic life pathway.

e. Tier 1 guideline = lowest of aquatic life guideline and all other guidelines.

f. As S, but can be applied to undissociated H_2S if concerns arise.

g. Eco-contact guidelines from Stantec (2012)

h. Eco-contact guidelines from Stantec (2008)

i. Guideline for protection of aquatic life (fine soil) is set at the maximum concentration of trichloromethane that will support biological degradation (MEMS, 2016).

NGR - no guideline required, calculated value > solubility or >1,000,000 mg/L

Potable GW = protection of groundwater for potable drinking water

Inhalation = protection of volatilization from groundwater and migration into indoor air

Eco Soil Contact = protection of terrestrial plants and soil invertebrates in areas with shallow groundwater

Aquatic Life = protection of groundwater discharging to a surface water body hosting aquatic life

Irrigation = protection of a potential irrigation groundwater source

Livestock Watering = protection of a potential livestock watering groundwater resource

Wildlife Watering = protection of groundwater discharging to a surface water body from which wildlife may drink

These tables below identify various testing procedures (or experimental work plans) for the qualification of the various types of Chemical Cement Alternatives based on their most likely failure modes [1]. This is not an exhaustive list for each type of Chemical Cement Alternative and more tests may be required to address other failure modes. Recommended Tests (NS, RT) do not have a standard value as they are not considered critical but informative [1]. Class G cement properties are primarily available through literature. However, after ageing, these properties will need to be determined using the standardized test procedures listed in the tables below where applicable. In some instances, like that of thermoplastics or gels, alternate test procedures will be required for Class G cement. These must be industry recognized standardized testing procedures for Class G cements and documented as part of the Test Reports for each type of Alternative.

Table 5: Acceptance Criteria for the Testing Procedures of Modified Cements/ceramics (non-setting)

Subject (Applicable Protocol Number)	Property	Standard Test Procedure	Test Value Before Ageing	Test Value After Ageing
PERMEATION TESTING				
I	Nitrogen Permeability	Section 8.2.1 of "Guidelines on Qualification of Materials for the Abandonment of Wells" [1]	≤10 microdarcy with a calculated release rate <0.07 m^3/year, see justification under diffusion.	≤ Class G cement under same conditions
I	Diffusion coefficient	Not required		
INTERACTION WITH FLUID				
V, IV	Dry Mass	Measurement of mass after drying to constant mass at 105^0C	Not Required	≤ Class G cement percentage loss in dry mass under same conditions
I, II	Absorption	Not required		
DIMENSIONAL STABILITY				
Expansion/Swelling				
I, II	During hardening	API RP 10B-5 ring test	≤ Class G cement linear expansion percentage under same conditions	Not Required
I, II	Hardened	API RP 10B-5 ring test	Not Required	≤ Class G cement percentage linear expansion under same conditions
Shrinkage				
I, II	During hardening	API RP 10B-5 ring test	≤ 1.0% bulk shrinkage	Not Required
I, II	Hardened	API RP 10B-5 ring test	Not required	≤ Class G cement bulk shrinkage percentage under same conditions
I, II	Differential thermal expansion	ASTM E228	Coefficient of thermal expansion ± 5 K^{-1} x 10^{-6} of casing [1]*	Not Required
I, II III	creep	ASTM C512-10	≤ Class G cement strain percentage under same conditions	Not required
MECHANICAL TESTING				
III	Triaxial testing	Not required		
III	Cohesion	Not required		
III	Poisson's ratio	Not required		
III	Internal friction angle	Not required		
III	Hydrostatic compressive yield	Not required		
III	UCS	API RP 10B-2	≥ 2.1 MPa [6] **	≥ Class G cement under same conditions
III	Tensile strength	ASTM C496	≥ 3.65 MPa [1] ***	≥ Class G cement under same conditions

III	Elastic modulus	ASTM C469	NS, RT	NS, RT
III	Hardness	ASTM E384	NS, RT	NS, RT
OTHER				
I, III	Shear bond strength	See Section 8.6 of "Guidelines on Qualification of Materials for the Abandonment of Wells" [1]	≥ 1.3 MPa	≥ Class G cement under same conditions
I, III	Tensile bond strength	Not required		
III	Decomposition temperature	Not required		
V	Density	ASTM C 138	NS, RT	NS, RT
I, II, III	Stress relaxation	Not required		
III, IV, VIII	Function Test	As identified in Appendix 8 performed by Shell Global Solutions in "Guidelines of the Qualification of Materials Used in the Abandonment of Wells" [1]. See also lines 291-299 of same document.	calculated permeability must be ≤10 microdarcy at a stabilized flow rate	calculated permeability must be ≤ Class G cement at a stabilized flow rate

Class G cement = Portland Class G cement
* See Table 4 in [1]
** At 8 hours thickening time for Portland Class G cement
*** Tensile strength of cement
NS = No Standard listed for this property
RT = Recommended test that could provide a useful indication of performance

Table 6: Acceptance Criteria for the Testing Procedures of Grouts (non-setting)

Subject (Applicable Protocol Number)	Property	Standard Test Procedure	Test Value Before Ageing	Test Value After Ageing
PERMEATION TESTING				
I	Nitrogen Permeability	See Section 8.2.1 of "Guidelines on Qualification of Materials for the Abandonment of Wells" [1]	≤10 microdarcy with a calculated release rate <0.07 m^3/year, see justification under diffusion.	≤ Class G cement under same conditions
I	Diffusion coefficient	Not required		
INTERACTION WITH FLUID				
V, IV	Dry Mass	Measurement of mass after drying to constant mass at 105^0C	Not Required	≤ Class G cement percentage loss in dry mass under same conditions
I, II	Absorption	Not required		
DIMENSIONAL STABILITY				
Expansion/Swelling				
I, II	During hardening	Not required		
I, II	Hardened	Not required		
Shrinkage				
I, II	During hardening	Not required		
I, II	Hardened	Non – identified		
I, II	Differential thermal expansion	ASTM E228	NS, RT	Not Required
I, II III	creep	Not required		
MECHANICAL TESTING				
III	Triaxial testing	Not required		
III	Cohesion	Not required		
III	Poisson's ratio	Not required		
III	Internal friction angle	Not required		
III	Hydrostatic compressive yield	Not required		
III	UCS	Not required		
III	Tensile strength	Not required		
III	Elastic modulus	Not required		
III	Hardness	Not required		
OTHER				
I, III	Shear bond strength	See Section 8.6 of "Guidelines on Qualification of Materials for the Abandonment of Wells" [1], substrate rugosity measurements done as per ASTM D7172	NS, RT	NS, RT
I, III	Tensile bond strength	Not required		
III	Decomposition temperature	Not required		
V	Density	Pressurized mud balance	NS, RT	NS, RT
I, II, III	Stress relaxation	Not required		
III, IV, VIII	Function Test	As identified in Appendix 8 performed by Shell Global Solutions in "Guidelines of the Qualification of Materials Used in the Abandonment of Wells" [1]. See also lines 291-299 of same document.	calculated permeability must be ≤10 microdarcy at a stabilized flow rate	calculated permeability must be ≤ Class G cement at a stabilized flow rate

Class G cement = Portland Class G cement
NS = No Standard listed for this property
RT = Recommended test that could provide a useful indication of performance

Table 7: Acceptance Criteria for the Testing Procedures of Thermosetting Polymers and Composites

Subject (Applicable Protocol Number)	Property	Standard Test Procedure	Test Value Before Ageing	Test Value After Ageing
PERMEATION TESTING				
I	Nitrogen Permeability	Not required		
I	Diffusion coefficient	See section 8.2.2 of "Guidelines on Qualification of Materials for the Abandonment of Wells" [1]	≤2.4 x10-8 m2/s with a calculated release rate <0.07 m^3/year, see justification under diffusion.	≤ Class G cement under same conditions
INTERACTION WITH FLUID				
V, IV	Dry Mass	Measurement of mass after drying to constant mass at 105^0C	-	≤ Class G cement percentage loss in dry mass under same conditions
I, II	Absorption	Not required		
DIMENSIONAL STABILITY				
Expansion/Swelling				
I, II	During hardening	See section 8.4.1 of "Guidelines on Qualification of Materials for the Abandonment of Wells" [1]	≤ Class G cement percentage linear expansion under same conditions	-
I, II	Hardened	See section 8.4.1 of [1]	-	≤ Class G cement percentage linear expansion under same conditions
Shrinkage				
I, II	During hardening	See section 8.4.2 of "Guidelines on Qualification of Materials for the Abandonment of Wells" [1]	≤ 1.0% bulk shrinkage	-
I, II	Hardened	See section 8.4.2 of [1]	Not required	≤ Class G cement percentage bulk shrinkage under same conditions
I, II	Differential thermal expansion	ASTM E228	Coefficient of thermal expansion ± 5 K^{-1} x 10^{-6} of casing [1]*	-
I, II III	creep	ISO 899-1	≤ Class G cement strain percentage under same conditions	-
MECHANICAL TESTING				
III	Triaxial testing	Not required		
III	Cohesion	Not required		
III	Poisson's ratio	Not required		
III	Internal friction angle	Not required		
III	Hydrostatic compressive yield	Not required		
III	UCS	API RP 10B-2	≥ 2.1 MPa [6] **	≥ Class G cement under same conditions
III	Tensile strength	ISO 527-1,	≥ 3.65 MPa [1] ***	≥ Class G cement under same conditions
III	Elastic modulus	ISO 527-1	NS, RT	NS, RT
III	Hardness	See section 8.4.2 of [1]	NS, RT	NS, RT
OTHER				
I, III	Shear bond strength	See Section 8.6 of "Guidelines on Qualification	≥ 1.3 MPa	≥ Class G cement under same conditions

		of Materials for the Abandonment of Wells" [1], substrate rugosity measurements done as per ASTM D7172		
I, III	Tensile bond strength	Not required		
III	Decomposition temperature	TGA/DTA/DSC measurement	No decomposition below operating temp.	-
V	Density	ISO 1183-1	NS, RT	NS, RT
I, II, III	Stress relaxation	Not required		
III, IV, VIII	Function Test	As identified in Appendix 8 performed by Shell Global Solutions in "Guidelines of the Qualification of Materials Used in the Abandonment of Wells" [1]. See also lines 291-299 of same document.	calculated permeability must be ≤10 microdarcy at a stabilized flow rate	calculated permeability must be ≤ Class G cement at a stabilized flow rate

Class G cement = Portland Class G cement
* See Table 6 in [1]
** At 8 hours thickening time for Portland Class G cement
*** Tensile strength of cement
NS = No Standard listed for this property
RT = Recommended test that could provide a useful indication of performance

Table 8: Acceptance Criteria for the Testing Procedures of Thermoplastic Polymers and Composites

Subject (Applicable Protocol Number)	Property	Standard Test Procedure	Test Value Before Ageing	Test Value After Ageing
PERMEATION TESTING				
I	Nitrogen Permeability	Not required	-	-
I	Diffusion coefficient	See section 8.2.2 of "Guidelines on Qualification of Materials for the Abandonment of Wells" [1]	≤2.4 x10-8 m2/s with a calculated release rate <0.07 m^3/year, see justification under diffusion.	≤ Class G cement under same conditions
INTERACTION WITH FLUID				
V, IV	Dry Mass	Measurement of mass after drying to constant mass at 105^0C	-	≤ Class G cement percentage loss in dry mass under same conditions
I, II	Absorption	Not required		
DIMENSIONAL STABILITY				
Expansion/Swelling				
I, II	During hardening	See section 8.4.1 of "Guidelines on Qualification of Materials for the Abandonment of Wells" [1]	≤ Class G cement percentage linear expansion under same conditions	-
I, II	Hardened	See section 8.4.1 of [1]	-	≤ Class G cement percentage linear expansion under same conditions
Shrinkage				
I, II	During hardening	See section 8.4.2 of "Guidelines on Qualification of Materials for the Abandonment of Wells" [1], may need to investigate thermal shock	≤ 1.0% bulk shrinkage	-
I, II	Hardened	See section 8.4.2 of [1]	Not required	≤ Class G cement bulk percentage shrinkage under same conditions
I, II	Differential thermal expansion	ASTM E228	Coefficient of thermal expansion ± 10 K^{-1} x 10^{-6} of casing [1]*	Not required
I, II III	creep	ISO 899-1	≤ Class G cement percentage linear strain, under same conditions	Not required
MECHANICAL TESTING				
III	Triaxial testing	Not required		
III	Cohesion	Not required		
III	Poisson's ratio	Not required		
III	Internal friction angle	Not required		
III	Hydrostatic compressive yield	Not required		
III	UCS	ISO 604	≥ 2.1 MPa [6] **	≥ Class G cement under same conditions
III	Tensile strength	ISO 527-1	≥ 3.65 MPa [1] ***	≥ Class G cement under same conditions
III	Elastic modulus	ISO 527-1	NS, RT	NS, RT
III	Hardness	ISO 868	NS, RT	NS, RT
OTHER				

I, III	Shear bond strength	See Section 8.6 of "Guidelines on Qualification of Materials for the Abandonment of Wells" [1], substrate rugosity measurements done as per ASTM D7172	≥ 1.3 MPa	≥ Class G cement under same conditions
I, III	Tensile bond strength	Not required		
III	Decomposition temperature	TGA/DTA/DSC measurement	No decomposition below operating temp.	-
V	Density	ISO 1183-1	NS, RT	NS, RT
I, II, III	Stress relaxation	Not required		
III, IV, VIII	Function Test	As identified in Appendix 8 performed by Shell Global Solutions in "Guidelines of the Qualification of Materials Used in the Abandonment of Wells" [1]. See also lines 291-299 of same document.	calculated permeability must be ≤10 microdarcy at a stabilized flow rate	calculated permeability must be ≤ Class G cement at a stabilized flow rate

Class G cement = Portland Class G cement
* See Table 7 in [1]
** At 8 hours thickening time for Portland Class G cement
*** Tensile strength of cement
NS = No Standard listed for this property
RT = Recommended test that could provide a useful indication of performance

Table 9: Acceptance Criteria for the Testing Procedures of Elastomeric Polymers and Composites

Subject (Applicable Protocol Number)	Property	Standard Test Procedure	Test Value Before Ageing	Test Value After Ageing
PERMEATION TESTING				
I	Nitrogen Permeability	Not required	-	-
I	Diffusion coefficient	See section 8.2.2 of "Guidelines on Qualification of Materials for the Abandonment of Wells" [1]	≤2.4 x10-8 m2/s with a calculated release rate <0.07 m^3/year, see justification under diffusion.	≤ Class G cement under same conditions
INTERACTION WITH FLUID				
V, IV	Dry Mass	Measurement of mass after drying to constant mass at 105^0C	-	≤ Class G cement percentage loss in dry mass under same conditions
I, II	Absorption	Not required		
DIMENSIONAL STABILITY				
Expansion/Swelling				
I, II	During hardening	See section 8.4.1 of "Guidelines on Qualification of Materials for the Abandonment of Wells" [1]	≤ Class G cement percentage linear expansion under same conditions	
I, II	Hardened	See section 8.4.1 of [1]	-	≤ Class G cement percentage linear expansion under same conditions
Shrinkage				
I, II	During hardening	See section 8.4.2 of "Guidelines on Qualification of Materials for the Abandonment of Wells" [1]	≤ 1.0% bulk shrinkage	-
I, II	Hardened	See section 8.4.2 of [1]	-	≤ Class G cement percentage bulk shrinkage under same conditions
I, II	Differential thermal expansion	ASTM E228	Coefficient of thermal expansion ± 10 K^{-1} x 10^{-6} of casing [1]*	-
I, II III	creep	ISO 899-1 / ASTM D395	≤ Class G cement percentage linear strain, under same conditions	-
MECHANICAL TESTING				
III	Triaxial testing	Not required		
III	Cohesion	Not required		
III	Poisson's ratio	ISRM suggested method	NS, RT	-
III	Internal friction angle	Not required		
III	Hydrostatic compressive yield	Not required		
III	UCS	BS EN ISO 604	≥ 2.1 MPa [6] **	≥ Class G cement under same conditions
III	Tensile strength	BS EN ISO 527-1	≥ 3.65 MPa [1] ***	≥ Class G cement under same conditions
III	Elastic modulus	BS EN ISO 527-1	NS, RT	NS, RT
III	Hardness	ISO 868	NS, RT	NS, RT
OTHER				
I, III	Shear bond strength	See Section 8.6 of "Guidelines on Qualification	≥ 1.3 MPa	≥ Class G cement under same conditions

		of Materials for the Abandonment of Wells" [4], substrate rugosity measurements done as per ASTM D7172		
I, III	Tensile bond strength	Not required		
III	Decomposition temperature	TGA/DTA/DSC measurement	No decomposition below operating temp.	
V	Density	ISO 1183-1	NS, RT	NS, RT
I, II, III	Stress relaxation	ASTM D395 and NORSOK M710	≤ Class G cement percentage loss in sealing stress, under same conditions	≤ Class G cement percentage loss in sealing stress, under same conditions
III, IV, VIII	Function Test	As identified in Appendix 8 performed by Shell Global Solutions in "Guidelines of the Qualification of Materials Used in the Abandonment of Wells" [1]. See also lines 291-299 of same document.	calculated permeability must be ≤10 microdarcy at a stabilized flow rate	calculated permeability must be ≤ Class G cement at a stabilized flow rate

Class G cement = Portland Class G cement
* See Table 8 in [1]
** At 8 hours thickening time for Portland Class G cement
*** Tensile strength of cement
NS = No Standard listed for this property
RT = Recommended test that could provide a useful indication of performance

Table 10: Acceptance Criteria for the Testing Procedures of Formations

Subject (Applicable Protocol Number)	Property	Standard Test Procedure	Test Value Before Ageing	Test Value After Ageing
PERMEATION TESTING				
I	Nitrogen Permeability	See Section 8.2.1 of "Guidelines on Qualification of Materials for the Abandonment of Wells" [1]	≤10 microdarcy with a calculated release rate <0.07 m^3/year, see justification under diffusion.	≤ Class G cement under same conditions
I	Diffusion coefficient	Not required	-	-
INTERACTION WITH FLUID				
V, IV	Dry Mass	Measurement of mass after drying to constant mass at 105^0C	-	≤ Class G cement percentage loss in dry mass under same conditions
I, II	Absorption	Not required		
DIMENSIONAL STABILITY				
Expansion/Swelling				
I, II	During hardening	Not required		
I, II	Hardened	ISRM suggested method	NS, RT	-
Shrinkage				
I, II	During hardening	Not required		
I, II	Hardened	ISRM suggested method	NS, RT	-
I, II	Differential thermal expansion	ASTM E228	NS, RT	-
I, II III	creep	ASTM C512-10	NS, RT	-
MECHANICAL TESTING				
III	Triaxial testing	ISRM suggested method	NS, RT	NS, RT
III	Cohesion	ISRM suggested method	NS, RT	NS, RT
III	Poisson's ratio	ISRM suggested method	NS, RT	NS, RT
III	Internal friction angle	ISRM suggested method	NS, RT	NS, RT
III	Hydrostatic compressive yield	ISRM suggested method	NS, RT	NS, RT
III	UCS	ISRM suggested method	NS, RT	NS, RT
III	Tensile strength	ASTM C496	NS, RT	NS, RT
III	Elastic modulus	ASTM C469	NS, RT	NS, RT
III	Hardness	Not required		
OTHER				
I, III	Shear bond strength	Not required		
I, III	Tensile bond strength	Not required		
III	Decomposition temperature	Not required		
V	Density	Not required		
I, II, III	Stress relaxation	Not required		
III, IV, VIII	Function Test	As identified in Appendix 8 performed by Shell Global Solutions in "Guidelines of the Qualification of Materials Used in the Abandonment of Wells" [1]. See also lines 291-299 of same document.	calculated permeability must be ≤10 microdarcy at a stabilized flow rate	calculated permeability must be ≤ Class G cement at a stabilized flow rate

Class G cement = Portland Class G cement
NS = No Standard listed for this property
RT = Recommended test that could provide a useful indication of performance

Table 11: Acceptance Criteria for the Testing Procedures of Gels

Subject (Applicable Protocol Number)	Property	Standard Test Procedure	Test Value Before Ageing	Test Value After Ageing
PERMEATION TESTING				
I	Nitrogen Permeability	See Section 8.2.1 of "Guidelines on Qualification of Materials for the Abandonment of Wells" [1]	≤10 microdarcy with a calculated release rate <0.07 m^3/year, see justification under diffusion.	≤ Class G cement under same conditions
I	Diffusion coefficient	See Section 8.2.1 of "Guidelines on Qualification of Materials for the Abandonment of Wells" [1]	≤2.4x10-8 m2/s with a calculated release rate <0.07 m^3/year, see justification under diffusion.	≤ Class G cement under same conditions
INTERACTION WITH FLUID				
V, IV	Dry Mass	Measurement of mass after drying to constant mass at 105^0C	-	≤ Class G cement percentage loss in dry mass under same conditions
I, II	Absorption	Absorption index	NS, RT	NS, RT
DIMENSIONAL STABILITY				
Expansion/Swelling				
I, II	During setting	Not required		
I, II	Set	Not required		
Shrinkage				
I, II	During setting	See Section 8.4.2 of "Guidelines on Qualification of Materials for the Abandonment of Wells"	≤ 1.0% bulk shrinkage	-
I, II	Set	See Section 8.4.2 of "Guidelines on Qualification of Materials for the Abandonment of Wells"	-	≤ Class G cement percentage bulk shrinkage under same conditions
I, II	Differential thermal expansion	ASTM E228	NS, RT	-
I, II III	creep	Not required		
MECHANICAL TESTING				
III	Triaxial testing	Not required		
III	Cohesion	Not required		
III	Poisson's ratio	Not required		
III	Internal friction angle	Not required		
III	Hydrostatic compressive yield	Not required		
III	UCS	Not required		
III	Tensile strength	Not required		
III	Elastic modulus	Not required		
III	Hardness	Not required		
OTHER				
II, III, IV	Corrosion	API Recommended Practice 13B-1.	NS, RT	NS, RT
I, III	Shear bond strength	See Section 8.6 of "Guidelines on Qualification of Materials for the Abandonment of Wells" [1], substrate rugosity measurements done as per ASTM D7172	≥ 1.3 MPa	≥ Class G cement under same conditions
I, III	Tensile bond strength	Not required		
III	Decomposition temperature	TGA / DTA / DSC	No decomposition below operating temp.	-

V	Density	Not required		
I, II, III	Stress relaxation	Not required		
III, IV, VIII	Function Test	As identified in Appendix 8 performed by Shell Global Solutions in "Guidelines of the Qualification of Materials Used in the Abandonment of Wells" [1]. See also lines 291-299 of same document.	calculated permeability must be ≤10 microdarcy at a stabilized flow rate	calculated permeability must be ≤ Class G cement at a stabilized flow rate
Class G cement = Portland Class G cement NS = No Standard listed for this property RT = Recommended test that could provide a useful indication of performance				

Table 12: Acceptance Criteria for the Testing Procedures of Glass

Subject (Applicable Protocol Number)	Property	Standard Test Procedure	Test Value Before Ageing	Test Value After Ageing
PERMEATION TESTING				
I	Nitrogen Permeability	Not required		
I	Diffusion coefficient	Not required		
INTERACTION WITH FLUID				
V, IV	Dry Mass	Measurement of mass after drying to constant mass at 105^0C	-	≤ Class G cement percentage loss in dry mass under same conditions
I, II	Absorption	Not required		
DIMENSIONAL STABILITY				
Expansion/Swelling				
I, II	During hardening	See Section 8.4.1 of "Guidelines on Qualification of Materials for the Abandonment of Wells" [1]	≤ Class G cement percentage linear expansion under same conditions	-
I, II	Hardened	See Section 8.4.1 of "Guidelines on Qualification of Materials for the Abandonment of Wells" [1]	-	≤ Class G cement percentage linear expansion under same conditions
Shrinkage				
I, II	During hardening	See Section 8.4.2 of "Guidelines on Qualification of Materials for the Abandonment of Wells" [1]	≤ 1.0% bulk shrinkage	-
I, II	Hardened	See Section 8.4.2 of "Guidelines on Qualification of Materials for the Abandonment of Wells" [1]	-	≤ Class G cement percentage bulk shrinkage under same conditions
I, II	Differential thermal expansion	ASTM E228, may need to investigate thermal shock	Coefficient of thermal expansion ± 5 K^{-1} x 10^{-6} of casing [1]*	-
I, II III	creep	Not required		
MECHANICAL TESTING				
III	Triaxial testing	Not required		
III	Cohesion	Not required		
III	Poisson's ratio	Not required		
III	Internal friction angle	Not required		
III	Hydrostatic compressive yield	Not required		
III	UCS	API RP 10B-2	≥ 2.1 MPa [6] **	≥ Class G cement under same conditions
III	Tensile strength	Not required	≥ 3.65 MPa [1] ***	≥ Class G cement under same conditions
III	Elastic modulus	ASTM C469	NS, RT	NS, RT
III	Hardness	ASTM E384	NS, RT	NS, RT
OTHER				
I, III	Shear bond strength	See Section 9.6 of "Guidelines on Qualification of Materials for the Abandonment of Wells" [1]	≥ 1.3 MPa	≥ Class G cement under same conditions
I, III	Tensile bond strength	Not required		
III	Decomposition temperature	Not required		
V	Density	ASTM C138	NS, RT	NS, RT
I, II, III	Stress relaxation	Not required		

III, IV, VIII	Function Test	As identified in Appendix 8 performed by Shell Global Solutions in "Guidelines of the Qualification of Materials Used in the Abandonment of Wells" [1]. See also lines 291-299 of same document.	calculated permeability must be ≤10 microdarcy at a stabilized flow rate	calculated permeability must be ≤ Class G cement at a stabilized flow rate

Class G cement = Portland Class G cement
* See Table 11 in [1]
** At 8 hours thickening time for Portland Class G cement
*** Tensile strength of cement
NS = No Standard listed for this property
RT = Recommended test that could provide a useful indication of performance

Table 13: Acceptance Criteria for the Testing Procedures of Metals

Subject (Applicable Protocol Number)	Property	Standard Test Procedure	Test Value Before Ageing	Test Value After Ageing
PERMEATION TESTING				
I	Nitrogen Permeability	Not required		
I	Diffusion coefficient	Not required		
INTERACTION WITH FLUID				
V, IV	Dry Mass	Measurement of mass after drying to constant mass at 105^0C	-	≤ Class G cement percentage loss in dry mass under same conditions
I, II	Absorption	Not required		
DIMENSIONAL STABILITY				
Expansion/Swelling				
I, II	During hardening	See Section 8.4.1 of "Guidelines on Qualification of Materials for the Abandonment of Wells" [1]	≤ Class G cement percentage linear expansion under same conditions	-
I, II	Hardened	See Section 8.4.1 of [1]	NS, RT	NS, RT
Shrinkage				
I, II	During hardening	See Section 8.4.2 of "Guidelines on Qualification of Materials for the Abandonment of Wells" [1], may need to investigate thermal shock	≤ 1.0% bulk shrinkage	-
I, II	Hardened	See Section 8.4.2 of [1]	NS, RT	NS, RT
I, II	Differential thermal expansion	ASTM E228	Coefficient of thermal expansion ± 10 K^{-1} x 10^{-6} of casing [1]*	-
I, II III	creep	ISO 204	≤ Class G cement percentage linear strain, under same conditions	-
MECHANICAL TESTING				
III	Triaxial testing	ISRM suggested method	NS, RT	NS, RT
III	Cohesion	Not required		
III	Poisson's ratio	ISRM suggested method (triaxial) or ASTM E1876	NS, RT	-
III	Internal friction angle	Not required		
III	Hydrostatic compressive yield	Not required	-	-
III	UCS	ASTM E9	≥ 2.1 MPa [6] **	≥ Class G cement under same conditions
III	Tensile strength	ISO 6892-1	≥ 3.65 MPa [1] ***	≥ Class G cement under same conditions
III	Elastic modulus	ISO 3312 or ASTM E9	NS, RT	NS, RT
III	Hardness	ASTM E18, ASTM E10 or ASTM E384	NS, RT	NS, RT
OTHER				
II, III, IV	Corrosion	ISO 1516/NACE MR0175		
I, III	Shear bond strength	See Section 8.6 of "Guidelines on Qualification of Materials for the Abandonment of	≥ 1.3 MPa	≥ Class G cement under same conditions

		Wells" [1], substrate rugosity measurements done as per ASTM D7172		
I, III	Tensile bond strength	Not required		
III	Decomposition temperature	TGA/DTA/DSC measurement	Non-melting at operating temp.	-
V	Density	ISO 3369	NS, RT	NS, RT
I, II, III	Stress relaxation	Not required		
III, IV, VIII	Function Test	As identified in Appendix 8 performed by Shell Global Solutions in "Guidelines of the Qualification of Materials Used in the Abandonment of Wells" [1]. See also lines 291-299 of same document.	calculated permeability must be ≤10 microdarcy at a stabilized flow rate	calculated permeability must be ≤ Class G cement at a stabilized flow rate

Class G cement = Portland Class G cement
* See Table 12 in [1]
** At 8 hours thickening time for Portland Class G cement
*** Tensile strength of cement
NS = No Standard listed for this property
RT = Recommended test that could provide a useful indication of performance

Table 14: Acceptance Criteria for the Testing Procedures of Modified in-situ materials

Subject (Applicable Protocol Number)	Property	Standard Test Procedure	Test Value Before Ageing	Test Value After Ageing
PERMEATION TESTING				
I	Nitrogen Permeability	See Section 8.2.1 of "Guidelines on Qualification of Materials for the Abandonment of Wells" [1]	≤10 microdarcy with a calculated release rate <0.07 m^3/year, see justification under diffusion.	≤ Class G cement under same conditions
I	Diffusion coefficient	Not required		
INTERACTION WITH FLUID				
V, IV	Dry Mass	Measurement of mass after drying to constant mass at 105^0C	-	≤ Class G cement percentage loss in dry mass under same conditions
I, II	Absorption	Not required		
DIMENSIONAL STABILITY				
Expansion/Swelling				
I, II	During hardening	Not required		
I, II	Hardened	ISRM suggested method	NS, RT	-
Shrinkage				
I, II	During hardening	Not required		
I, II	Hardened	ISRM suggested method	NS, RT	-
I, II	Differential thermal expansion	ASTM E228	NS, RT	-
I, II III	creep	ASTM C512-10	Creep rate determined by application	-
MECHANICAL TESTING				
III	Triaxial testing	ISRM suggested method	NS, RT	NS, RT
III	Cohesion	ISRM suggested method	NS, RT	NS, RT
III	Poisson's ratio	ISRM suggested method	NS, RT	NS, RT
III	Internal friction angle	ISRM suggested method	NS, RT	NS, RT
III	Hydrostatic compressive yield	ISRM suggested method	NS, RT	NS, RT
III	UCS	ISRM suggested method	NS, RT	NS, RT
III	Tensile strength	ASTM C496	NS, RT	NS, RT
III	Elastic modulus	ASTM C469	NS, RT	NS, RT
III	Hardness	Not required		
OTHER				
I, III	Shear bond strength	Not required		
I, III	Tensile bond strength	Not required		
III	Decomposition temperature	Not required		
V	Density	Not required		
I, II, III	Stress relaxation	Not required		
III, IV, VIII	Function Test	As identified in Appendix 8 performed by Shell Global Solutions in "Guidelines of the Qualification of Materials Used in the Abandonment of Wells" [1]. See also lines 291-299 of same document.	calculated permeability must be ≤10 microdarcy at a stabilized flow rate	calculated permeability must be ≤ Class G cement at a stabilized flow rate

Class G cement = Portland Class G cement
NS = No Standard listed for this property
RT = Recommended test that could provide a useful indication of performance

APPENDIX II-A: CALCULATIONS, FORMULAS AND ASSUMPTIONS IN ACCEPTANCE CRITERIA

1) *Function test (see Appendix 8 of [1] for more details)*

A function test is a procedure used to verify the sealing ability of the Chemical Cement Alternative. The first procedure described in Appendix 8 [1] is a small scale setup and serves as a screening process prior to more expensive larger scale experiments. In general, testing in smaller diameter tubes gives better results than testing in larger diameter tubes [7]. If an Alternative fails a leak test at the smaller scale, do not test at a large scale.

The small scale apparatus consists of a test cell with a temperature probe, pressure regulators and pressure sensors, Nitrogen gas source, flow meters, bubble vessel, oven and a computer to record test data. This procedure applies differential pressure across the Alternative in a manner that prevents ballooning of the casing which causes leaks [1].

Figure 2 illustrates a standard functional test of Portland Class G cement in a small scale setup [7]. The blue line shows the output of the mass flow meter with a maximum flow of Nitrogen at 50 nml/min (normal millimetres per minute at 0^0C and 1.013 bar) reached at a differential pressure of 2 bars as reflected by the green line. The red line is from the mass flow meter with a maximum flow rate capability of 700 nml/min. The flow rate does not stabilise at higher differential pressures in a 2 hour interval. Thus when conducting a function test on Chemical Cement Alternatives, at higher leak rates, longer time steps are required to get a stable reading. Permeation of some kind will always occur through a Chemical Cement Alternative [1]. These measurements in conjunction with the Flow Equation may be used to obtain the permeability of the Chemical Cement Alternative as described in equation ([1]) below.

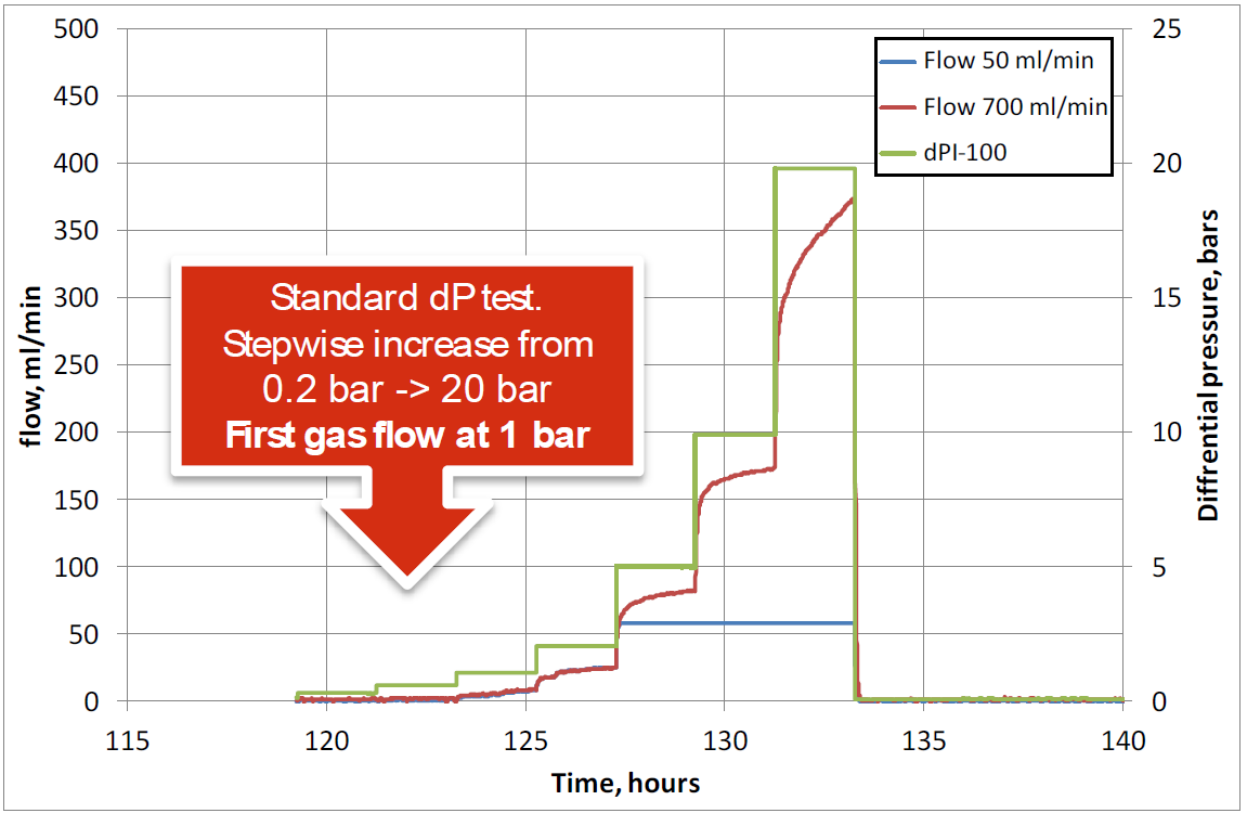

Figure 2: Small-Scale Function Test of Portland Class G Cement [7]

$$Q = -k \cdot A \cdot \left[\frac{(p_1 - p_2)}{\mu \cdot L}\right]$$ *Equation 1 [1]*

Where:

Q	=	Flow rate (m^3/s)
k	=	Permeability (m^2)
A	=	Cross sectional area of the Chemical Cement Alternative (m^2)
$p_1 - p_2$	=	Pressure difference between the top and bottom of the Alternative (Pa)
μ	=	Dynamic viscosity of the fluid (Pa.s)
L	=	Length of the Alternative (m)

The permeability of a good caprock capable of trapping hydrocarbons typically ranges from 1 to 0.001 microdarcy. Good cement has a permeability of approximately 10 microdarcy. For these reasons, a Chemical Alternative must not exceed this permeability value.

Note: The length of the cement column is increased to combat its high permeability and because its cross sectional area is significantly less than the caprock [1]. This must be done with Chemical Cement Alternatives as well.

Acceptance Value: calculated permeability must be ≤10 microdarcy at a stabilized flow rate

2) *Permeability*
Acceptance Value: ≤ 10 Microdarcy
Same justification as acceptance value for function test.

3) *Diffusion Coefficient*

$$-j = D \cdot \left[\frac{(c_1 - c_2)}{L}\right]$$ *Equation 2 [1]*

Where:

j	=	Flux per unit area ($mole/m^2$)
D	=	Diffusion coefficient
$c_1 - c_2$	=	Concentration difference between the top and bottom of the Alternative
L	=	Length of the Alternative (m)

By utilizing the ideal gas law this may be converted to

$$-j = D \cdot \left[\frac{(P_1 - P_2)}{R \cdot T \cdot L}\right]$$ *Equation 3 [1]*

Where:

j	=	Flux per unit area (mole/m^2)
D	=	Diffusion coefficient
$P_1 - P_2$	=	Partial pressure difference between the top and bottom of the Alternative
R	=	Gas constant (J/mol.K)
T	=	Temperature (K)
L	=	Length of the Alternative (m)

Since the rate of gas diffusion is linearly related to the casing internal diameter (ID) and diffusion coefficient, diffusion coefficient acceptance values must include a some assumptions. As previously mentioned, all Chemical Cement Alternatives must be held to the same standard as Portland Class G cement. In Alberta, Portland Class G cement is expected to successfully pass a 7.0 MPa differential pressure test post-setting according to the AER Directive 20, Guidelines on Well Abandonment. In that directive, zonal abandonments require 15 m of good Portland Class G cement above the top of perforations and 15 m below the bottom of the perforations. As previously recognized, Portland Class G cement has a permeability of 10 microdarcy. Using the permeability equation ([1]) and applying the mentioned differential pressure standard (7.0 MPa) from the reservoir to the described cement plug (15m length above perforations), a methane gas flow rate of 0.07 m^3 per year would be obtained in 177.8 mm casing (15.75 cm ID) assuming methane has a dynamic viscosity of 4.00 x 10^{-05} Pa.S [1].

Converting flux per unit area in equation (3) to this methane gas release rate at standard conditions will result in a diffusion coefficient of 2.4x10^{-8} m^2/s. Under these assumptions the standard values are

a. a diffusion coefficient of 2.4x10^{-8} m^2/s
b. With a maximum gas flow rate of 0.07 m^3/year.

Note: For a 15 m plug of Chemical Cement Alternative, a smaller casing ID will result in a smaller rate of gas diffusion. Subsequently, a larger casing size would result in a larger rate of gas diffusion. Therefore, to maintain the maximum gas flow rate of 0.07 m^3/year, the length of the Chemical Cement Alternative plug must be increased accordingly.

Acceptance Value: Diffusion Coefficient ≤ 2.4 x10^{-8} m^2/s, gas flow rate <0.07 m^3/year

4) *Shrinkage and Expansion*

Standard Portland Class G cement will normally undergo total shrinkage (internal or chemical shrinkage) during hardening and up to 4-5% total shrinkage post hardening, whether the expanding additives such as Calcium Oxide or Magnesium Oxide are added or not [7]. Without adding an expanding additive, the standard Portland Class G cement undergoes a bulk (external) shrinkage of 1% after hardening while the inclusion of an expanding additive will result in a bulk expansion after hardening (120 hours) [7]. Any shrinkage during or post hardening is detrimental to the performance of a Chemical Cement Alternatives [1]. It is preferred that a Chemical Cement Alternative demonstrates a bulk volume increase greater than or equal to a Portland G blend mixed with an expanding additive. Given that standard Portland Class G cement with no expanding additive is the Alberta Provincial standard for plug and abandonments, a bulk shrinkage performance equal to or better than Portland Class G cement's performance is set as the standard.

Acceptance Value: Bulk Shrinkage ≤ 1.0%

5) Shear Bond Strength

The value for the minimum shear bond strength is based on the equation below that describes the shear stress required to move the Chemical Cement Alternative from it's set position.

$$\tau = \frac{\Delta p \cdot A}{A_c} \qquad \textit{Equation 4 [1]}$$

Where:

τ = Stress required to break the bond between the casing and the Alternative (Pa)

Δp = Pressure difference across the Alternative (Pa)

A = Cross-sectional area of the Alternative (m^2)

A_c = Contact surface between the Alternative and casing (m^2)

Portland G cement has a shear bond strength in steel of approximately 1.31 MPa [8]. A Chemical Cement Alternative must perform equal to or better than this value. Using equation (4) above, a 1.0 m length Portland G cement plug in 177.8 mm, 34.23 kg/m casing would require a differential pressure of over 26 MPa to break the bond between the cement and the casing.

Acceptance Value: Shear Bond Strength ≥ 1.3 MPa

6) Outstanding Properties

Justification for remaining mechanical and chemical properties as captured in Table 5 through to Table 14 are on the basis that Portland Class G cement is the Alberta Provincial standard product for well remediation thus Portland Class G's properties will serve as the acceptance values for the Chemical Cement Alternatives' properties.

Acceptance Value: Portland Class G cement properties

7) *Ageing Testing*

This involves exposing Chemical Cement Alternatives to likely worst case downhole conditions and measuring changes to certain properties over time. Extrapolation techniques are used to determine longevity of the product in the selected well environment [1]. Therefore, the performance of the Chemical Cement Alternatives' mechanical and chemical properties should be the same as or better than Portland Class G cement's properties post ageing.

Acceptance Value ≥ Performance Mechanical and Chemical Properties Post Ageing of Portland G Cement

7.1 Ageing Environments In the Absence of Relevant Well Data

Ageing testing performed on Portland Class G cement in crude oil, brine and H_2S in brine showed minimal effects in crude oil, moderate effects in brine and significant degradation in brine with 0.5% H_2S dissolved gas [9]. It is critical that ageing testing be conducted in one or more of these environments based on the functional specifications of the Chemical Cement Alternative. Since fluid compositions vary from well to well, in the absence of relevant well data, the environments captured in ASTM D1141-98 for brine solution (i.e artificial

seawater) [9] and the *Guidelines on the Qualification of Abandonment Materials* for oil and gas environments will serve as conservative choices.

Table 15: Chemical Composition of a Formation Water Brine [9]

Species	Concentration (g/L)
NaCl	24.53
$MgCl_2$	5.2
Na_2SO_4	4.09
$CaCl_2$	1.16
KCl	0.695
$NaHCO_3$	0.201
KBr	0.101
H_3BO_3	0.027
$SrCl_2$	0.025
NaF	0.003

Table 16: Chemical Constituents of Crude Oil [1]

Species	Approximate Proportion (% by volume)
Asphaltenes	5
Resins	10
Aromatics	15
Naphthenes	35
Iso-Alkanes	15
n-Alkanes	20

Table 17:Typical Composition of Natural Gas [1]

Species	Range (mole %)
Methane	87.0 – 96.0
Ethane	1.5 – 5.1
Propane	0.1 – 1.5
Iso – Butane	0.01 -0.3
Normal – Butane	0.01 -0.3
Iso – Pentane	Trace – 0.14
Normal – Pentane	Trace – 0.04
Hexane plus	Trace – 0.06
Nitrogen	0.7 – 5.6
Carbon Dioxide	0.1 – 1.0
Hydrogen	Trace -0.02

Actual well conditions may vary significantly from these tables. Use numerical or analytical models when extrapolating because the chemical degradation reactions occur several orders of magnitude faster in laboratory ageing tests than in a well [10].

Note: Depending on the area of application, the medium and high risk failure modes associated with the Chemical Cement Alternative, the properties of Portland class G cement may be an inadequate qualification standard. It is recommended that a remedial cement blend is used as a standard for Chemical Cement Alternatives when superior sealing of micro channels is desired. When high temperature performance is desired, a thermal blend should be used as a baseline alternative. Portland Class G cement blend with silica designed to withstand H_2S may be used when attempting to validate performance of the Alternative in a highly sour environment [9]. Table 18 shows generic recipes for each of the three types of cement products.

Table 18: Generic Types of Remedial Cement Blends

Cement Blends	Base Formulation	Common Expanding Additives	Range of Expanding Additives (%)	Common Dispersants	Range of Dispersants (%)	Common Fluid Loss Additives	Range of Fluid Loss Additives (%)
Class G	OWG Cement (OWG = Oil Well G)	CaO, MgO	1.0 to 3.0%	Sodium Lignosulfonate, PolyCarbonxylates	0.5 - 1.0	PVA, AMPS, Polyacrylamide	0.4 - 1.0
Microfine	Blast furnace slag based cement	CaO, MgO	Not commonly used	Sodium Lignosulfonate, PolyCarbonxylates	1.0	Not Commonly used	N/A
Thermal 40 F	OWG Cement + 40% Silica Flour (By Weight of Cement)	CaO, MgO	1.0 to 3.0%	Sodium Lignosulfonate, PolyCarbonxylates	0.5 - 1.0	PVA, AMPS, Polyacrylamide	0.4 - 1.0

APPENDIX III: LABORATORY INSPECTION REPORT FORMAT

INSPECTION REPORT FORMAT

Approval Form for Chemical Cement Alternative Protocol Testing Laboratories in Alberta

1	Inspection Date	
2	Inspectors	Lead Inspector:
		Inspector:
		Inspector:

The Laboratory

1	Laboratory Name	
2	Laboratory Address	
3	Contact Phone Number	
4	Contact Email	
5	Contact Person	

The Laboratory Inspection

	Inspection	Items	Remarks
1	Laboratory Certificate of Incorporation	Registration #:	
		Date:	
2	Valid Laboratory APEGA or ASET Permit to Practice	Permit #:	
		Expiry Date:	
3	Laboratory relationship with any Chemical Cement Alternative manufacturer		
4	Certificate of Recognition (COR) – Alberta Occupational Health and Safety	Certificate #:	
		Certificate Issuer:	
		Date Issued:	
		Expiration Date:	
5	ISO 9001:2015 Certified	Certificate #:	
		Certificate Issuer:	
		Date Issued:	
		Expiration Date:	
6	List of Procedures per Chemical Cement Alternative this Laboratory can handle	See Appendix III-A - III-J	
7	List of Equipment Per Procedure	See Appendix III-A – III-J	
8	List of Equipment Calibration Certificates	See Appendix III-A – III-J	
9	List of Personnel and Relevant Certification	See Appendix III-K	

The Inspection Result (delete one)

All criteria for approving this Laboratory for conducting Chemical Cement Alternative Protocol Testing in Alberta has been met. **Or** The following gaps have been identified and will have to be addressed for a follow-up inspection. See attached summary sheet of the gaps supported by Appendix III-A to III-J and Appendix III-K.

Report Signed by Lead Inspector:

Name: _____ Signature: _____

Date: _____

APPENDIX III-A: LIST OF PROCEDURES, EQUIPMENT, CURRENT CALIBRATION CERTIFICATE FOR MODIFIED CEMENTS/CERAMICS (NON-SETTING)

Subject (Applicable Protocol #)	Property	Procedure Code #	Test Procedures		Does the Alternative Procedure meet Recommended Test Requirements	Applicable Equipment	Equipment Calibration Certificate # & Expiry Date
			Standard Test Procedures	Alternative Procedures Used by the Laboratory			
PERMEATION TESTING							
I	Nitrogen Permeability	CCA-A-001	Section 8.2.1 of "Guidelines on Qualification of Materials for the Abandonment of Wells" [1]				
I	Diffusion coefficient	CCA-A-002	Not required				
INTERACTION WITH FLUID							
V, IV	Dry Mass	CCA-A-003	Measurement of mass after drying to constant mass at 105^0C				
I, II	Absorption	CCA-A-004	Not required				
DIMENSIONAL STABILITY							
Expansion/Swelling							
I, II	During hardening	CCA-A-005	API RP 10B-5 ring test				
I, II	Hardened	CCA-A-006	API RP 10B-5 ring test				
Shrinkage							
I, II	During hardening	CCA-A-007	API RP 10B-5 ring test				
I, II	Hardened	CCA-A-008	API RP 10B-5 ring test				
I, II	Differential thermal expansion	CCA-A-009	ASTM E228				
I, II III	creep	CCA-A-010	ASTM C512-10				
MECHANICAL TESTING							
III	Triaxial testing	CCA-A-0011	Not required				
III	Cohesion	CCA-A-0012	Not required				
III	Poisson's ratio	CCA-A-0013	Not required				
III	Internal friction angle	CCA-A-0014	Not required				
III	Hydrostatic compressive yield	CCA-A-0015	Not required				
III	UCS	CCA-A-0016	API RP 10B-2				
III	Tensile strength	CCA-A-0017	ASTM C496				
III	Elastic modulus	CCA-A-0018	ASTM C469				
III	Hardness	CCA-A-0019	ASTM E384				
OTHER							
I, III	Shear bond strength	CCA-A-0020	See Section 8.6 of "Guidelines on Qualification of Materials for the Abandonment of				

			Wells" [1], substrate rugosity measurements done as per ASTM D7172				
I, III	Tensile bond strength	CCA-A-0021	Not required				
III	Decomposition temperature	CCA-A-0022	Not required				
V	Density	CCA-A-0023	ASTM C 138				
I, II, III	Stress relaxation	CCA-A-0024	Not required				
II, III, IV	Ageing Testing (i.e. Product integrity under anticipated adverse conditions such as H2S or diesel products)	CCA-A-0025	'See Section 8.10 of "Guidelines on Qualification of Materials for the Abandonment of Wells" [1]				
III, IV, VIII	Function Test	CCA-A-0026	As identified in Appendix 8 performed by Shell Global Solutions in "Guidelines of the Qualification of Materials Used in the Abandonment of Wells" [1]. See also lines 291-299 of same document.				
V, VI	Leaching Toxicity	CCA-A-0027	AER accepted modified US EPA 1311 procedure for leachate testing of Chemical Cement Alternatives				

APPENDIX III-B: LIST OF PROCEDURES, EQUIPMENT, CURRENT CALIBRATION CERTIFICATE FOR GROUTS

Subject (Applicable Protocol #)	Property	Procedure Code #	Test Procedure		Does the Alternative Procedure meet Standard Test Requirements	Applicable Equipment	Equipment Calibration Certificate # & Expiry Date
			Standard Test Procedures	Alternative Procedures Used by the Laboratory			
PERMEATION TESTING							
I	Nitrogen Permeability	CCA-B-001	Section 8.2.1 of "Guidelines on Qualification of Materials for the Abandonment of Wells" [1]				
I	Diffusion coefficient	CCA-B-002	Not required				
INTERACTION WITH FLUID							
V, IV	Dry Mass	CCA-B-003	Measurement of mass after drying to constant mass at 105^0C				
I, II	Absorption	CCA-B-004	Not required				
DIMENSIONAL STABILITY							
Expansion/Swelling							
I, II	During hardening	CCA-B-005	Not required				
I, II	Hardened	CCA-B-006	Not required				
Shrinkage							
I, II	During hardening	CCA-B-007	Not required				
I, II	Hardened	CCA-B-008	Non – identified				
I, II	Differential thermal expansion	CCA-B-009	ASTM E228				
I, II III	creep	CCA-B-010	Not required				
MECHANICAL TESTING							
III	Triaxial testing	CCA-B-0011	Not required				
III	Cohesion	CCA-B-0012	Not required				
III	Poisson's ratio	CCA-B-0013	Not required				
III	Internal friction angle	CCA-B-0014	Not required				
III	Hydrostatic compressive yield	CCA-B-0015	Not required				
III	UCS	CCA-B-0016	Not required				
III	Tensile strength	CCA-B-0017	Not required				
III	Elastic modulus	CCA-B-0018	Not required				
III	Hardness	CCA-B-0019	Not required				
OTHER							
I, III	Shear bond strength	CCA-B-0020	See Section 8.6 of "Guidelines on Qualification				

			of Materials for the Abandonment of Wells" [1], substrate rugosity measurements done as per ASTM D7172				
I, III	Tensile bond strength	CCA-B-0021	Not required				
III	Decomposition temperature	CCA-B-0022	Not required				
V	Density	CCA-B-0023	Pressurized mud balance				
I, II, III	Stress relaxation	CCA-B-0024	Not required				
II, III, IV	Ageing Testing (i.e. Product integrity under anticipated adverse conditions such as H2S or diesel products)	CCA-B-0025	'See Section 8.10 of "Guidelines on Qualification of Materials for the Abandonment of Wells" [1]				
III, IV, VIII	Function Test	CCA-B-0026	As identified in Appendix 8 performed by Shell Global Solutions in "Guidelines of the Qualification of Materials Used in the Abandonment of Wells" [1]. See also lines 291-299 of same document.				
V, VI	Leaching Toxicity	CCA-B-0027	AER accepted modified US EPA 1311 procedure for leachate testing of Chemical Cement Alternatives				

APPENDIX III-C: LIST OF PROCEDURES, EQUIPMENT, CURRENT CALIBRATION CERTIFICATE FOR THERMOSETTING POLYMERS AND COMPOSITES

Subject (Applicable Protocol #)	Property	Procedure Code #	Test Procedure		Does the Alternative Procedure meet Standard Test Requirements	Applicable Equipment	Equipment Calibration Certificate # & Expiry Date
			Standard Test Procedures	Alternative Procedures Used by the Laboratory			
PERMEATION TESTING							
I	Nitrogen Permeability	CCA-C-001	Not required				
I	Diffusion coefficient	CCA-C-002	See section 8.2.2 of "Guidelines on Qualification of Materials for the Abandonment of Wells" [1]				
INTERACTION WITH FLUID							
V, IV	Dry Mass	CCA-C-003	Measurement of mass after drying to constant mass at 105^0C				
I, II	Absorption	CCA-C-004	Not required				
DIMENSIONAL STABILITY							
Expansion/Swelling							
I, II	During hardening	CCA-C-005	See section 8.4.1 of "Guidelines on Qualification of Materials for the Abandonment of Wells" [1]				
I, II	Hardened	CCA-C-006	See section 8.4.1 of [1]				
Shrinkage							
I, II	During hardening	CCA-C-007	See section 8.4.2 of "Guidelines on Qualification of Materials for the Abandonment of Wells" [1]				
I, II	Hardened	CCA-C-008	See section 8.4.2 of [1]				
I, II	Differential thermal expansion	CCA-C-009	ASTM E228				
I, II III	creep	CCA-C-010	ISO 899-1				
MECHANICAL TESTING							
III	Triaxial testing	CCA-C-0011	Not required				
III	Cohesion	CCA-C-0012	Not required				
III	Poisson's ratio	CCA-C-0013	Not required				
III	Internal friction angle	CCA-C-0014	Not required				
III	Hydrostatic compressive yield	CCA-C-0015	Not required				
III	UCS	CCA-C-0016	API RP 10B-2				

III	Tensile strength	CCA-C-0017	ISO 527-1				
III	Elastic modulus	CCA-C-0018	ISO 527-1				
III	Hardness	CCA-C-0019	See section 8.4.2 of [1]				
OTHER							
I, III	Shear bond strength	CCA-C-0020	See Section 8.6 of "Guidelines on Qualification of Materials for the Abandonment of Wells" [1], substrate rugosity measurements done as per ASTM D7172				
I, III	Tensile bond strength	CCA-C-0021	Not required				
III	Decomposition temperature	CCA-C-0022	TGA/DTA/DSC measurement				
V	Density	CCA-C-0023	ISO 1183-1				
I, II, III	Stress relaxation	CCA-C-0024	Not required				
II, III, IV	Ageing Testing (i.e. Product integrity under anticipated adverse conditions such as H2S or diesel products)	CCA-C-0025	'See Section 8.10 of "Guidelines on Qualification of Materials for the Abandonment of Wells" [1]				
III, IV, VIII	Function Test	CCA-C-0026	As identified in Appendix 8 performed by Shell Global Solutions in "Guidelines of the Qualification of Materials Used in the Abandonment of Wells" [1]. See also lines 291-299 of same document.				
V, VI	Leaching Toxicity	CCA-C-0027	AER accepted modified US EPA 1311 procedure for leachate testing of Chemical Cement Alternatives				

APPENDIX III-D: LIST OF PROCEDURES, EQUIPMENT, CURRENT CALIBRATION CERTIFICATE FOR THERMOPLASTIC POLYMERS AND COMPOSITES

Subject (Applicable Protocol #)	Property	Procedure Code #	Test Procedure		Does the Alternative Procedure meet Standard Test Requirements	Applicable Equipment	Current Equipment Calibration Certificate
			Standard Test Procedures	Alternative Procedures Used by the Laboratory			
PERMEATION TESTING							
I	Nitrogen Permeability	CCA-D-001	Not required				
I	Diffusion coefficient	CCA-D-002	See section 8.2.2 of "Guidelines on Qualification of Materials for the Abandonment of Wells" [1]				
INTERACTION WITH FLUID							
V, IV	Dry Mass	CCA-D-003	Measurement of mass after drying to constant mass at 105^0C				
I, II	Absorption	CCA-D-004	Not required				
DIMENSIONAL STABILITY							
Expansion/Swelling							
I, II	During hardening	CCA-D-005	See section 8.4.1 of "Guidelines on Qualification of Materials for the Abandonment of Wells" [1]				
I, II	Hardened	CCA-D-006	See section 8.4.1 of [1]				
Shrinkage							
I, II	During hardening	CCA-D-007	See section 8.4.2 of "Guidelines on Qualification of Materials for the Abandonment of Wells" [1]				
I, II	Hardened	CCA-D-008	See section 8.4.2 of [1]				
I, II	Differential thermal expansion	CCA-D-009	ASTM E228				
I, II III	creep	CCA-D-010	ISO 899-1				
MECHANICAL TESTING							
III	Triaxial testing	CCA-D-0011	Not required				
III	Cohesion	CCA-D-0012	Not required				
III	Poisson's ratio	CCA-D-0013	Not required				
III	Internal friction angle	CCA-D-0014	Not required				
III	Hydrostatic compressive yield	CCA-D-0015	Not required				
III	UCS	CCA-D-0016	ISO 604				
III	Tensile strength	CCA-D-0017	ISO 527-1				
III	Elastic modulus	CCA-D-0018	ISO 527-1				

III	Hardness	CCA-D-0019	ISO 868				
OTHER							
I, III	Shear bond strength	CCA-D-0020	See Section 8.6 of "Guidelines on Qualification of Materials for the Abandonment of Wells" [1], substrate rugosity measurements done as per ASTM D7172				
I, III	Tensile bond strength	CCA-D-0021	Not required				
III	Decomposition temperature	CCA-D-0022	TGA/DTA/DSC measurement				
V	Density	CCA-D-0023	ISO 1183-1				
I, II, III	Stress relaxation	CCA-D-0024	Not required				
II, III, IV	Ageing Testing (i.e. Product integrity under anticipated adverse conditions such as H2S or diesel products)	CCA-D-0025	'See Section 8.10 of "Guidelines on Qualification of Materials for the Abandonment of Wells" [1]				
III, IV, VIII	Function Test	CCA-D-0026	As identified in Appendix 8 performed by Shell Global Solutions in "Guidelines of the Qualification of Materials Used in the Abandonment of Wells" [1]. See also lines 291-299 of same document.				
V, VI	Leaching Toxicity	CCA-D-0027	AER accepted modified US EPA 1311 procedure for leachate testing of Chemical Cement Alternatives				

APPENDIX III-E: LIST OF PROCEDURES, EQUIPMENT, CURRENT CALIBRATION CERTIFICATE FOR ELASTOMERIC POLYMERS AND COMPOSITES

Subject (Applicable Protocol #)	Property	Procedure Code #	Test Procedure		Does the Alternative Procedure meet Standard Test Requirements	Applicable Equipment	Equipment Calibration Certificate # & Expiry Date
			Standard Test Procedures	Alternative Procedures Used by the Laboratory			
PERMEATION TESTING							
I	Nitrogen Permeability	CCA-E-001	Not required				
I	Diffusion coefficient	CCA-E-002	See section 8.2.2 of "Guidelines on Qualification of Materials for the Abandonment of Wells" [1]				
INTERACTION WITH FLUID							
V, IV	Dry Mass	CCA-E-003	Measurement of mass after drying to constant mass at 105^0C				
I, II	Absorption	CCA-E-004	Not required				
DIMENSIONAL STABILITY							
Expansion/Swelling							
I, II	During hardening	CCA-E-005	See section 8.4.1 of "Guidelines on Qualification of Materials for the Abandonment of Wells" [1]				
I, II	Hardened	CCA-E-006	See section 8.4.1 of [1]				
Shrinkage							
I, II	During hardening	CCA-E-007	See section 8.4.2 of "Guidelines on Qualification of Materials for the Abandonment of Wells" [1]				
I, II	Hardened	CCA-E-008	See section 8.4.2 of [1]				
I, II	Differential thermal expansion	CCA-E-009	ASTM E228				
I, II III	creep	CCA-E-010	ISO 899-1 / ASTM D395				
MECHANICAL TESTING							
III	Triaxial testing	CCA-E-0011	Not required				
III	Cohesion	CCA-E-0012	Not required				
III	Poisson's ratio	CCA-E-0013	ISRM suggested method				
III	Internal friction angle	CCA-E-0014	Not required				
III	Hydrostatic compressive yield	CCA-E-0015	Not required				
III	UCS	CCA-E-0016	BS EN ISO 604				
III	Tensile strength	CCA-E-0017	BS EN ISO 527-1				
III	Elastic modulus	CCA-E-0018	BS EN ISO 527-1				

III	Hardness	CCA-E-0019	ISO 868				
OTHER							
I, III	Shear bond strength	CCA-E-0020	See Section 8.6 of "Guidelines on Qualification of Materials for the Abandonment of Wells" [1], substrate rugosity measurements done as per ASTM D7172				
I, III	Tensile bond strength	CCA-E-0021	Not required				
III	Decomposition temperature	CCA-E-0022	TGA/DTA/DSC measurement				
V	Density	CCA-E-0023	ISO 1183-1				
I, II, III	Stress relaxation	CCA-E-0024	ASTM D395 and NORSOK M710				
II, III, IV	Ageing Testing (i.e. Product integrity under anticipated adverse conditions such as H2S or diesel products)	CCA-E-0025	'See Section 8.10 of "Guidelines on Qualification of Materials for the Abandonment of Wells" [1]				
III, IV, VIII	Function Test	CCA-E-0026	As identified in Appendix 8 performed by Shell Global Solutions in "Guidelines of the Qualification of Materials Used in the Abandonment of Wells" [1]. See also lines 291-299 of same document.				
V, VI	Leaching Toxicity	CCA-E-0027	AER accepted modified US EPA 1311 procedure for leachate testing of Chemical Cement Alternatives				

APPENDIX III-F: LIST OF PROCEDURES, EQUIPMENT, CURRENT CALIBRATION CERTIFICATE FOR FORMATION

Subject (Applicable Protocol #)	Property	Procedure Code #	Test Procedure		Does the Alternative Procedure meet Standard Test Requirements	Applicable Equipment	Equipment Calibration Certificate # & Expiry Date
			Standard Test Procedures	Alternative Procedures Used by the Laboratory			
PERMEATION TESTING							
I	Nitrogen Permeability	CCA-F-001	See Section 8.2.1 of "Guidelines on Qualification of Materials for the Abandonment of Wells" [1]				
I	Diffusion coefficient	CCA-F-002	Not required				
INTERACTION WITH FLUID							
V, IV	Dry Mass	CCA-F-003	Measurement of mass after drying to constant mass at 105^0C				
I, II	Absorption	CCA-F-004	Not required				
DIMENSIONAL STABILITY							
Expansion/Swelling							
I, II	During hardening	CCA-F-005	Not required				
I, II	Hardened	CCA-F-006	ISRM suggested method				
Shrinkage							
I, II	During hardening	CCA-F-007	Not required				
I, II	Hardened	CCA-F-008	ISRM suggested method				
I, II	Differential thermal expansion	CCA-F-009	ASTM E228				
I, II III	creep	CCA-F-010	ASTM C512-10				
MECHANICAL TESTING							
III	Triaxial testing	CCA-F-0011	ISRM suggested method				
III	Cohesion	CCA-F-0012	ISRM suggested method				
III	Poisson's ratio	CCA-F-0013	ISRM suggested method				
III	Internal friction angle	CCA-F-0014	ISRM suggested method				
III	Hydrostatic compressive yield	CCA-F-0015	ISRM suggested method				
III	UCS	CCA-F-0016	ISRM suggested method				
III	Tensile strength	CCA-F-0017	ASTM C496				
III	Elastic modulus	CCA-F-0018	ASTM C469				
III	Hardness	CCA-F-0019	Not required				
OTHER							
I, III	Shear bond strength	CCA-F-0020	Not required				
I, III	Tensile bond strength	CCA-F-0021	Not required				
III	Decomposition temperature	CCA-F-0022	Not required				

V	Density	CCA-F-0023	Not required				
I, II, III	Stress relaxation	CCA-F-0024	Not required				
II, III, IV	Ageing Testing (i.e. Product integrity under anticipated adverse conditions such as H2S or diesel products)	CCA-F-0025	'See Section 8.10 of "Guidelines on Qualification of Materials for the Abandonment of Wells" [1]				
III, IV, VIII	Function Test	CCA-F-0026	As identified in Appendix 8 performed by Shell Global Solutions in "Guidelines of the Qualification of Materials Used in the Abandonment of Wells" [1]. See also lines 291-299 of same document.				
V, VI	Leaching Toxicity	CCA-F-0027	AER accepted modified US EPA 1311 procedure for leachate testing of Chemical Cement Alternatives				

APPENDIX III-G: LIST OF PROCEDURES, EQUIPMENT, CURRENT CALIBRATION CERTIFICATE FOR GELS

Subject (Applicable Protocol #)	Property	Procedure Code #	Test Procedure		Does the Alternative Procedure meet Standard Test Requirements	Applicable Equipment	Equipment Calibration Certificate # & Expiry Date
			Standard Test Procedures	Alternative Procedures Used by the Laboratory			
PERMEATION TESTING							
I	Nitrogen Permeability	CCA-G-001	See Section 8.2.1 of "Guidelines on Qualification of Materials for the Abandonment of Wells" [1]				
I	Diffusion coefficient	CCA-G-002	See Section 8.2.2 of "Guidelines on Qualification of Materials for the Abandonment of Wells" [1]				
INTERACTION WITH FLUID							
V, IV	Dry Mass	CCA-G-003	Measurement of mass after drying to constant mass at 105^0C				
I, II	Absorption	CCA-G-004	Absorption index				
DIMENSIONAL STABILITY							
Expansion/Swelling							
I, II	During hardening	CCA-G-005	Not required				
I, II	Hardened	CCA-G-006	Not required				
Shrinkage							
I, II	During hardening	CCA-G-007	See Section 8.4.2 of "Guidelines on Qualification of Materials for the Abandonment of Wells"				
I, II	Hardened	CCA-G-008	See Section 8.4.2 of "Guidelines on Qualification of Materials for the Abandonment of Wells"				
I, II	Differential thermal expansion	CCA-G-009	ASTM E228				
I, II III	creep	CCA-G-010	Not required				
MECHANICAL TESTING							
III	Triaxial testing	CCA-G-0011	Not required				
III	Cohesion	CCA-G-0012	Not required				

III	Poisson's ratio	CCA-G-0013	Not required				
III	Internal friction angle	CCA-G-0014	Not required				
III	Hydrostatic compressive yield	CCA-G-0015	Not required				
III	UCS	CCA-G-0016	Not required				
III	Tensile strength	CCA-G-0017	Not required				
III	Elastic modulus	CCA-G-0018	Not required				
III	Hardness	CCA-G-0019	Not required				
OTHER							
II, III, IV	Corrosion	CCA-G-0020	API Recommended Practice 13B-1.				
I, III	Shear bond strength	CCA-G-0021	See Section 8.6 of "Guidelines on Qualification of Materials for the Abandonment of Wells" [1], substrate rugosity measurements done as per ASTM D7172				
I, III	Tensile bond strength	CCA-G-0022	Not required				
III	Decomposition temperature	CCA-G-0023	TGA / DTA / DSC				
V	Density	CCA-G-0024	Not required				
I, II, III	Stress relaxation	CCA-G-0025	Not required				
II, III, IV	Ageing Testing (i.e. Product integrity under anticipated adverse conditions such as H2S or diesel products)	CCA-G-0026	'See Section 8.10 of "Guidelines on Qualification of Materials for the Abandonment of Wells" [1]				
III, IV, VIII	Function Test	CCA-G-0027	As identified in Appendix 8 performed by Shell Global Solutions in "Guidelines of the Qualification of Materials Used in the Abandonment of Wells" [1]. See also lines 291-299 of same document.				
V, VI	Leaching Toxicity	CCA-G-0028	AER accepted modified US EPA 1311 procedure for leachate testing of Chemical Cement Alternatives				

APPENDIX III-H: LIST OF PROCEDURES, EQUIPMENT, CURRENT CALIBRATION CERTIFICATE FOR GLASS

Subject (Applicable Protocol #)	Property	Procedure Code #	Test Procedure		Does the Alternative Procedure meet Standard Test Requirements	Applicable Equipment	Equipment Calibration Certificate # & Expiry Date
			Standard Test Procedures	Alternative Procedures Used by the Laboratory			
PERMEATION TESTING							
I	Nitrogen Permeability	CCA-H-001	Not required				
I	Diffusion coefficient	CCA-H-002	Not required				
INTERACTION WITH FLUID							
V, IV	Dry Mass	CCA-H-003	Measurement of mass after drying to constant mass at 105^0C				
I, II	Absorption	CCA-H-004	Not required				
DIMENSIONAL STABILITY							
Expansion/Swelling							
I, II	During hardening	CCA-H-005	See Section 8.4.1 of "Guidelines on Qualification of Materials for the Abandonment of Wells" [1]				
I, II	Hardened	CCA-H-006	See Section 8.4.1 of "Guidelines on Qualification of Materials for the Abandonment of Wells" [1]				
Shrinkage							
I, II	During hardening	CCA-H-007	See Section 8.4.2 of "Guidelines on Qualification of Materials for the Abandonment of Wells" [1]				
I, II	Hardened	CCA-H-008	See Section 8.4.2 of "Guidelines on Qualification of Materials for the Abandonment of Wells" [1]				
I, II	Differential thermal expansion	CCA-H-009	ASTM E228, may need to investigate thermal shock				
I, II III	creep	CCA-H-010	Not required				
MECHANICAL TESTING							
III	Triaxial testing	CCA-H-0011	Not required				
III	Cohesion	CCA-H-0012	Not required				
III	Poisson's ratio	CCA-H-0013	Not required				
III	Internal friction angle	CCA-H-0014	Not required				
III	Hydrostatic compressive yield	CCA-H-0015	Not required				

III	UCS	CCA-H-0016	API RP 10B-2				
III	Tensile strength	CCA-H-0017	Not required				
III	Elastic modulus	CCA-H-0018	ASTM C469				
III	Hardness	CCA-H-0019	ASTM E384				
OTHER							
I, III	Shear bond strength	CCA-H-0020	See Section 8.6 of "Guidelines on Qualification of Materials for the Abandonment of Wells" [1], substrate rugosity measurements done as per ASTM D7172				
I, III	Tensile bond strength	CCA-H-0021	Not required				
III	Decomposition temperature	CCA-H-0022	Not required				
V	Density	CCA-H-0023	ASTM C138				
I, II, III	Stress relaxation	CCA-H-0024	Not required				
II, III, IV	Ageing Testing (i.e. Product integrity under anticipated adverse conditions such as H2S or diesel products)	CCA-H-0025	'See Section 8.10 of "Guidelines on Qualification of Materials for the Abandonment of Wells" [1]				
III, IV, VIII	Function Test	CCA-H-0026	As identified in Appendix 8 performed by Shell Global Solutions in "Guidelines of the Qualification of Materials Used in the Abandonment of Wells" [1]. See also lines 291-299 of same document.				
V, VI	Leaching Toxicity	CCA-H-0027	AER accepted modified US EPA 1311 procedure for leachate testing of Chemical Cement Alternatives				

APPENDIX III-I: LIST OF PROCEDURES, EQUIPMENT, CURRENT CALIBRATION CERTIFICATE FOR METALS

Subject (Applicable Protocol #)	Property	Procedure Code #	Test Procedure		Does the Alternative Procedure meet Standard Test Requirements	Applicable Equipment	Equipment Calibration Certificate # & Expiry Date
			Standard Test Procedures	Alternative Procedures Used by the Laboratory			
PERMEATION TESTING							
I	Nitrogen Permeability	CCA-I-001	Not required				
I	Diffusion coefficient	CCA-I-002	Not required				
INTERACTION WITH FLUID							
V, IV	Dry Mass	CCA-I-003	Measurement of mass after drying to constant mass at 105^0C				
I, II	Absorption	CCA-I-004	Not required				
DIMENSIONAL STABILITY							
Expansion/Swelling							
I, II	During hardening	CCA-I-005	See Section 8.4.1 of "Guidelines on Qualification of Materials for the Abandonment of Wells" [1]				
I, II	Hardened	CCA-I-006	See Section 8.4.1 of "Guidelines on Qualification of Materials for the Abandonment of Wells" [1]				
Shrinkage							
I, II	During hardening	CCA-I-007	See Section 8.4.2 of "Guidelines on Qualification of Materials for the Abandonment of Wells" [1], may need to investigate thermal shock				
I, II	Hardened	CCA-I-008	See Section 8.4.2 of "Guidelines on Qualification of Materials for the Abandonment of Wells" [1]				
I, II	Differential thermal expansion	CCA-I-009	ASTM E228				
I, II III	creep	CCA-I-010	ISO 204				
MECHANICAL TESTING							
III	Triaxial testing	CCA-I-0011	ISRM suggested method				
III	Cohesion	CCA-I-0012	Not required				
III	Poisson's ratio	CCA-I-0013	ISRM suggested method (triaxial) or ASTM E1876				

III	Internal friction angle	CCA-I-0014	Not required				
III	Hydrostatic compressive yield	CCA-I-0015	ISRM suggested method				
III	UCS	CCA-I-0016	ASTM E9				
III	Tensile strength	CCA-I-0017	ISO 6892-1				
III	Elastic modulus	CCA-I-0018	ISO 3312 or ASTM E9				
III	Hardness	CCA-I-0019	ASTM E18, ASTM E10 or ASTM E384				
OTHER							
II, III, IV	Corrosion	CCA-I-0020	ISO 1516/NACE MR0175				
I, III	Shear bond strength	CCA-I-0021	See Section 8.6 of "Guidelines on Qualification of Materials for the Abandonment of Wells" [1], substrate rugosity measurements done as per ASTM D7172				
I, III	Tensile bond strength	CCA-I-0022	Not required				
III	Decomposition temperature	CCA-I-0023	TGA/DTA/DSC measurement				
V	Density	CCA-I-0024	ISO 3369				
I, II, III	Stress relaxation	CCA-I-0025	Not required				
II, III, IV	Ageing Testing (i.e. Product integrity under anticipated adverse conditions such as H2S or diesel products)	CCA-I-0026	'See Section 8.10 of "Guidelines on Qualification of Materials for the Abandonment of Wells" [1]				
III, IV, VIII	Function Test	CCA-I-0027	As identified in Appendix 8 performed by Shell Global Solutions in "Guidelines of the Qualification of Materials Used in the Abandonment of Wells" [1]. See also lines 291-299 of same document.				
V, VI	Leaching Toxicity	CCA-I-0028	AER accepted modified US EPA 1311 procedure for leachate testing of Chemical Cement Alternatives				

APPENDIX III-J: LIST OF PROCEDURES, EQUIPMENT, CURRENT CALIBRATION CERTIFICATE FOR MODIFIED IN-SITU MATERIALS

Subject (Applicable Protocol #)	Property	Procedure Code #	Test Procedure		Does the Alternative Procedure meet Standard Test Requirements	Applicable Equipment	Equipment Calibration Certificate # & Expiry Date
			Standard Test Procedures	Alternative Procedures Used by the Laboratory			
PERMEATION TESTING							
I	Nitrogen Permeability	CCA-J-001	See Section 8.2.1 of "Guidelines on Qualification of Materials for the Abandonment of Wells" [1]				
I	Diffusion coefficient	CCA-J-002	Not required				
INTERACTION WITH FLUID							
V, IV	Dry Mass	CCA-J-003	Measurement of mass after drying to constant mass at 105^0C				
I, II	Absorption	CCA-J-004	Not required				
DIMENSIONAL STABILITY							
Expansion/Swelling							
I, II	During hardening	CCA-J-005	Not required				
I, II	Hardened	CCA-J-006	ISRM suggested method				
Shrinkage							
I, II	During hardening	CCA-J-007	Not required				
I, II	Hardened	CCA-J-008	ISRM suggested method				
I, II	Differential thermal expansion	CCA-J-009	ASTM E228				
I, II III	creep	CCA-J-010	ASTM C512-10				
MECHANICAL TESTING							
III	Triaxial testing	CCA-J-0011	ISRM suggested method				
III	Cohesion	CCA-J-0012	ISRM suggested method				
III	Poisson's ratio	CCA-J-0013	ISRM suggested method				
III	Internal friction angle	CCA-J-0014	ISRM suggested method				
III	Hydrostatic compressive yield	CCA-J-0015	ISRM suggested method				
III	UCS	CCA-J-0016	ISRM suggested method				
III	Tensile strength	CCA-J-0017	ASTM C496				
III	Elastic modulus	CCA-J-0018	ASTM C469				
III	Hardness	CCA-J-0019	Not required				
OTHER							
I, III	Shear bond strength	CCA-J-0020	Not required				
I, III	Tensile bond strength	CCA-J-0021	Not required				
III	Decomposition temperature	CCA-J-0022	Not required				

V	Density	CCA-J-0023	Not required				
I, II, III	Stress relaxation	CCA-J-0024	Not required				
II, III, IV	Ageing Testing (i.e. Product integrity under anticipated adverse conditions such as H2S or diesel products)	CCA-J-0025	'See Section 8.10 of "Guidelines on Qualification of Materials for the Abandonment of Wells" [1]				
III, IV, VIII	Function Test	CCA-J-0026	As identified in Appendix 8 performed by Shell Global Solutions in "Guidelines of the Qualification of Materials Used in the Abandonment of Wells" [1]. See also lines 291-299 of same document.				
V, VI	Leaching Toxicity	CCA-J-0027	AER accepted modified US EPA 1311 procedure for leachate testing of Chemical Cement Alternatives				

APPENDIX III-K: LIST OF PERSONNEL AND RELEVANT QUALIFICATION

	Equipment as Per Appendix III-A-III-J	Operator's Name	Relevant Certification
1		1)	1)
		2)	2)
		3)	3)
2		1)	1)
		2)	2)
		3)	3)
3		1)	1)
		2)	2)
		3)	3)
4		1)	1)
		2)	2)
		3)	3).
5		1)	1)
		2)	2)
		3)	3)
6		1)	1)
		2)	2)
		3)	3)
7		1)	1)
		2)	2)
		3)	3)
8		1)	1)
		2)	2)
		3)	3)
9		1)	1)
		2)	2)
		3)	3)
10		1)	1)
		2)	2)
		3)	3)

APPENDIX IV: FORMAT FOR TEST REPORTING

Report Format for Chemical Cement Alternative Testing in Alberta

1	Laboratory Name	
2	Laboratory Address	
3	Contact Phone Number	
4	Contact Email	
5	Contact Person	

Toxicity Testing

Leachates from Chemical Cement Alternative

General and Inorganic parameters	Alberta Tier 1 Soil and Groundwater Remediation Guideline Values for Agricultural Land – Table B.2	Test Values	Acceptable Performance (Y/N)
pH	6.5 – 8.5		
An "N" under "Acceptable Performance means that the Alternative has failed and needs to be modified and requalified following a review of the remaining test results			

Composition of Ageing Environment

Chemical Composition of a Formation Water Brine

Pressure _____ kPa, Temperature _____ ^{0}C
Test Duration _____ days _____hours _____minutes

Species	Recommended Concentration (g/L)	Actual Concentration (g/L)
NaCl	24.53	
$MgCl_2$	5.2	
Na_2SO_4	4.09	
$CaCl_2$	1.16	
KCl	0.695	
$NaHCO_3$	0.201	
KBr	0.101	
H_3BO_3	0.027	
$SrCl_2$	0.025	
NaF	0.003	

Chemical Constituents of Crude Oil

Pressure _____ kPa, Temperature _____ ^{0}C
Test Duration _____ days _____hours _____minutes

Species	Recommended Proportion (% by volume)	Actual Proportion (% by volume)
Asphaltenes	5	
Resins	10	
Aromatics	15	
Naphthenes	35	
Iso-Alkanes	15	
n-Alkanes	20	

Pressure _____ kPa, Temperature _____ ^{0}C
Test Duration _____ days _____hours _____minutes

Species	Recommended Range (mole %)	Actual Range (mole %)
Methane	87.0 – 96.0	
Ethane	1.5 – 5.1	
Propane	0.1 – 1.5	
Iso – Butane	0.01 -0.3	
Normal – Butane	0.01 -0.3	
Iso – Pentane	Trace – 0.14	
Normal – Pentane	Trace – 0.04	
Hexane plus	Trace – 0.06	
Nitrogen	0.7 – 5.6	
Carbon Dioxide	0.1 – 1.0	
Hydrogen	Trace -0.02	

Testing of Critical Parameters

Generic Types of Remedial Cement Blends

Cement Blends	Base Formulation	Common Expanding Additives	Range of Expanding Additives (%)	Common Dispersants	Range of Dispersants (%)	Common Fluid Loss Additives	Range of Fluid Loss Additives (%)
Class G	OWG Cement (OWG = Oil Well G)	CaO, MgO	1.0 to 3.0%	Sodium Lignosulfonate, PolyCarbonxylates	0.5 - 1.0	PVA, AMPS, Polyacrylamide	0.4 - 1.0
Microfine	Blast furnace slag based cement	CaO, MgO	Not commonly used	Sodium Lignosulfonate, PolyCarbonxylates	1.0	Not Commonly used	N/A
Thermal 40 F	OWG Cement + 40% Silica Flour (By Weight of Cement)	CaO, MgO	1.0 to 3.0%	Sodium Lignosulfonate, PolyCarbonxylates	0.5 - 1.0	PVA, AMPS, Polyacrylamide	0.4 - 1.0

Actual Cement Blend Used Before and After Ageing

Cement Blend	Base Formulation	Expanding Additives	Percentage Expanding Additives (%)	Dispersants	Percentage of Dispersants (%)	Fluid Loss Additives	Percentage of Fluid Loss Additives (%)

Acceptance Criteria for the Testing Procedures of Modified Cements/ceramics (non-setting)

Subject (Applicable Protocol Number)	Property	Standard Test Procedure	Accepted Test Value Before Ageing	Test Value of Alternative Before Ageing	Test Value of Class G Cement Before Ageing	Acceptable Performance Before Ageing (Y/N)	Accepted Test Value After Ageing	Test Value of Alternative After Ageing	Test Value of Class G Cement After Ageing	Acceptable Performance After Ageing (Y/N)
PERMEATION TESTING										
I	Nitrogen Permeability	Section 8.2.1 of "Guidelines on Qualification of Materials for the Abandonment of Wells" [1]	≤10 microdarcy with a calculated release rate <0.07 m^3/year, see justification under diffusion.				≤ Class G cement under same conditions			
I	Diffusion coefficient	Not required								
INTERACTION WITH FLUID										
V, IV	Dry Mass	Measurement of mass after drying to constant mass at 105^{0}C	Not Required				≤ Class G cement percentage loss in dry mass under same conditions			
I, II	Absorption	Not required								
DIMENSIONAL STABILITY										
Expansion/Swelling										
I, II	During hardening	API RP 10B-5 ring test	≤ Class G cement linear expansion percentage under same conditions				Not Required			
I, II	Hardened	API RP 10B-5 ring test	Not Required				≤ Class G cement percentage linear expansion under same conditions			

Shrinkage										
I, II	During hardening	API RP 10B-5 ring test	≤ 1.0% bulk shrinkage				Not Required			
I, II	Hardened	API RP 10B-5 ring test	Not required				≤ Class G cement bulk shrinkage percentage under same conditions			
I, II	Differential thermal expansion	ASTM E228	Coefficient of thermal expansion ± 5 K^{-1} x 10^{-6} of casing [1]*				Not Required			
I, II III	creep	ASTM C512-10	≤ Class G cement strain percentage under same conditions				Not required			
MECHANICAL TESTING										
III	Triaxial testing	Not required								
III	Cohesion	Not required								
III	Poisson's ratio	Not required								
III	Internal friction angle	Not required								
III	Hydrostatic compressive yield	Not required								
III	UCS	API RP 10B-2	≥ 2.1 MPa [7] **				≥ Class G cement under same conditions			
III	Tensile strength	ASTM C496	≥ 3.65 MPa [1] ***				≥ Class G cement under same conditions			
III	Elastic modulus	ASTM C469	NS, RT				NS, RT			
III	Hardness	ASTM E384	NS, RT				NS, RT			
OTHER										
I, III	Shear bond strength	See Section 8.6 of "Guidelines	> 1.3 MPa				≥ Class G cement			

		on Qualification of Materials for the Abandonment of Wells" [1]					under same conditions			
I, III	Tensile bond strength	Not required								
III	Decomposition temperature	Not required								
V	Density	ASTM C 138	NS, RT				NS, RT			
I, II, III	Stress relaxation	Not required								
III, IV, VIII	Function Test	As identified in Appendix 8 performed by Shell Global Solutions in "Guidelines of the Qualification of Materials Used in the Abandonment of Wells" [1]. See also lines 291-299 of same document.	calculated permeability must be ≤10 microdarcy at a stabilized flow rate	Permeability _____ microdarcy Flow Rate _____ ml/min	Permeability _____ microdarcy Flow Rate _____ ml/min		calculated permeability must be ≤ Class G cement at a stabilized flow rate	Permeability _____ microdarcy Flow Rate _____ ml/min	Permeability _____ microdarcy Flow Rate _____ ml/min	

Class G cement = Portland Class G cement

* See Table 4 in [1]

** At 8 hours thickening time for Portland Class G cement

*** Tensile strength of cement

NS = No Standard listed for this property

RT = Recommended test that could provide a useful indication of performance

An "N" under "Acceptable Performance Before" or "Acceptable Performance After Ageing" means that the Alternative has failed and needs to be modified and requalified following a review of the remaining test results.

This Table is only for Modified Cements/ceramics (non-setting). Standard Test Procedures and Acceptance Values will need to correspond to those of Table 5-Table 14 in Appendix II for the remaining types of Chemical Cement Alternatives.

Note: Class G cement properties are primarily available through literature. However, after ageing these properties will need to be determined using the standardized test procedures listed in this table where applicable. In some instances, alternate test procedures will be required for Class G cement. These must be industry recognized standardized testing procedures for Class G cements and documented as part of the Test Reports for each type of Alternative.

Testing Result (delete one)

All criteria for approving this Chemical Cement Alternative for use in in Alberta has been met.

Or

Some gaps have been identified as captured in the tables above and the Chemical Cement Alternative needs to be modified and requalified at a later date.

Report Signed by Laboratory Technical Authority:

Name: _____ Signature: _____

Date: _____